

Effect of Coconut Water on Physical Characteristics and Yield of *Vanilla planifolia* Fruit

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ABSTRACT

Objective: To evaluate the effect of coconut water spray on the physical characteristics and yield of vanilla fruit and to identify the relationship between environmental variables and yield components in Gutiérrez Zamora, Veracruz, Mexico.

Design/Methodology/Approach: The study was conducted in a 3- to 4-year-old vanilla plantation under shade mesh with bamboo stakes as support. The variables measured were fruit and plant dimensions, weight, yield components, and environmental variables (temperature, relative humidity, and photosynthetically active radiation, PAR). Beginning at flowering, the plants were sprayed every two weeks for three months with one of four treatments (T1: 100% water; T2: 50% coconut water; T3: 100% coconut water; and T4: Megafol solution) at two sites within the same vanilla plantation. Statistical analysis consisted of ANOVA, comparison of means, and canonical correlation analysis.

Results: The highest averages of fruit dimensions and weight were obtained from Site 1. T2 and T3 fruits were heavier than T1 and T4 fruits. The canonical correlation analysis showed that PAR and relative humidity were related in different ways to yield component variables in function of the vanilla plantation site.

Study Limitations/Implications: Using coconut water as an organic alternative for fertilization can decrease application of chemical substances and reduce production costs, among other advantages.

Findings/Conclusion: Coconut water applied at the beginning of the vanilla flowering stage has a significant effect on fruit dimensions and on the accumulation of fruit dry matter and may be an organic option for supplying nutrients and increasing vanilla yield.

Keywords: *Cocos nucifera* L., organic fertilizer, yield, environment.

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INTRODUCTION

In 2019, Mexico produced 850.4 tons of vanilla, production that was distributed over four states: Veracruz (Totonacapan region) with approximately 80% (679.5 t) of the country's total production, Oaxaca with 10.11% (86 t), Puebla with 7.74% (65.9 t), and San Luis Potosí with 2.23% (19 t) (SIAP, 2019).

Vanilla can be cultivated in various ways. It can be grown in *acahual*, or secondary vegetation, or intensively with live or inert supports. In the Totonacapan region, the two most used systems are in *acahual* and under shade mesh (Espinoza-Pérez *et al.*, 2018). In *acahual*, the plant obtains most of its nutrients from the organic matter that accumulates on the soil when the support tree loses its leaves (Barrera-Rodríguez *et al.*, 2009), while management and monitoring is easier under shade mesh, and agrochemical application and irrigation is controlled (Hernández-Hernández, 2014). Because vanilla cultivation depends essentially on organic nutrition and traditional management, vanilla plantations lack a management system that standardizes variables such as the amount and quality of organic matter that should be incorporated (González-Chávez *et al.*, 2018). For this reason, in terms of establishment and maintenance of vanilla plantations, one of the main challenges is to maintain adequate plant nutrition (Carrillo-González & González-Chávez, 2018), which has positive effects on number of inflorescences, flower budding, number of fruits, and fruit size, among other variables (Diez *et al.*, 2018). Naturally, these variables can also depend on management, water availability, solar radiation, and temperature (Rocha-Flores *et al.*, 2018). Vanilla is a species that is highly sensitive to climate events (Borbolla-Pérez *et al.*, 2016), and for this reason, production on the national level is low.

It has been documented that coconut (*Cocos nucifera* L.) fruit promotes plant growth because of its content of phytohormones (Sandoval-Prando *et al.*, 2014), such as cytokines, which are known to play an important role in plant growth and development (Ge *et al.*, 2006). Several studies have found that coconut water contains diverse organic compounds and mineral nutrients that are important for plant development (Ramírez-Luna *et al.*, 2005; Vieira de Souza *et al.*, 2013; Sandoval-Prando *et al.*, 2014). Worldwide, Mexico is eighth in the production of coconut palm, contributing 1.7% of the world production. This palm is found in mostly in tropical regions (SAGARPA, 2017), and the tropical state of Veracruz is one of the main producer states of *C. nucifera* L. as well as of *Vanilla planifolia* L. For this reason, we propose the application of coconut water in the cultivation of vanilla to make use of the plant genetic resources that exist in the region. The objective of this study was to evaluate the effect of applying coconut water at different concentrations on physical characteristics and yield of vanilla fruit, as well as to determine the relationship between yield components and environmental variables at two sites of the same vanilla plantation in Paso de Barriles, Gutiérrez Zamora, Veracruz.

MATERIALS AND METHODS

Study Sites

The study was conducted during the 2019 crop cycle in a vanilla plantation established with inert supports (bamboo) in a system under 50% shade mesh. The vanilla plantation is found in the locality Paso de Barriles, Gutiérrez Zamora, Veracruz, at -97.123611 W and 20.443056 N, at an altitude of 20 m. Two experiments were established in the vanilla plantation: Site 1 was placed on the northern side of the plantation and Site 2 on the southern side to determine the possible effects of the treatments in different locations within the same plantation.

Applied Treatments

The experiment consisted of applying four treatments at each site. The treatments were T1: control (400 mL of potable water), T2: 400 mL of water from tender coconut (*C. nucifera* L.) diluted (50%) with potable water, T3: 400 mL coconut water (100%), and T4: 400 mL of the biostimulant MEGAFOL (Valagro[®]) (Figure 1), which contains vitamins, amino acids and proteins, betaines, and growth factors, as well as organic carbon, potassium oxide, total nitrogen and organic nitrogen, applied at the dose recommended by the manufacturer (3 mL L⁻¹). Treatments were applied by directly spraying the flowers two weeks after the beginning of the flowering period (March-April), in the morning (9 to 10 a.m.), every other week for three months.

Evaluated Variables

The variables used in the evaluation of vanilla yield were selected from Rocha-Flores *et al.* (2018). The following plant variables were recorded: plant height, cutting thickness, number of vines/m², number of racemes/vine, number of racemes/m², number of fruits/vine, number of fruits/raceme, number of fruits/kg, number of fruits/m², total fruit weight/m², and yield in g/m². To evaluate the physical characteristics of the fruits, six variables were used: length, width, thickness, length×width, volume, and weight. Length was measured with a measuring tape (cm); width and thickness were determined (cm) with a digital Vernier (Mitutoyo 500 Digimatic ABSOLUTE); fruits were weighed (g) with a digital balance (ADAM, model HCB3001).

Environmental Variables

From February to October 2019, data on temperature (°C), relative humidity (%) and luminosity, which was transformed to photosynthetically active radiation, PAR ($\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$), were recorded with a datalogger U12-012 (Onset HOBO) at the two sites in the vanilla plantation.

Experimental Design and Statistical Analysis

At each site, four treatments with 10 replications each were evaluated. The useful plot consisted of a linear line of plants. An analysis of variance (ANOVA) was performed with the data on quantified traits within and between sites under a completely randomized



Figure 1. Vanilla fruits with the application of the treatments: T1=100% potable water (control); T2=50% coconut water; T3=100% coconut water; T4=Megafol (Valagro[®]).

blocks design (PROC GLM SAS) with SAS statistical software (SAS, 2004). Comparison of means was calculated based on the harmonic mean (\bar{n}) with Tukey's test for all the variables. With the aim of relating the dataset on biological variables and the climate variables, an analysis of canonical correlations (ACC) was performed.

RESULTS AND DISCUSSION

Analysis of the Effect of Treatments on Physical Fruit Characteristics of *Vanilla planifolia*

The analysis of variance indicated that there were statistical differences in fruit variables between sites ($P \leq 0.001$) and treatments ($P \leq 0.05$). The coefficient of variation ranged from 3.79 and 13.66%, indicating that the data is reliable. Fruits from Site 1 had significantly higher values in fresh weight, dimensions, and volume than those from Site 2. The difference was possibly due to earlier (two weeks) application of the treatments in Site 1. In this respect, González *et al.* (2007) point out that cauliflower growth was higher when application of gibberellic acid was made —at a certain concentration— at an early stage after planting than when application was later. Also, the first site on the northern part of the plantation receives sunlight earlier than the second site, so that temperature, humidity and PAR may have been different.

Fruit weight, length, and thickness are characteristics related to vanilla's physical quality (NMX-FF-074-SCFI-2009). Table 1 shows that spraying foliage with coconut water at different concentrations had a significant effect on these characteristics. For example, the fruit from plants treated with 50% (T2) and 100% coconut water (T3) had heavier fresh weights that were significantly different from the control (T1) and from the Megafol treatment (T4). The length, thickness, and volume of fruits from treatments T2, T3, and T4 had higher values than those of T1. However, T2 was significantly different from T1 in length only, while in thickness and volume only T3 was significantly different from T1 (Table 1). These results suggest that coconut water at concentrations of 50% or more has a positive impact on vanilla fruit weight and dimensions; that is, on their physical quality.

Table 1. Fresh weight and dimensions of *Vanilla planifolia* fruits after four treatments at two sites in a vanilla plantation in Paso de Barriles, Gutiérrez Zamora, Veracruz.

Factor		Weight (g)	Length (cm)	Width (cm)	Thickness (cm)	Length/width (cm ²)	Volume (cm ³)
Site	1	8.852 ^a	15.934 ^a	1.032 ^a	0.837 ^a	16.475 ^a	13.880 ^a
	2	6.892 ^b	14.713 ^b	0.946 ^b	0.756 ^b	13.921 ^b	10.557 ^b
	DMS	0.335	0.259	0.023	0.021	0.567	0.743
Treatment	T1	7.165 ^b	14.983 ^b	0.975 ^a	0.770 ^b	14.628 ^a	11.331 ^b
	T2	8.232 ^a	15.557 ^a	0.993 ^a	0.806 ^{ab}	15.510 ^a	12.619 ^{ab}
	T3	8.608 ^a	15.438 ^{ab}	1.007 ^a	0.810 ^a	15.578 ^a	12.770 ^a
	T4	7.484 ^b	15.315 ^{ab}	0.981 ^a	0.802 ^{ab}	15.075 ^a	12.155 ^{ab}
	DMS	0.625	0.483	0.044	0.039	1.058	1.387

T1= 100% potable water (control); T2= 50% coconut water; T3= 100% coconut water; T4= Megafol. Different letters in a row indicate significant difference (Tukey; $P \leq 0.05$).

These results agree with those of Buah & Agu-Asare (2014), who compared the effect of coconut water (CW) from fresh and dry fruits against benzyl amino purines—a synthetic cytokinin—on *in vitro* growth of banana. The best results were obtained with CW from fresh fruits on the variables number of roots, plant height, number of leaves, and fruit fresh and dry weight. CW increases the content of nitrogen in leaves, which is important in forming plant enzymes and hormones (Al-hasnawi, 2018), as well as in inducing cell division for more rapid growth (Peixe *et al.*, 2007).

Relationship between Environmental Variables and Yield Components

The analysis of canonical correlation (Table 2) included yield component variables (number of vines/plant, plant height, support height, distance between supports, cutting thickness) and fruit variables (length, width, thickness and weight) (Rocha-Flores *et al.*, 2018). These analyses revealed that some environmental variables had different effects on certain yield components in the sites where the experiments were conducted.

In Site 1, located on the northern side of the vanilla plantation, there was a moderate correlation (0.545 and $r^2=0.297$) between environmental variables and yield components. The highest correlation was found between relative humidity at 10 a.m. (−0.0041) and number of vines/m² (0.1734), and between relative humidity and number of racemes/vine (0.0292). Moreover, PAR at 2 p.m. (0.4336) and at 6 p.m. (0.4568) strongly correlated with fruit weight (−0.1921), length (−0.3180) and thickness (−0.1931) (Table 2). This correlation could be explained by photosynthesis, which is the orchid’s principal means of

Table 2. Canonical correlation between environmental variables and *Vanilla planifolia* yield component (YC) variables, Site 1, and Site 2 in the locality of Paso de Barriles, Gutiérrez Zamora, Veracruz, Mexico.

	Correlation between environmental variables and canonical YC variables	
	Site 1	Site 2
Temperature (°C) - 6 p.m.	−0.0177	0.3130
Relative humidity (%) - 10 a.m.	−0.0041	−0.1623
PAR ($\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) - 2 p.m.	0.4336	−0.4678
PAR ($\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) - 6 p.m.	0.4568	−0.4191
	Correlation between YC variables and canonical environmental variables	
	Site 1	Site 2
Num. racemes/vine	0.0292	0.0128
Weight (g)	−0.1921	0.4089
Length (cm)	−0.3180	−0.0226
Thickness (cm)	−0.1931	0.0461
Num. racemes/m ²	0.0067	−0.0025
Num. vines/m ²	0.1734	0.3065
R ²	0.297	0.353
Canonical correlation	0.545	0.594

obtaining carbon (Zhang *et al.*, 2015); carbon fixed by photosynthesis makes up 90-95% of plant dry weight (Flore, 1989). Figure 2A shows the structural correlation of environmental variables and yield components, in which the first two factors explain 86.4% of the total variation. Also, it also shows that higher relative humidity and PAR incidence at 2 and 6 p.m. generate a larger number of vines/m².

Analysis of canonical correlations for Site 2 (Table 2) indicated a moderate correlation (0.594 and $r^2=0.353$) between environmental variables and yield components. PAR at 2 p.m. (-0.4678) and at 6 p.m. (-0.4191) had a high inverse correlation with fruit weight (0.4089) and number of vines/m² (0.3065), and a lower correlation with fruit thickness (0.0461) (Figure 2B). To a certain extent, this showed a different effect from the results in Site 1, suggesting that placement of the plants within the vanilla plantation affected the orchid's productivity. This is possibly due to the CAM photosynthesis pathway, in which CO₂ exchange begins at night, when the stomata open, and increases during the night (Rodrigues *et al.*, 2013). Moreover, the light intensity that vanilla receives in this schedule directly affects its capacity for dry matter accumulation. However, this is not the only factor; factors such as the plant's nutritional state, growth habit, age and habitat also have an influence (Zhang *et al.*, 2018).

CONCLUSIONS

Coconut water applied to vanilla at the beginning of flowering had a significant effect on fruit length, width, volume, fresh weight, and accumulation of dry weight. These results were obtained with a concentration of 50% coconut water, which can be used

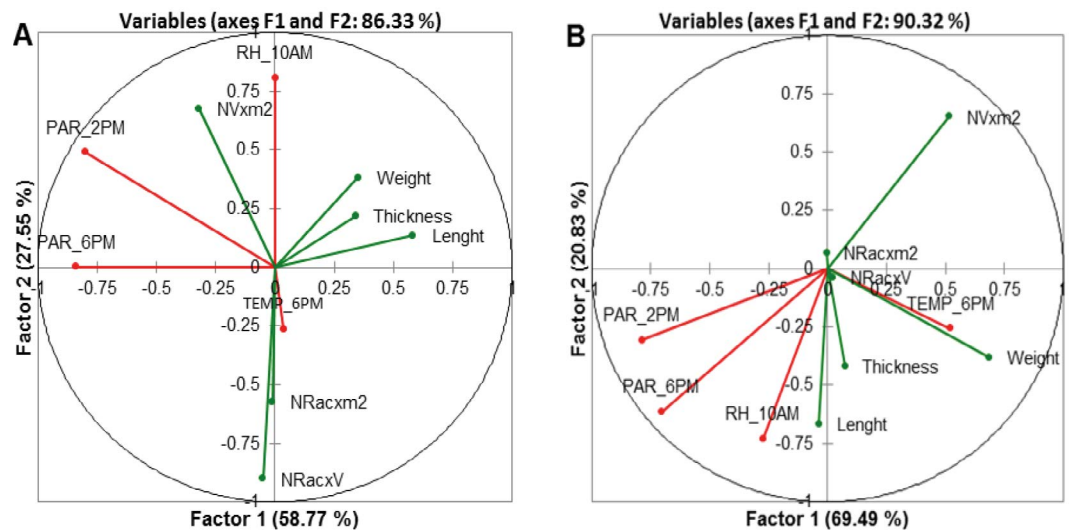


Figure 2. Graphic representation of the structural correlation coefficients of the first two factors in the interaction environmental variables (●) and *Vanilla planifolia* yield component variables (●) at Site 1 (A) and Site 2 (B) of the locality Paso de Barriles, Veracruz. PAR_2PM: Photosynthetically active radiation at 2 p.m.; PAR_6PM: Photosynthetically active radiation at 6 p.m.; RH_10AM: Relative humidity at 10 a.m.; TEMP_6PM: temperature at 6 p.m. NVxm²: number of vines/m²; NRacxm²: number of racemes/m²; NRacxV: number of racemes/vine.

as an organic option for nutrition to increase vanilla yield. In terms of environmental effects, photosynthetically active radiation has a direct effect on fruit weight, thickness and length. The effects of coconut water and the environment should be considered among the management and crop nutrition practices for vanilla.

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