Australian Journal of Basic and Applied Sciences
2019 January; 13(1): pages 17-22
DOI: 10.22587/ajbas.2019.13.1.3
Original paper
AENSI Publications
Journal home page: www.ajbasweb.com

Agro Industrial Waste as Source of N for the Production of *Eruca sativa*.

Eliene dos Reis Matos[1], Adriana Rodolfo Costa[2], Patrícia Costa Silva[2], Franciele de Freitas Silva[3], Andréia Mendes da Costa[3], Vitor Marques Vidal[4]

[1]*Agricultural Engineer, Santa Helena de Goias, Brazil.*
[2]*School of Agricultural Engineering, State University of Goias, Santa Helena de Goias, Brazil.*
[3]*Postgraduate Program in Agrarian Sciences - Agronomy, Goiano Federal Institute, Rio Verde, Goiás, Brazil.*
[4]*Federal Institute of Northern Minas Gerais, Arinos, Minas Gerais, Brazil.*

Correspondence Author: Eliene dos Reis Matos, *Agricultural Engineer, Santa Helena de Goias, Brazil.*

Received date: 11 December 2018, **Accepted date:** 22 Janaury 2018, **Online date:** 29 January 2019

Abstract

The use of agroindustrial residues as a substrate for vegetable production has shown to be a promising alternative aiming at both environmental and economic sustainability issues. They can be obtained through waste, from various agricultural activities and are likely to be used in the organic cultivation of vegetables. Therefore, the objective of this study was to evaluate the influence of different substrates and doses of biofertilizers, on growth and productivity in arugula plants. The experimental design was a randomized complete block design, in a 4 x 3 + 1 factorial scheme, composed of four N sources from biofertilizers (cattle manure, earthworm humus, filter cake and neem pie), three doses (50, 100 and 200 kg of N ha^{-1}) and one control (without addition of biofertilizers) with 4 replicates. The cultivar of arugula used was Folha Larga. The data were submitted to analysis of variance associated to the F test at 5% of probability, being significant the regression analysis for the dose factor of N and Tukey test at 5% of significance for comparison between the different organic compounds adopted. The filter cake and earthworm humus presented better results when compared to the Azadirachta indica compound under different N sources of biofertilizers. The Azadirachta indica composite obtained better performance than the filter cake in relation to stem diameter at doses of 50 kg ha^{-1} to 100 kg ha^{-1} of N. The best overall performances of the variables were observed in plants fertilized with manure bovine.

Key words: *Eruca sativa*. Hardwood greenery. Organic fertilization. biofertilizers.

INTRODUCTION

The arugula (*Eruca sativa)* is a vegetable with great economic potential, constituting a great option for the cultivation, especially when associated to a family agriculture, because the adaptation to the different regions of the country (Borges et al., 2014). In Brazil, it has been cultivated in several regions, being considered one of the most nutritious vegetables, mainly because it is a source of minerals such as potassium, sulfur, and iron, and vitamins A and C (Porto et al., 2013).

Organic fertilization is of great importance to improve the physical and chemical characteristics of the soil, as it provides nutrients to plants in a gradual and continuous way and may favor a lower incidence of pathogens Trani (2014). There are several sources of organic substrates that can be used in growing vegetables, replacing the synthetic products from sowing to harvesting through a different production from conventional.

Organic biofertilizers can be obtained through a variety of wastes from various agricultural activities (leaves, twigs, straws, roots, tree bark, fruit peels), as well as easy material acquisition and low production costs, but serve as a source of alternative raw material, as well as the production of earthworm humus. These residues must pass through the aerobic composting process that transforms them into quality organic fertilizer (Al-Taey et al.,2018; Nunes, 2009) that can be used in the organic cultivation of vegetables. The need to reuse the by-products of agroindustries in agriculture has been the subject of study by several authors, who have proven that this is a tool that can guarantee the sustainability of the system, as it generates revenue for the companies and gives an adequate disposal to the residue when properly used Rocha et al., (2013), also contributes to the fixation of man in the field. However, if the nutritional balance of the crop is not according to its requirements, its development and productivity can be compromised.

Citation: Eliene dos Reis Matos, *et al.*, Agro Industrial Waste as Source of N for The Production of *ERUCA SATIVA*. Australian Journal of Basic and Applied Sciences, 13(1): 17-22. DOI: 10.22587/ajbas.2019.13.1.3

In recent years, the reuse of waste generated in the different agroindustrial processes has attracted attention. Sustainable alternatives that minimize the use of chemical fertilizers such as carbonized rice hulls, coconut fiber, and bagasse have been increasingly sought after by both organic and business producers. In a study with different substrates in the production of rocket Salles et al. (2017) observed a high content of phosphorus (P) in the filter cake, and when combined with poultry manure favored the growth of the plants, resulting in a higher yield in the arugula culture.

Studies have shown that arugula cultivation can be favored by increasing its productivity through organic cultivation practices. Significant difference between organic and mineral cultivation systems was found in arugula characteristics (plant height, number of leaves per plant, green mass yield and dry shoot mass), with higher average values in organic cultivation (Oliveira et al., 2010). Silva et al. (2015) observed that the use of compost of *Azadirachta indica* in mixture with commercial substrate promoted a greater growth of the sage plants, when compared to the substrate without the addition of compost of Azadirachta indica.

Considering the need to exploit the potential of residues, including agroindustrial, in the production of arugula (*Eruca sativa*), the objective of this study was to evaluate if the use of agroindustrial residues as a source of Nitrogen contributes to the increase of productivity in the cultivation of Eruca Sativa.

MATERIAL AND METHODS

The experiment was conducted in the experimental area of the State University of Goiás - Campus Santa Helena de Goiás, GO, located at a latitude (17º 48 '49 "S) and longitude (50º 35'49" W), with 595 meters of altitude.
The experiment consisted of thirteen treatments, in a randomized complete block design, in a factorial scheme of 4 x 3 + 1, with four sources of biofertilizers (cattle manure, earthworm humus, filter cake and compost of Azadirachta indica) in three doses, (50, 100 and 200 kg ha^{-1}) plus one control (without addition of biofertilizers). The blocks consisted of four beds measuring one meter wide and 7.8 meters long.

O ensaio foi composto por treze tratamentos, em delineamento de quatro blocos casualizados, em esquema fatorial de 4 x 3 + 1, sendo quatro fontes de biofertilizantes (esterco bovino, húmus de minhoca, torta de filtro e torta de nim) em três doses, tomando como referência o teor de N em cada um (50, 100 e 200 kg ha^{-1}) mais uma testemunha (sem adição de biofertilizantes). Os blocos foram constituídos por quatro canteiros de um metro de largura e 7,8 metros de comprimento. Each plot has dimensions of 1 m wide and 0.6 m long, with spacing between rows of 0.15 m, totaling 0.6 m^2 of total area and 0.3 m^2 of floor space.

The doses were determined according to the recommendations necessary for the plant from the chemical analysis of each agroindustrial residue, using as reference the element considered the most important for the leaf development of arugula, the nitrogen present in each biofertilizer. The analyzes of the substrate samples (Table 1) were done according to the methodology of Silva et al. (2009).

Table 1 - Nitrogen (N), Potassium (K) and Phosphorus (P) contents constituents of the biofertilizer used for arugula cultivation in Cerrado Red Latosol.

Biofertilizer	Nutrient content (g/kg)		
	N	K	P
HM	17	17	32
TF	14	4,5	18,3
EB	12	14,5	8,4
TN	60	14,2	14,4

Data: HM - Worm Humus, TF - Filter Pie, EB – Cattle manure, TN - Compost of Azadirachta indica.

Soon after the construction of the beds, a micro sprinkler irrigation system was installed to supply the water demand of the crop, irrigating twice a day according to the method of Marouelli et al. (2009), used the irrigation blade referring to the respective crop. The biofertilizers were applied in total dose and incorporated to the soil fifteen days before sowing, as recommended.

The cultivar of arugula used was Leaf Broad, seeds with germination of 95% and physical purity of 99.9%. Seeding was carried out directly on the soil at a depth of 1 cm. At approximately ten days after emergence the thinning was performed, so that the spacing between plants was 5 cm. Manual weeding with weed control was performed to control weeds. After 40 days of sowing with the plants presenting height around 25 cm, the arugula plants were harvested for sampling.

Five plants of each plot were collected, totaling 3,380 plants in 52 plots, which were separated according to each treatment, being determined: 1- Plant height was measured with ruler graduated in centimeters. 2- Fresh shoot mass, leaves and stem were weighed on analytical balance and then stored in identified paper bags. 3- Diameter of the stem, determined with the aid of a digital caliper. 4- Aerial dry mass: referring to the oven drying at 65ºC for approximately 72 hours, until reaching constant weight, immediately after the drying process was weighed the plants with the aid of an analytical balance. 5- Count the number of leaves per plant.

Statistical analysis

Data were submitted to analysis of variance, at a significance level of 5%. For the comparison of the N rates from each biofertilizer in the arugula cultivation, regression analysis was used, and for the comparison between the four biofertilizers, averages test was applied, with Tukey at 5% probability using the SISVAR program 5.8 (Ferreira, 2011).

RESULTS AND DISCUSSION

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Nitrogen Dose (DN) in the Dry Weight (PS) and the sources (FN) in the number of leaves (NF) of the arugula plants (Table 2) were verified by the analysis of variance. The other variables, however, presented differences to the isolated treatments and the interaction. It is also observed that the coefficients of variation for the PU and PS variables were higher than 20%, but the other variables presented a CV close to 10%, indicating low variability around the mean, demonstrating some accuracy in the data collection.

Table 2: Summary of variance analysis for Wet Weight (PU), Dry Weight (PS), Stem Diameter (DC), Number of Leaves (NF), Plant Height (AP), obtained from the evaluation of the sources and Nitrogen doses (DN), evaluated in the production of arugula in Santa Helena de Goiás, GO, 2015.

FV	GL	F CALCULATED (Fc)				
		PU	PS	DC	NF	AP
DN	3	4,22*	2,25^{ns}	19,57**	5,33**	16,82**
Source	4	9,91**	5,52**	29,38**	0,32^{ns}	6,39**
DN x Source	5	2,43*	3,12*	6,82**	3,14*	13,73**
BLOCK	3	0,61^{ns}	0,31^{ns}	5,30**	0,06^{ns}	2,81*
Error	36	-	-	-	-	
CV (%)	-	23,68	26,08	13,71	11,82	11,24

FV: Source of Variation, GL: Degree of Freedom, * Significant, by F test, at 5% probability, ** Significant, by F test, at 1% probability. NS: was not significant.

Table 3 shows the unfolding of the interaction between the treatment factors for the variables evaluated in the arugula culture. At the dose of 50 kg ha^{-1} of N, it is possible to observe the highlight of the Filter Pie (TF) source in the PU, PS and DC variables, which presented lower values than the other sources. At the dose 100 kg ha^{-1} of N, we noticed a greater relevance of the Bovine Spur compound (EB), in the variables PU, PS and AP. At the dose 200 kg ha^{-1} of N once again the bovine manure has a prominence regarding PU and PS, the variable AP was considerable in the source TN and the NF the EB had greater relevance. In the case of lettuce plants, the highest amount of leaves per plant usually results in a larger leaf area and fresh mass, and, consequently, in productivity (Araújo et al., 2011). As Costa et al. (2011) producing *Corymbia citriodora* seedlings in pots under five doses of bovine manure, obtained better plant growth and dry matter production at a dose of bovine manure of approximately 27 t ha^{-1}.

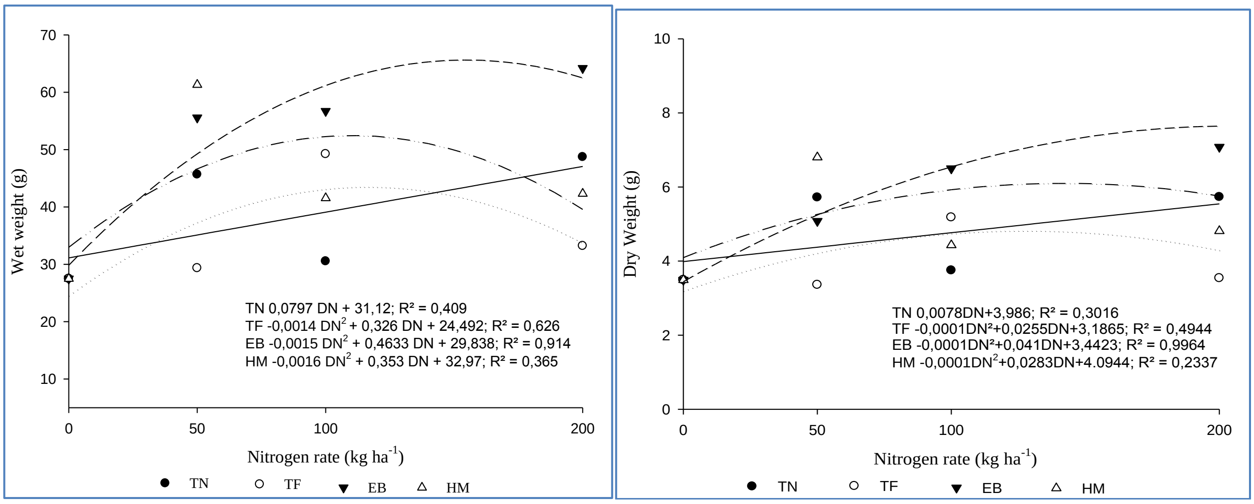
Table 3: Analysis of the mean values of the Nitrogen Dens (DN) in (kg ha^{-1}), Nitrogen Source (FN), Wet Weight (g) in (g), Dry Weight (PS) in (g), Stem diameter (DC) in (g), Height of Plants (AP) in (cm), Number of Leaves (NF) of arugula plants. From doses and sources of Nitrogen, evaluated in Santa Helena de Goiás, GO, 2015.

Dose de N (kg N ha^{-1})	N source	PU		PS		DC		AP		NF	
0	TN	27,49	a	3,49	a	5,99	a	12,79	a	6,93	a
	TF	27,49	a	3,49	a	5,99	a	12,79	a	6,93	a
	EB	27,49	a	3,49	a	5,99	a	12,79	a	6,93	a
	HM	27,49	a	3,49	a	5,99	a	12,79	a	6,93	a
50	TN	45,66	ab	5,72	ab	7,61	b	17,19	a	7,05	a
	TF	29,33	b	3,36	b	3,71	c	17,93	a	7,80	a
	EB	55,57	a	5,08	ab	9,16	ab	13,87	b	6,73	a
	HM	61,29	a	6,80	a	10,05	a	18,31	a	7,40	a
100	TN	30,52	b	3,75	b	6,81	a	8,04	c	6,93	a
	TF	49,22	ab	5,18	ab	6,67	a	16,45	a	7,45	a
	EB	56,70	a	6,50	a	6,10	a	15,49	a	6,20	a
	HM	41,54	ab	4,43	ab	8,03	a	11,90	b	7,00	a
200	TN	48,71	ab	5,73	ab	8,60	b	13,57	ab	8,27	ab
	TF	33,21	b	3,54	b	6,28	c	12,79	b	7,10	b
	EB	64,19	a	7,08	a	11,51	a	16,25	a	8,95	a
	HM	42,31	b	4,81	ab	11,22	a	15,02	ab	7,90	ab

Means followed by the same lowercase letter in the column are not differentiated by the Tukey test at 5% probability. HM: earthworm humus, TN: Pie Nim, TF: Filter cake, EB: Cattle Manure.

The TN source did not obtain the expected development in the arugula plants, since non-significant results were observed when compared to the conventionally used EB and HM (Figure 1A). In rocket seedlings Lopes et al. (2017) reported that the production of dry mass increased significantly with the increase of biofertilizer dilutions from biodigester residue, especially in plants grown on the substrate Tri mix 50-25-25 (coconut fiber, vermiculite and charcoal rice husk, respectively). Júnior et al. (2010) verified an increase in the production of arugula (leaf area, fresh and dry biomass) with the average application at the dose of 193.3 kg ha^{-1} of N.

It is also observed that the compound EB presented the best results in the production of fresh mass of the plants, in the estimated dose of 154.43 kg ha^{-1} of N obtaining a PU of 65.61 g, it is estimated a productivity of approximately 73.26 t ha^{-1} (Figure 1A). Dose similar to that observed was reported in a study with okra commercial fruit production, in which the best yield per plant was quadratic in nature, with the maximum production estimated at 833g, obtained with 141 kg ha^{-1} of N, from sulfate of ammonium (Oliveira et al., 2003). In obtaining higher total fresh mass yield in American lettuce, Yuri et al. (2011) verified a recommendation in the application of 95.0 kg ha^{-1} of N in cover fertilization. Already Carvalho et al. (2013) in chili cultivation, which observed that the increase in nitrogen doses resulted in lower fruit development, where doses lower than 100 mg dm^{-3} of N would give a better result.



(A) (B)

Figure 1: Average weight of the aerial part of the arugula plants in relation to the Nitrogen doses for the sources of Pie of neem (TN), Filter cake (TF), Worm humus (HM), Bovine manure (EB). Wet Weight (A), Dry Weight (B).

In this study the best behavior for PS was with the earthworm compost at the dose of 141.5 kg ha^{-1} of N, obtaining a result of 6.09 g in the PS of the aerial part of arugula (Figure 1B). Differing from this result, Steiner et al. (2012) cultivating lettuce submitted to different doses of N using urea as source of N observed that the doses influenced significantly the results of dry mass of the aerial part, being the doses of 180, 200 and 230 kg ha^{-1} of N responsible by higher dry mass production.

For each 1 kg of N from the EB source, an increase of about 0.0276 mm in stem diameter was observed in the arugula plants, presenting linear growth with increasing doses up to 200 kg ha^{-1} of N (Figure 2). For other sources this increase would be 0.026, 0.002 and 0.013 mm for HM, TF and TN, respectively. For other sources this increase would be 0.026, 0.002 and 0.013 mm for HM, TF and TN, respectively. Note that the TF source showed a smaller increase in stem diameter. These results differ from the results of Zanão Júnior et al. (2005) that did not obtain significant difference in relation to N sources (calcium urea and nitrate) in the production of "kale of malaysia". However, Rodrigues et al. (2015) working with the application of N observed that the doses of 101 and 168 kg ha^{-1} of N increased the percentage of onion bulbs of larger diameter (50-75 mm).

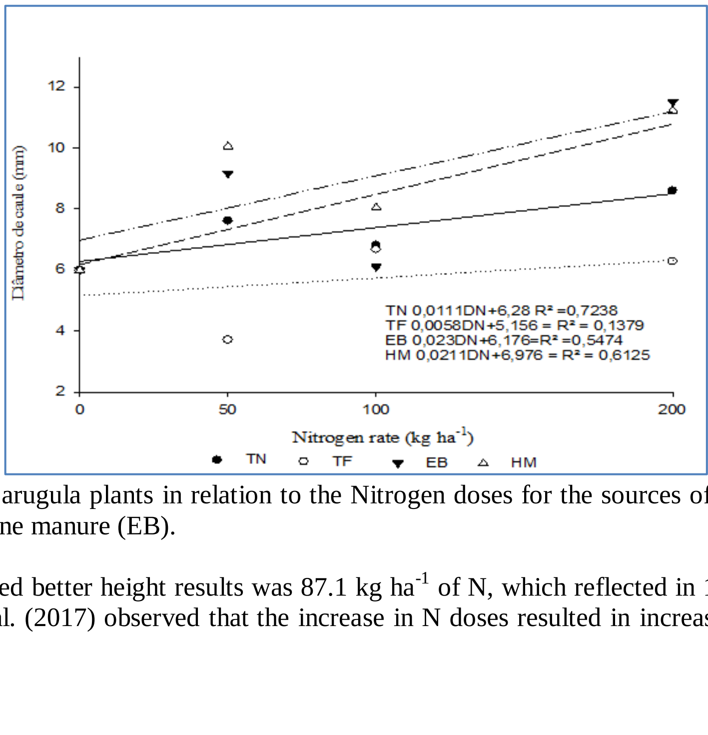
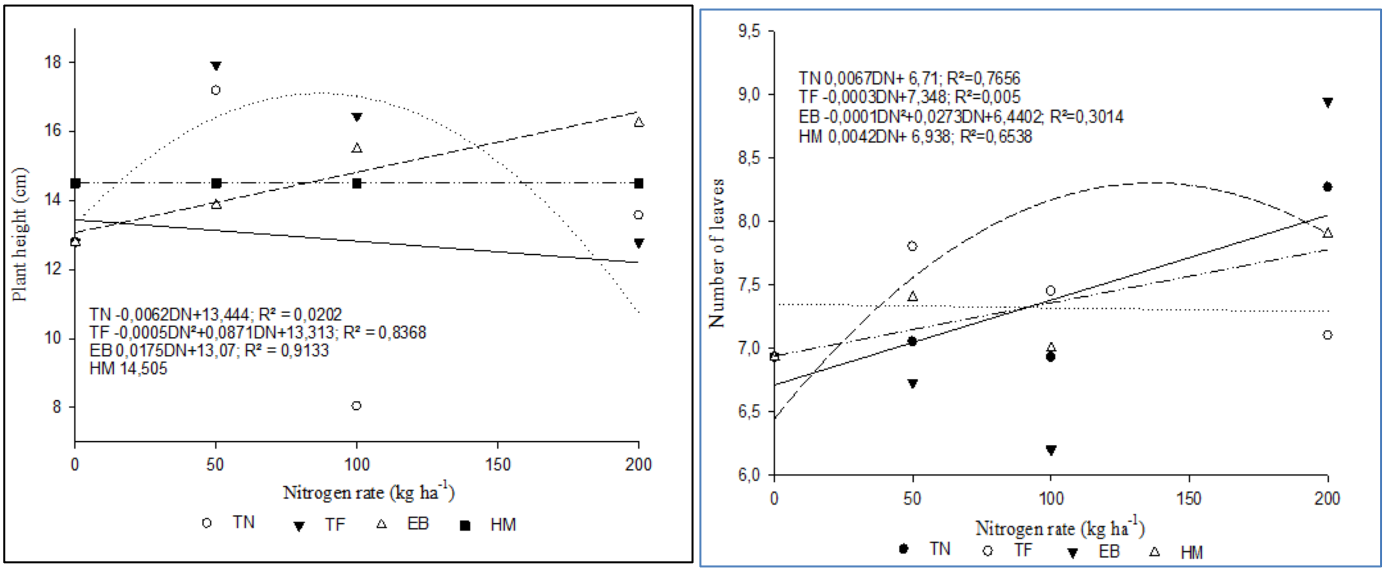


Figure 2: Stem diameter of the arugula plants in relation to the Nitrogen doses for the sources of Pie of neem (TN), Pie of filter (TF), Worm humus (HM), Bovine manure (EB).

The dose of TF that provided better height results was 87.1 kg ha^{-1} of N, which reflected in 17.1 cm plants (Figure 3A). In a study with arugula Dijkstra et al. (2017) observed that the increase in N doses resulted in increases in plant height ranging from

6.21 cm to 16.79 cm, regardless of the type of source used (normal or protected urea). However, the earthworm compost did not present linear and quadratic adjustment in the graph (Figure 3A), this may have been a consequence of having a higher K content.



(A) (B)

Figure 3: Mean height and number of leaves of arugula plants grown under doses and Nitrogen sources, Compost of *Azadirachta indica* (TN), Filter cake (TF), Worm humus (HM), Bovine manure (EB). Height of plants (A), Number of leaves (B).

The EB source was adjusted to a quadratic equation, presenting an optimum estimated dose of 136.5 kg ha^{-1} N, with a mean yield of 8.3 leaves (Figure 3B). In the other sources such as TN and HM, linearity in the graph is observed and practically constant value for TF (Figure 3B). According to Sediyama et al. (2016) who evaluated organic fertilizers in the American lettuce cultivation and found that the organic compounds present high nitrogen content, one of the most extracted nutrients, being responsible for the greater vegetative development, higher productivity and fresh mass of the plant.

CONCLUSION

Cattle manure in general showed better performance in all analyzed variables, presenting optimal doses of 154.43 kg ha^{-1} for a shoot weight of 65.61 g and a dose of 136.5 kg ha^{-1} of N with production average of 8.3 leaves.

The filter cake and earthworm humus as a source of nitrogen presented good results when compared to compost of *Azadirachta indica* in the wet and dry weight variables under different sources of biofertilizer compounds. The filter cake presented results of 65.61 g at a dose of 87.1 kg ha^{-1} of N, reflecting a plant height of 17.1 cm.

The compost of *Azadirachta indica* obtained better performance than the filter cake in relation to the stem diameter in the doses of 50 kg ha^{-1} to 100 kg ha^{-1} of N.

ACKNOWLEDGEMENT

To the State University of Goiás for the support in carrying out the study.

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