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Morphological and yield responses of 'BRS Vitória' grapevines subjected to bio-fertigation with aquaculture wastewater

Abstract – The objective of this work was to evaluate the agronomic responses of 'BRS Vitória' grapevines under bio-fertigation with and without conventional soil fertilizer. A completely randomized design was used, with three treatments and 18 replicates. The treatments were: CFI, conventional soil fertilizer and irrigation; BF+CF, bio-fertigation and conventional fertilizer; and BF, only bio-fertigation. The following variables were evaluated: graft and rootstock diameters; plant growth; number of lateral buds; root, leaf, petiole, and gem starch contents; bunch number per plant, length, circumference, and fresh weight; berry number per bunch, length, diameter, fresh weight, soluble solid contents, titratable acidity, and pH; yield; and leaf macro- and micronutrient contents. From 100 to 150 days after transplanting (DAT), rootstock and graft diameters were similar, increasing from 250 to 300 DAT in the CFI treatment. The highest root starch content was 7.19% in BF at 150 DAT and 37.35% in BF+CF at 300 DAT. The plants in BF+CF showed the best results for bunch number per plant and fresh weight, resulting in a fruit yield 22% higher than that obtained in the other treatments. 'BRS-Vitória' grapevines show a satisfactory agronomic performance when bio-fertigated.

Index terms: *Vitis vinifera*, aquaculture effluents, fertilizer application.

Respostas morfológicas e produtivas de videiras 'BRS Vitória' submetidas à nutribioirrigação com água residuária da piscicultura

Resumo – O objetivo deste trabalho foi avaliar as respostas agronômicas de videiras 'BRS Vitória' submetidas à nutribioirrigação com e sem adubação convencional. Utilizou-se o delineamento inteiramente casualizado, com três tratamentos e 18 repetições. Os tratamentos foram: TC, adubação e irrigação convencionais; TNC, nutribioirrigação e adubação; e TN, apenas nutribioirrigação. Foram analisadas as seguintes variáveis: diâmetros do porta-enxerto e do enxerto; crescimento da planta; número de botões laterais; teores de amido na raiz, na folha, no pecíolo e nas gemas; número por planta, comprimento, circunferência e massa fresca dos cachos; número por cacho, comprimento, diâmetro, massa fresca, sólidos solúveis, acidez titulável e pH das frutas; produção; e teores de macro e micronutrientes nas folhas. De 100 a 150 dias após o transplantio (DAT), os diâmetros do porta-enxerto e do enxerto foram similares, tendo aumentando de 250 a 300 DAT no TC. O maior teor de amido na raiz foi de 7,19% no TN aos 150 DAT e de 37,35% no TNC aos 300 DAT. As plantas no TNC apresentaram os melhores resultados para número por planta e massa fresca dos cachos, o que resultou em produção 22% superior à obtida nos demais tratamentos. A videira 'BRS Vitória' apresenta desempenho agronômico satisfatório quando submetida à nutribioirrigação.

Termos para indexação: *Vitis vinifera*, efluentes da aquicultura, adubação.

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Introduction

Grape production is increasing in Brazil due to the emergence of new cultivars, the adaptation of the crop to tropical regions, and the increasing domestic consumption and exportation of fine fresh grapes, juices, and wines (Soares & Leão, 2009). In the country, according to the same authors, the lower-middle São Francisco Valley presents conditions that are favorable for viticulture development, such as high temperatures throughout the year, high solar radiation incidence, low relative air humidity, and low water availability for irrigation, which decrease disease incidence in grapevines, increase soluble solid contents in berries, reduce the phenological cycle up to 30–50 days, and maintain plant growth for up to five haverstings every two years.

Recently, several new grapevine cultivars have been launched in Brazil, among them BRS Vitória. BRS Vitória – resulting from the CNPUV 681-29 [Arkansas 1976 x CNPUV 147-3 ('Niágara Branca' x 'Vênus')] x 'BRS Linda' crossing – presents seedless table grapes with a special flavor, a high reproductive vigor, a good tolerance to diseases, a lower need of fungicide applications, tolerance to berry cracking, and a high fruit yield above 30 Mg ha^{-1} (Maia et al., 2014; Souza et al., 2018; Leão et al., 2020). In addition, it is adapted to a wide range of climates and, consequently, shows an outstanding agronomic performance in different regions of the country.

Specifically in the semiarid region of Northeastern Brazil, water availability is often a limiting factor for agriculture and soils are nutrient deficient, especially of nitrogen and phosphorous (Tiessen et al., 1992). In this scenario, correctly disposed wastewater, such as that of aquaculture, is an alternative source of water with nutrients for plant uptake. Since 25 to 30% of the non-digestible dry matter of fish feed remain in the aquaculture system as fecal material, aquaculture effluents contain 29 to 51% N, 7 to 64% P, and 3% organic matter according to the contents present in the feed (Zaheer et al., 2020a, 2020b; Saleem et al., 2022). Therefore, an integrated aquaculture-agriculture production system can minimize production costs and, consequently, increase the income of family farmers.

To date, aquaculture wastewater has been used as a viable alternative for the bio-fertigation of several crops, such as: banana (*Musa* spp.) (Gomes et al., 2012), papaya (*Carica papaya* L.) and passion fruit (*Passiflora edulis* Sims) seedlings (Oliveira et al., 2020), cashew (*Anacardium Occidentale* L.) and mango (*Mangifera indica* L.) (Pereira Junior et al., 2018, 2020), soursop (*Annona muricata* L.) (Azevedo et al., 2019), acerola cherry (*Malpighia punicifolia* L.) (Santos et al., 2020), only papaya (Rosa et al., 2018; Santos et al., 2018b; Bezerra et al., 2019), and tomato (*Lycopersicon esculentum* L.) (Nascimento et al., 2016). However, there is a lack of studies on the application of such effluents to grapevines, which show a high potential for cultivation in semiarid regions.

The objective of this work was to evaluate the agronomic responses of 'BRS Vitória' grapevines under bio-fertigation with and without conventional soil fertilizer.

Materials and Methods

The experiment was conducted from July 2019 to January 2022 in the experimental area of Universidade Federal do Oeste da Bahia, in the municipality of Barra, in the state of Bahia, Brazil. This site was chosen because it presents edaphoclimatic conditions similar to those of important viticulture areas of the country (Moura et al., 2017). It is located at an altitude of 404 m and has a Bsh climate according to Köppen's classification, with an annual rainfall of 650 mm and a mean temperature of 27.5°C (Inmet, 2022). The soil is classified as a Neossolo Quartzarênico, according to the Brazilian soil classification system (Santos et al., 2018a), i.e., a Quartzipsamment.

A closed aquaculture production system consisting of a 15 m^3 circular fish-breeding tank (Vinitank, Sansuy, Embu, SP, Brazil) was used to obtain the wastewater for bio-fertigation (BF). Nile tilapia (*Oreochromis niloticus* L.), with an average weight of 10 g, were placed in this system, resulting in a density of 60 fish per cubic meter. Microbial flakes were cultivated to encourage fish feeding and to transform nitrogen compounds in the water. To oxygenate the water, a turbine was used to pump 18 m^3 of air per hour. Before plant bio-fertigation, the water was stabilized and the following microorganisms were added as probiotics for the gastrointestinal tract of the fish: *Bacillus cereus* var. toyoi, *Bacillus subtilis*, *Bifidobacterium bifidum*, *Enterococcus faecium*, *Lactobacillus acidophilus*, and *Pseudomonas* spp. Sugarcane molasses (250 mL) and

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wheat bran (100 g) were added daily for 30 days as carbon sources (Silva et al., 2017).

To prepare the vineyard site, 60 days before the 'BRS Vitória' grapevine seedlings were planted, 1.5 Mg ha^{-1} dolomitic limestone was applied and incorporated using a harrow. Then, 30 days before planting, 40×40×40 cm pits were dug in 50 cm raised beds. Each pit was filled with 20 L organic matter (biochar, cured caprine manure, and dried cut grass), 100 g dolomitic limestone, and 200 g simple superphosphate.

Thirty days after the pits were prepared, grapevine seedlings grafted on 'Paulsen 1103' (*Vitis berlandieri* Planch. x *Vitis rupestris* Scheele) rootstocks were transplanted to them. The irrigation system consisted of 25 mm diameter hoses with diffusers spaced at 1.5 m; irrigation volume was adjusted according to the crop coefficient and the climate of the region (Soares & Leão, 2009).

The treatments were based on soil and aquaculture effluent analyses. Soil samples were collected at 0.0–0.2 and 0.2–0.4 m to determine nutrient availability as described in Teixeira et al. (2017) (Table 1). The nutrient profile of the solution to be used for bio-fertigation showed: 5.5 mg L^{-1} Ca, 0.2 mg L^{-1} Mg, 0.18 mg L^{-1} total N, 0.01 mg L^{-1} Al, 0.25 mg L^{-1} Fe, 0.93 mg L^{-1} Na, 0.92 mg L^{-1} total P, 0.12 mg L^{-1} SO_4^{2-}, and 0.15 mg L^{-1} NH_4.

The experiment was carried out in a completely randomized design with three treatments and 18 replicates. The experimental area had 12x30 m, and the experimental unit consisted of one plant. The treatments were: CFI, control treatment, with conventional soil fertilizer and conventional irrigation; BF+CF, bio-fertigation and conventional soil fertilizer applied at rates defined according to the wastewater nutrient analysis; and BF, continuous bio-fertigation throughout all plant development stages.

The grapevines were analyzed as recommended by Soares & Leão (2009), starting at 60 days after seedling transplantation and, then, every 15 days. The evaluated variables were: graft and rootstock diameters (mm), measured at 3.0 and 5.0 cm height from the grafting point and from the ground level, respectively; plant growth, considered the number of days for plants to reach the trellis height of 1.90 m; number of days for plants to reach the shoot-topping stage, counted when the vines reached 2.0 m in the main wire; leaf electrical conductivity, measured in ten randomly chosen leaves of each plant per treatment; root, leaf, petiole, and gem starch contents; bunch number per plant, length, circumference, and fresh weight; berry number per bunch, fresh weight, length, diameter, soluble solid contents, titratable acidity, and pH; fruit yield; disease and pest incidence, monitored weekly; and average macro- and micronutrient contents of petiolated leaves.

To determine leaf electrical conductivity, the selected leaves were washed in running water and placed on absorbent paper to remove excess water. Then, five 10 mm diameter disks were punched out from each leaf and immediately immersed in 50 mL distilled water for 24 hours. Conductivity was read using the CD-880 portable conductivity meter (Instrutherm, São Paulo, SP, Brazil), and data were expressed as µS cm^{-1}.

Specifically for starch content, the method of Patel (1970) was used. First, samples of 30 g fresh matter were collected from plants of each treatment at the vegetative (150 and 300 DAT) and full-flowering stages, dried in an oven at 60°C, and crushed. Then, a subsample of 0.1 g of each sample was evaluated.

For mineral analyses (macro- and micronutrients), 20 leaves from the opposite side of the bunch were collected from each plant. A sample of 0.2 g and another of 0.5 g were digested by sulfuric and nitric-perchloric acids, respectively. The sulfuric extract was used to determine total N by the Kjeldahl method, and the nitric-perchloric extract, to quantify P, K, Ca, Mg, Cu, Mn, Fe, Zn, and S contents. P content was obtained through colorimetry using the UVS-752N spectrophotometer (JKI, Shanghai, China). The contents of K, Ca, Mg, Cu, Mn, Fe, Zn, and S were quantified by atomic absorption spectrophotometry using the SpectrAA 220 FS spectrophotometer (Varian

Table 1. Chemical analysis of the soil of the experimental area(1).

Layer (cm)	pH $CaCl_2$	OM (g dm^{-3})	Prem (mg dm^{-3})	K^{2+}	Ca^{2+}	Mg^{2+}	Al+H	BS (%)	S	B	Cu	Fe	Mn	Zn
				(mmol$_c$ dm^{-3})					(mg dm^{-3})					
0–20	6.50	13.63	54.04	2.55	38.77	5.62	9.0	83.91	3.77	0.32	0.19	35.35	1.63	1.21
20–40	5.88	4.66	54.39	2.76	20.18	3.24	7.0	78.90	6.77	0.12	0.24	38.77	1.98	1.03

(1)OM, organic matter; Prem, remaining phosphorus; and BS, base saturation.

Inc., Palo Alto, CA, USA). The results were expressed in g kg^{-1} and mg kg^{-1} dry matter for macro- and micronutrients, respectively, and classified according to Raij et al. (1997).

Regarding the phytosanitary analysis, the found diseases were described, the caused symptoms were photographed, and, then, control measures were taken.

The data met the assumptions of the analysis of variance. The normality of residuals was tested by Shapiro-Wilks' test, and the homogeneity of variance by Hartley's test. The independence of errors was checked using a residual plot. The calculated coefficient of determination (R^2=0.99) indicated a good fit as a linear model. The data were subjected to the one-way analysis of variance and, when significant differences were observed, to regression analysis, and means were compared by Tukey's test, at 1% probability. The incidence of diseases and pests was analyzed using descriptive statistics.

Results and Discussion

The linear regression of the graft and rootstock growth data presented a linear fit (Figure 1 A), and the regression coefficients were significant by the t-test, at 5% probability. Both the graft and rootstock diameters were larger in the CFI treatment, not differing in BF+CF and BF. However, the graft diameters remained similar in the three treatments until 150 DAT, only increasing in CFI after 250 DAT (Figure 1 B). The final diameter of the rootstock was larger in the CFI treatment, as was that of the graft, when compared with that of BF, not differing from that in BF+CF (Table 2).

The obtained results are an indicative that the wastewater from aquaculture positively affected the diameter of 'BRS Vitória' grapevine plants. Oliveira et al. (2020) also observed a positive effect on papaya and passion fruit seedlings irrigated with wastewater, which was recommended as a nutritional alternative to water for plant maintenance and growth. However, Pereira Junior et al. (2018, 2020) found no difference in the diameters of cashew and mango seedlings irrigated with agroindustrial wastewater. In other studies, the stem diameter of soursop (Azevedo et al., 2019) and acerola berry (Santos et al., 2020) was even shown to decrease over time with the application of agroindustrial wastewater, which is attributed to the salt level in the used effluents (Oliveira et al., 2020).

Plants presented a faster growth in height in the BF+CF treatment, meaning that a shorter time, on average 70.66 days, was required to reach the main wire, representing 10 and 6 days less than in CFI and BF, respectively (Table 2). Consequently, the plants in BF+CF also reached the shoot-topping stage 13 and 10 days earlier than those in the two other treatments, possibly due to the extra N uptake from the wastewater used for bio-fertigation, in which nitrite was converted into nitrate, essential for plant development. According to Soares & Leão (2009), shoot topping, consisting of

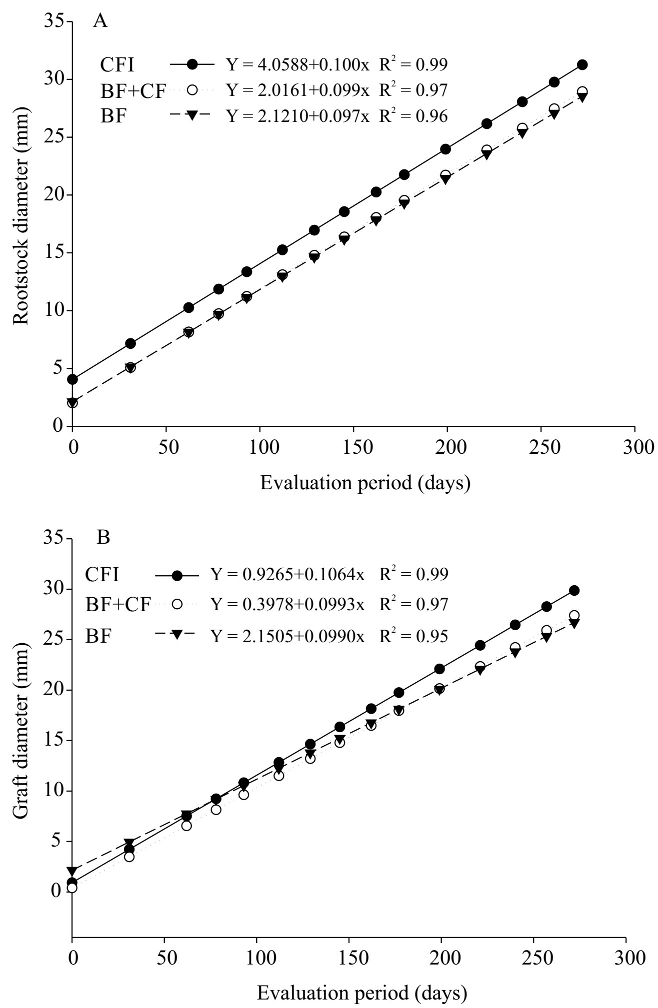

Figure 1. Stem diameter growth of the rootstock (A) and graft (B) of grapevines of the BRS Vitória (*Vitis vinifera*) cultivar from planting to 270 days after transplanting. CFI, conventional soil fertilizer and irrigation; BF+CF, bio-fertigation + conventional fertilizer; and BF, only bio-fertigation.

bud removal to decrease apical dominance, favors both the maturation of basal gems, balancing plant growth, increasing bunch weight, and improving grape quality, as well as the stimulation of axillary gem sprouting for spur pruning in seedless grapes; therefore, an earlier shoot topping leads to a higher fruit yield.

Regarding leaf electrical conductivity, the highest values, with a mean of 30.44 µS cm^{-1}, were found in the BF treatment (Table 2), showing no evidence of plant stress. This result is in alignment with that of Moreira (2018), who concluded that fully green grapevine leaves presented electrical conductivities lower than 30 µS cm^{-1} under non-stressful conditions. Monitoring electrical conductivity is important to evaluate the stress level of the plants, helping to determine when specific products should be applied to improve grapevine photosynthetic rate, minimize reserve losses, and prevent a low fruit yield.

In all treatments, the amount of branches and fruits was similar (Table 2), which is an indicative that bio-fertigation provided nutrients to the plants up to pre-pruning. This is an important finding for integrated aquaculture systems.

Leaf starch contents were 31% higher in CFI, compared with BF, at 150 DAT. However, since the plants accumulated a greater amount of starch in the petiole (~35%) and roots (~18%) in CFI (Table 3), bio-fertigation promoted a greater plant growth and, consequently, accumulation of initial reserves in BF.

Higher starch contents were found in the roots in the BF+CF treatment and in the gems in BF and BF+CF at 300 DAT. At the flowering stage, the starch contents in the roots were similar to those obtained in CFI and BF+CF at 300 DAT, whereas those in the gems were lower in CFI, with no significant differences in BF+CF and BF (Table 3). Root and gem starch contents are a parameter used to define the ideal moment for spur pruning and to adjust the nutritional requirements of commercial vineyards, being good predictors of fruit yield in the following crop season (Mohamed et al., 2012).

The analysis of the starch contents in the tissues (leaves, petioles, and roots) of the plant can indicate

Table 2. Mean rootstock diameter (RD), graft diameter (GD), days to reach the main wire (DMW), days for shoot topping (DCP), leaf electrical conductivity (LEC), and number of lateral buds in the main branch (NLB), as well as their respective coefficients of variation (CV), for grapevines of the BRS Vitória (*Vitis vinifera*) cultivar[(1)].

Treatment[(2)]	RD	GD	DMW	DCP	LEC	NLB
	--------------(mm)--------------		---------------(days)---------------		(µS cm^{-1})	
CFI	31.87a	31.99a	81.66a	127.38ab	27.28b	11.27a
BF+CF	30.02ab	28.26b	70.66b	117.33b	28.32ab	11.44a
BF	28.75b	28.95ab	76.77ab	130.55a	35.72a	10.83a
General mean	30.22	29.73	76.57	125.09	30.44	11.18
CV (%)	7.98	11.04	12.57	14.96	14.94	11.24

[(1)]Means followed by equal letters, in the columns, do not differ from each other by Tukey's test, at 1% probability. [(2)]CFI, conventional soil fertilizer and irrigation; BF+CF, bio-fertigation + conventional fertilizer; BF, only bio-fertigation.

Table 3. Mean percentage of starch contents in the leaves (LSC), petioles (PSC), roots (RSC), and gems (GSC) at 150 and 300 days after transplanting (DAT) and in the roots (RSC-F) and gems (GSC-F) at flowering, as well as their respective coefficients of variation (CVs), for grapevines of the BRS Vitória (*Vitis vinifera*) cultivar[(1)].

Treatment[(2)]	LSC (%)	PSC (%)	RSC (%)	RSC (%)	GSC (%)	RSC-F (%)	GSC-F (%)
	150 DAT			300 DAT		Flowering	
CFI	6.61a	6.61b	6.66ab	36.80ab	22.18b	34.22a	24.21b
BF+CF	5.46ab	6.80b	6.06b	37.35a	24.38a	35.04a	25.47a
BF	5.04b	9.08a	7.19a	35.25b	24.60a	32.92b	25.45a
General mean	5.70	7.50	6.64	36.95	23.72	34.06	25.04
CV (%)	27.79	14.71	33.91	6.95	6.99	5.65	4.50

[(1)]Means followed by equal letters, in the columns, do not differ from each other by Tukey's test, at 1% probability. CFI, conventional soil fertilizer and irrigation; BF+CF, bio-fertigation + conventional fertilizer; and BF, only bio-fertigation.

whether it is photosynthetically active and whether it allocates reserves to other non-photosynthetic tissues, such as roots. The root system is one of the main storage organs in plants, being responsible for maintaining the carbohydrate reserves required for sprouting and new branches in the subsequent cycle (Matsuura et al., 2001). In Brazil, where annual pruning causes vineyards to spread continuously, the BF+CF treatment provides conditions for the plant to accumulate carbohydrates for its growth and fruit yield.

Bunch number per plant, bunch fresh weight, and fruit yield were greater in BF+CF, with means of 74.38, 276.46 g, and 20.6 kg, respectively, being similar in the other treatments (Table 4). The mean number of bunches per plant was 67.62 in all treatments, representing a density of 8.45 bunches per square meter, close to that considered ideal, which is of 10 bunches per square meter (Leão & Lima, 2016). Also evaluating 'BRS Vitória' grapevines in the lower-middle São Francisco River Valley, Leão & Lima (2016) found a mean bunch weight of 220 g, lower than that of the present study, whereas Leão et al. (2020) reported bunch weights ranging from 191.62 to 214.28 g when using the SO_4 rootstock during eight production cycles. These results are an indicative of the potential for grape production in the municipality of Barra using an integrated aquaculture system.

The mean fruit yield was 22% higher in BF+CF compared with the other treatments, being 20.6 kg per plant, with an estimated yield of 30 Mg ha^{-1}. Maia et al. (2014) highlighted that the ideal fruit yield ranges from 25 to 30 Mg ha^{-1} per cycle in regions with only one annual crop season and from 16 to 30 Mg ha^{-1} per cycle in regions with two annual crop seasons.

The superior performance of the BF+CF treatment in terms of bunch number per plant, fresh bunch weight, and fruit yield is an indicative that the combination of aquaculture effluents and commercial fertilizers may have enhanced the effect of nutrients on the plants. This could be attributed to the increase in nutrient availability and the decomposition of organic matter over time when concentrated aquaculture effluents are used (Santos, 2009).

Although bunch circumference was similar in all treatments, with a mean of 20.43 cm, the plants in BF produced shorter bunches (Table 4), with a mean of 14.00 cm, a value slightly lower than the 15.43 cm found for 'BRS Vitória' by Leão & Lima (2016).

There were no significant differences for berry number per bunch, diameter, length, fresh weight, soluble solids, and pH (Table 5). Similar values were reported by Leão et al. (2020) for berry diameter and length (17.64 and 23.49 mm, respectively) and by Leão & Lima (2016) for berry diameter, length, and fresh weight (16.8 mm, 25.5 mm, and 3.70 g). Considering these results, CFI and BF produced bunches suitable for the market.

The values obtained for the soluble solids, pH, and titratable acidity of the berries (Table 5) were similar to those found in the literature, which were, respectively: mean soluble solid contents of 19 to 22.5 ºBrix for ripe 'BRS Vitória' berries in production areas (Maia et al., 2014), pH 3.77 (Caldeira et al., 2018), and ideal titratable juice acidity from 0.6 to 0.8 g 100 mL^{-1} tartaric acid at harvesting time (Leão & Lima, 2016). However, titratable acidity was higher in berries from the CFI treatment. According to Maia et al. (2014), the ideal balance between soluble solids and titratable acidity ranges from 20 to 30, with soluble solids from 19 to 23 ºBrix and titratable acidity from 0.75 and 0.9 g 100 mL^{-1} tartaric acid. Considering these values, in the present study, the 'BRS Vitória' grapes were at the

Table 4. Mean number of bunches per plant (NBP), bunch weight, fruit yield, bunch circumference, and bunch length, as well as their respective coefficients of variation (CVs), for grapevines of the BRS Vitória (*Vitis vinifera*) cultivar[(1)].

Treatment[(2)]	NBP	Bunch weight (g)	Fruit yield (kg per plant)	Bunch circumference (cm)	Bunch length (cm)
CFI	62.94b	267.20b	16.81b	20.57a	14.94a
BF+CF	74.38a	276.46a	20.60a	20.52a	15.78a
BF	65.55b	255.45c	16.74b	20.21a	14.00b
General mean	67.62	266.37	18.05	20.43	14.90
CV (%)	8.88	9.00	12.73	3.42	7.63

[(1)]Means followed by equal letters, in the columns, do not differ from each other by Tukey's test, at 5% probability. CFI, conventional soil fertilizer and irrigation; BF+CF, bio-fertigation + conventional fertilizer; and BF, only bio-fertigation.

ideal time for consumption, presenting a pronounced red raspberry-like flavor.

The macronutrient analysis in petiolated leaves showed higher N and Mg contents in CFI, higher P and Ca contents in BF, and similar K and S contents among treatments (Table 6). According to the classification of Raij et al. (1997), N contents were low in BF+CF and BF and even lower in CFI, K content was low in all treatments, P content was slightly excessive in CFI and excessive in BF+CF and BF, Ca contents were low in CFI and BF+CF and even lower in BF, and Mg and S contents were low in all treatments.

The micronutrient analysis showed: low contents of Cu and Fe in the three treatments; higher B, Cu, Fe, and Zn contents in BF; and higher Mn contents in CFI. According to the classification of Raij et al. (1997), B contents were within the ideal range in BF but were very low in the other treatments, Mn contents were slightly low in BF+CF, Mn was slightly excessive in CFI and ideal in BF, and Zn contents were very low in all treatments. The general low mineral contents in the studied leaves can be related to the full-flowering stage, whose nutritional demand is high due to fruit yield.

During the evaluation period, powdery mildew [*Uncinula necator* (Schw.) Burr.] and grapevine rust (*Phakopsora euvitis* Ono) were observed between November and December and between February and April, respectively.

Powdery mildew is an important disease in grapevine crops because it infects all green and tender organs of the plant, reducing fruiting due to the lower number of flowers and possibly causing under development and cracks in the remaining fruits (Barbosa et al., 2016). The disease was controlled using sulfur- and triflumizole-based fungicides every 7 days, totaling four applications.

The emergence of the grapevine rust pathogen was related to the climatic conditions of the site, characterized by an atypical accumulated rainfall

Table 5. Mean number of berries per bunch (NBB), berry diameter, berry length, berry fresh weight (BFW), soluble solids, titratable acidity (TA), and pH, as well as their respective coefficients of variation (CVs), for berries of the BRS Vitória (*Vitis vinifera*) cultivar[(1)].

Treatment[(2)]	NBB	Berry diameter	Berry length	BFW	Soluble solids	TA	pH
		-------------(mm)-------------		(g)	(°Brix)	(%)	
CFI	85.72a	17.70a	20.21a	3.33a	21.01a	0.77a	3.90a
BF+CF	86.22a	18.00a	22.65a	3.32a	21.66a	0.70b	3.92a
BF	79.94a	17.70a	20.74a	3.06a	21.33a	0.66b	3.95a
General mean	83.96	17.80	21.20	3.23	21.33	0.71	3.92
CV (%)	11.32	3.13	20.31	23.09	8.44	8.24	4.34

[(1)]Means followed by equal letters, in the columns, do not differ from each other by Tukey's test, at 5% probability. [(2)]CFI, conventional soil fertilizer and irrigation; BF+CF, bio-fertigation + conventional fertilizer; and BF, only bio-fertigation.

Table 6. Mean nitrogen, phosphorus, calcium, magnesium, sulfur, boron, copper, iron, manganese, and zinc contents in petiolated leaves, as well as their respective coefficients of variation (CVs), for grapevines of the BRS Vitória (*Vitis vinifera*) cultivar grown under bio-fertigation with aquaculture effluents[(1)].

Treatment[(2)]	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	----------------(g kg^{-1})----------------						----------------(mg kg^{-1})----------------				
CFI	26.50a	3.90b	14.70a	8.70b	2.00a	1.80a	41.60b	6.90b	60.90b	83.30a	16.20b
BF+CF	25.80b	4.00b	14.90a	8.70b	1.80b	1.90a	41.00b	6.90b	58.20c	60.50c	15.90b
BF	25.50b	4.40a	14.80a	10.40a	1.60c	1.90a	47.10a	7.00a	71.70a	71.70b	16.90a
General mean	25.93	4.10	14.80	9.26	1.80	1.86	43.22	6.93	63.6	71.83	16.33
CV (%)	2.96	4.17	8.75	5.75	14.04	9.55	2.29	5.37	4.59	4.19	4.30

[(1)]Means followed by equal letters, in the columns, do not differ from each other by Tukey's test, at 5% probability. CFI, conventional soil fertilizer and irrigation; BF+CF, bio-fertigation + conventional fertilizer; and BF, only bio-fertigation.

of 702 mm. According to Alves et al. (2018), this disease is spread by the wind and the germination of urediniospores is favored by leaf wetness for more than 12 hours, low luminosity throughout the day, and temperatures from 15 to 25°C. The fungus causes early senescence, leaf fall, and decreased fruit yield and quality (Xavier et al., 2012; Barbosa et al., 2016). A copper sulfate- and metiram + pyraclostrobin-based systemic fungicide was used to control the pathogen, being applied sequentially to minimize the dissemination of the disease in the area.

Throughout the experiment, spittlebug (*Clastoptera* sp.) was also observed attacking petioles and bunch stalks. The bug was monitored, but no chemical control was needed.

The obtained results confirm that the reuse of aquaculture effluents can optimize water use in agriculture, specifically in vineyards, mitigating the environmental impacts of fish farming.

Conclusions

1. 'BRS Vitória' grapevines (*Vitis vinifera*) show a satisfactory growth, development, and yield when bio-fertigated with aquaculture wastewater.
2. The treatment combining bio-fertigation with conventional fertilizer application and conventional irrigation presents the best overall results for the analyzed variables.
3. The edaphoclimatic conditions of the municipality of Barra, in the state of Bahia, Brazil, are favorable for 'BRS Vitória' grapevine production.

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