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Irrigation

Application of fertilizers and root enhancers by two irrigation systems on 'BRS Imperial' pineapple

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Abstract - The objective of this work was to evaluate two irrigation systems, by drip and diffuser microjets, two types of fertigation, by spraying at the base of the plant and in the soil, and two types of root enhancers in the development and production of the pineapple 'BRS Imperial'. The drip system promoted greater root development than the diffuser microjet system. Much of the root system was concentrated in the stalk and soil up to 0.1 m depth, where the drip system promoted a higher relative percentage of root growth in the stalk compared to the microjet. The root enhancers promoted greater root growth in the stalk than in the soil. The use of the root enhancers based on humic and fulvic acids was not significant, while the use of the root enhancers based on phosphoric acid and amines was significant for root growth only in the microjet system. Application of fertilizers by spraying at the base of the plant promoted root growth and increased yield compared to the use of fertigation. The drip system showed higher efficiency of crop and irrigation water productivity for 'BRS Imperial' pineapple.
Index terms: *Ananas comosus* (L.), drip irrigation, sprayer microjets, fertigation.

Aplicação de fertilizantes e enraizadores por dois sistemas de irrigação no abacaxizeiro 'BRS Imperial'

Resumo -O trabalho objetivou-se em avaliar dois sistemas de irrigação, por gotejamento e microjatos difusores, dois tipos de fertirrigação, por pulverização na base da planta e no solo, e dois tipos de enraizadores no desenvolvimento e na produção do abacaxizeiro 'BRS Imperial'. O sistema de gotejamento promoveu maior desenvolvimento radicular que o sistema de microjato difusor. Grande parte do sistema radicular concentrou-se no talo e no solo até 0,1 m de profundidade, em que o sistema de gotejo promoveu uma maior porcentagem relativa de crescimento de raiz no talo em relação ao microjato. Os enraizadores promoveram maior crescimento de raízes no talo que no solo. Sendo que o uso do enraizador à base de ácidos húmicos e fúlvicos não foi significativo, enquanto o uso do enraizador a base de ácido fosfórico e aminas foi significativo no crescimento radicular apenas no sistema de microjato. A aplicação de fertilizantes por pulverização na base da planta promoveu maior crescimento radicular e produtividade em comparação ao uso de fertirrigação. O sistema de gotejamento apresentou maior eficiência de produtividade da água de irrigação e da cultura para o abacaxizeiro 'BRS Imperial'.
Termos para indexação: *Ananas comosus* (L.), gotejamento, microjatos difusores, fertirrigação.

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Introduction

Pineapple is considered a dryland crop, but it is commonly cultivated under irrigation. The crop adapts to several irrigation systems, especially sprinkler, which combines the fact that plants extract water from the adventitious roots in the leaf axils and the favorable characteristics of water capture by the leaves. This irrigation method is not recommended after the beginning of the flowering stage and opening of the petals, as it favors fruit diseases (PAULL et al., 2016; CARR, 2012).

Drip irrigation uses less water than sprinkler, due to the very characteristic of the system, being indicated for places where the water supply is restricted, the cost of labor is high and cultivation techniques are advanced. Diffuser micro-sprinklers installed directly on the hoses, also called diffuser microjets, can be used depending on site conditions (CARR, 2012). These emitters can distribute water in a circular or fan-shaped pattern and have lower cost compared to drip emitters or micro-sprinklers, in addition to the larger spacing required, which reduces their number per linear meter of lateral line.

Restrictions on soil fertility affect the yield and quality of pineapple fruits (GARCÍA et al., 2017). Thus, fertigation, mainly used through drip, becomes a good option for better control of the site and frequency of nutrient application (BONOMO et al., 2020). Several authors have observed the benefits of fertigation in pineapple, such as Maneesha et al. (2019) with the cultivar Giant Kew and Ribeiro et al. (2019) with the cultivar 'Pérola', due to the increased frequency of nutrient application promoted by fertigation.

Root enhancers are products used to improve the soil environment and stimulate root formation, improving root architecture and consequently improving plant growth and yield. It is possible to use several substances in various formulations and some of them have their efficacy verified in the literature, such as: humic acid (NUNES et al., 2019), sulfuric acid (BAYAT et al., 2021) and phosphoric acid (AMEEN et al. 2019). It is verified that information regarding the use of root enhancers in pineapple in field studies is unknown. The availability of root enhancers has been increasing in the market, which leads to the need to know their effects on crops in field studies.

In this context, the objective was to evaluate the effects of irrigation system, fertigation system and two types of root enhancers on the development and production of 'BRS Imperial' pineapple in soil of Coastal Tablelands.

Material and methods

The experiment was carried out at Embrapa Cassava & Fruits, located in the municipality of Cruz das Almas – BA, Brazil (12º48' S; 39°06' W; 225 m). According to Köppen's classification, the climate is hot and humid tropical (Af), without defined dry season (ALVARES et al., 2013). The average rainfall is 1,224 mm per year, with annual average relative humidity above 82%.

The textural classification of the soil of the study site is Sandy Clay Loam, and its physical characteristics are described in Table 1 (CAMPOS, 2018) and chemical analysis in Table 2.

Table 1. Physical analysis of the soil of the experimental area.

	Total sand	Silt	Clay	Density
Depth (cm)	----------- g kg^{-1} -------------			g cm^{-3}
0-20	571	105	324	1.65
40-100	567.5	79	353.5	1.41

Source: CAMPOS (2018).

Slipt of the pineapple cultivar 'BRS Imperial' were used and the crop was planted in May 2019, in double rows, at spacing of 0.40 m x 0.40 m x 0.90 m, in 38.460 plants per hectare.

The experimental design was in randomized blocks with four replicates, in a split-split-plot scheme: the two irrigation systems in the plot, the variation in the use of fertigation in the subplot, and the variation in the use of root enhancer in the sub-subplot, in 12 treatments (2 x 2 x 3).

Two irrigation systems were used. The first one was a drip system, with drip tape with flow emitters of 1.8 L/h spaced 0.30 m apart, between two rows of plants. The second was a diffuser microjets system, with emitters of 35 L/h, sectorized with fan-type distribution. The emitters were installed at spacing of 0.80 m in the lateral line between two rows of plants (Figure 1).

Table 2. Chemical analysis of the soil before the beginning of the experiment.

	pH	P	K	Ca	Mg	Ca+Mg	Al	Na	H+Al	SB	CEC	V	OM
Depth (cm)	In water	Mg dm^{-3}	----------------------------------- Cmol dm^{-3} --------------------------------------										
0-10	6.8	34	0.77	2.46	1.35	3.81	0.0	0.04	1.21	4.62	5.83	79	19
20-40	6.4	10	0.69	1.65	1.10	2.75	0.0	0.03	1.87	3.48	5.35	65	14

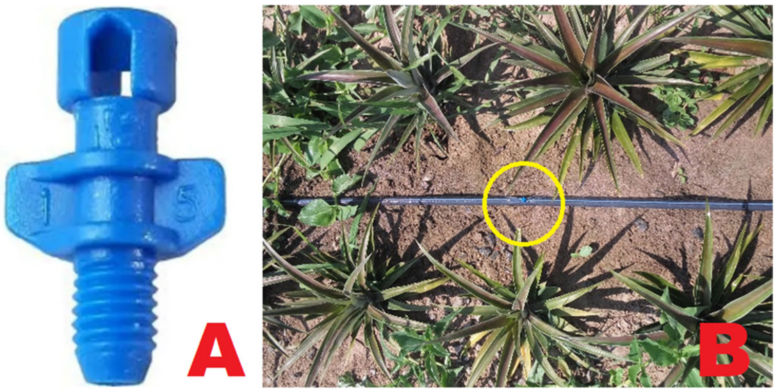

Figure 1. A) Diffuser microjet and B) Irrigation with diffuser microjets in ‘BRS Imperial’ pineapple.

The amount of irrigation water applied every two days was calculated based on crop evapotranspiration, obtained by multiplying the reference evapotranspiration, estimated with data from a meteorological station installed close to the experimental area, and the crop coefficient, which varies in time along with the phenological stages of the plant, following the recommendation of FAO (ALLEN, 2006).

Total rainfall in the experimental period was 1693.2 mm, and irrigations were only complementary, concentrated in the months from October to March, totaling 370.85 mm with drip irrigation and 475.57 mm with diffuser microjet irrigation. Total crop evapotranspiration in the period was 1554.12 mm (Figure 2).

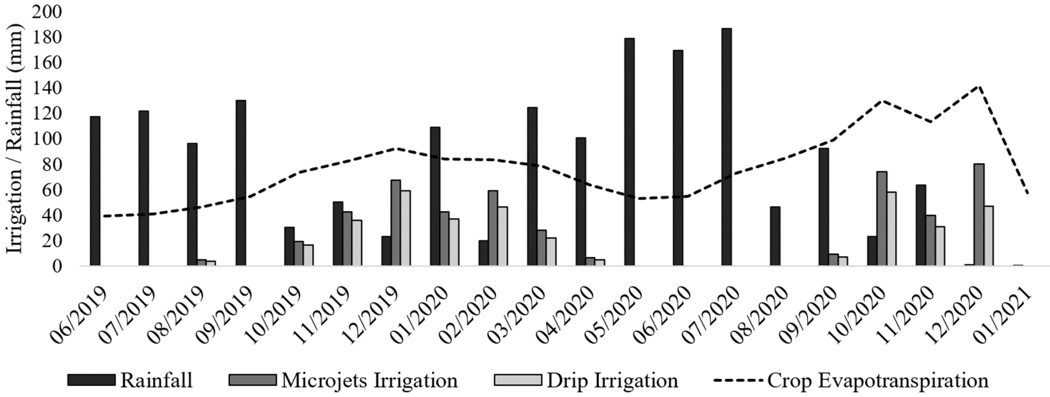

Figure 2. Monthly irrigation, rainfall and crop evapotranspiration in the experimental period.

Crop water productivity and irrigation water productivity were calculated by equations 1 and 2, respectively (IGBADUN et al., 2006; LI et al., 2016).

$$\mathrm{WPc} = \frac{\mathrm{Y}}{I+Pe} \quad (1)$$

$$\mathrm{WPi} = \frac{\mathrm{Y}}{I} \quad (2)$$

Where:

WPc - crop water productivity (Kg m^{-3});

WPi – irrigation water productivity (Kg m^{-3});

Y – yield (Kg ha^{-1});

Pe^3 – precipitation, limited by crop evapotranspiration in the period, disregarding surplus (m ha^{-1});

I – irrigation carried out in the period by the diffuser microjet and drip systems (m^3 ha^{-1}).

TDR (time domain reflectometry) probes were installed in each treatment at 0.10 m depth to monitor soil moisture variation over time and assist in irrigation water management.

Two treatments related to fertigation were performed: one with application of macronutrients by fertigation and the other using a sprayer with a dosing nozzle applying the amount of macronutrients per plant to the base of the plant. Fertilizer applications were based on soil chemical analysis and plant requirements (OLIVEIRA et al., 2009). Three treatments corresponded to the use of root enhancers: the first without the use of root enhancers, the second with the use of root enhancer composed of humic and fulvic acids, and the third with the use of root enhancer composed of phosphoric acid and amines. 5.0 L/ha was applied in three doses, the first at 30 days after planting and the others with a 30-day interval between them, following the manufacturer’s recommendations.

Plant growth variables were monitored at 149, 209 and 302 days after planting, determining the number of leaves and 'D' leaf width and length. Leaf area was calculated by Equation 3 (SANTOS et al., 2018).

$$LA = N * (-214.727 + 2.938 * L + 74.329 * W) \quad (3)$$

Where:
LA is the plant leaf area (cm^2);
N is number of leaves in the plant;
L is 'D' leaf length, cm;
W is 'D' leaf width, cm.

Daily analyses of absolute growth rate were performed for two intervals, or two phases of the crop: the first corresponding to the end of the vegetative stage and the beginning of flowering, from October to December 2019, and the second corresponding to the fruiting stage, from December 2019 to March 2020.

Harvest was carried out from 12/04/2020 to 01/20/2021, following the natural order of fruit maturation. The biometric characteristics evaluated in the fruits were: fruit length, fruit circumference, crown length and whole fruit mass. Yield per hectare (kg ha^{-1}) was determined by weighing the fruits with crown, and multiplying the results by planting density (38460 plants per hectare). Fruit length and crown length were obtained by measurements in the longitudinal direction, from the insertion of the stalk to the insertion of the fruit crown for the fruit and from the insertion of the fruit crown to the top of the crown for the crown, using a measuring tape. The average circumference of the fruits was determined with a measuring tape, in the transverse direction, in their middle region. Fruit mass was determined on an electronic scale (Mars UX4200H Model), with capacity of 4200 g and precision of 0.01 g.

At the end of the cycle, the root system of one plant of each replicate of each treatment was sampled. The roots were collected from the area occupied by the plant (0.40 m x 0.40 m), where the soil was removed together with the roots at depth intervals of 0.10 m from the soil surface to 0.40 m depth (Figure 3). Adventitious roots originated from the stalk of the plants were counted separately. The roots were separated from the soil by washing and were dried in an oven at 65 °C until reaching constant mass. the analyses considered the total dry mass of roots at each depth.

Statistical analyses were performed using the statistical software SISVAR 5.6 (FERREIRA, 2011), submitting the data to Tukey test at 5% probability level.

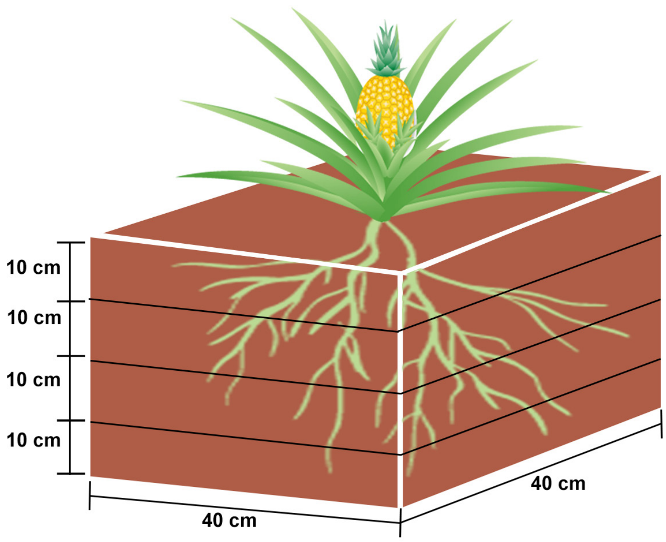

Figure 3. Sketch of root samples collected.

Results and discussion

Table 3 shows the total mass of roots removed from the plant stalk and soil in the 0-0.4 m layer. The analysis of variance detected effect of interactions between irrigation system and type of root enhancers and between the fertilizer application method and type of root enhancer for the percentage of adventitious roots, roots at 0.10 m depth and in the 0-0.40 m layer.

Table 3. Total dry mass of roots (g) in the 0.40 x 0.40 m area of the plant in the 0-0.40 m layer including the adventitious roots of the stalk.

	Plant stalk		0-40 cm layer	
	Microjet	**Drip**	**Microjet**	**Drip**
Via fertigation	11.6 aB	26.5 aA	19.4 aB	36.5 aA
Base of the plant	7.8 aB	21.4 aA	19.2 aB	34.5 aA
	Microjet	**Drip**	**Microjet**	**Drip**
Humic sub.	6.7 bB	31.3 aA	14.0 aB	36.7 aA
Phosphoric ac./amines	13.2 aA	13.4 bA	17.8 aB	32.5 aA
Without root enhancer	8.3 bB	30.9 aA	26.1 aB	37.4 aA
Means	9.5 B	23.9 A	19.3 B	35.5 A

Equal lowercase letters in the same column do not differ from each other, and equal uppercase letters in the same row do not differ from each other by Tukey test at $p<0.05$.

Higher dry mass of roots under the drip system was observed in all treatments, except for the one using root enhancer based on phosphoric acid and amines. Similar results were found for mango (COELHO et al., 2001) and 'Prata' banana (SANT'ANA et al., 2012), with the drip system leading to higher root mass density compared to the micro-sprinkler (microjet). Pineapple root system is fasciculated, concentrated around the plant with no tendency towards lateral expansion. The drip system between two plant rows at 0.20 m from each row, with emitters every 0.30 m, supplied greater volume of water per volume of soil in the root zone than the microjet or micro-sprinkler system inserted in the irrigation line, favoring root development.

The use of root enhancers did not influence roots in the soil; only for the development of roots in the stalk under the diffuser microjet irrigation, possibly because microjet irrigation reaches the stalk of the plant. However, root enhancer based on phosphoric acid and amines did not work like the ones based on humic substances and the treatment without root enhancer under the drip system. When studying the influence of humic acid on the root volume of 'Smooth Cayenne' pineapple, Santos et al. (2014) observed no efficiency of the product for cultivation in pots under greenhouse conditions.

From the total roots concentrated in the plant stalk at 0.10 m depth, 98% and 95.2% were in the diffuser microjet and drip systems, respectively (Table 4), with the 0.10 m depth being more representative of the root system in the soil for the cultivar 'BRS Imperial'. The microjet system was significant for root growth in the 0-0.1 m layer, regardless of the fertilizer application method. The highest percentage of roots in the microjet system at this depth, and consequently in the 0-0.40 m layer, may be due to higher soil moisture in the root zone of the plants, detected by soil moisture sensors (Figure 4). This higher moisture and greater water availability favored greater root development.

Table 4. Means of the percentages of roots present in the plant stalk, in the 0-10 cm and 0-40 cm layers under the interaction between the irrigation system and fertilizer application method.

	Plant Stalk		0-0.10 m layer		0-0.40 m layer	
	Microjet	**Drip**	**Microjet**	**Drip**	**Microjet**	**Drip**
Via fertigation	37.33 aA	42.11 aA	60.02 bA	52.87 aB	62.67 aA	57.88 aA
Base of the planta	28.84 aA	38.26 aA	68.58 aA	57.74 aB	71.16 aA	61.74 aA
Mean	33.08 B	40.18 A	64.30 A	55.30 B	66.92 A	59.81 B

Equal lowercase letters in the same column do not differ from each other, and equal uppercase letters in the same row do not differ from each other by Tukey test at $p<0.05$.

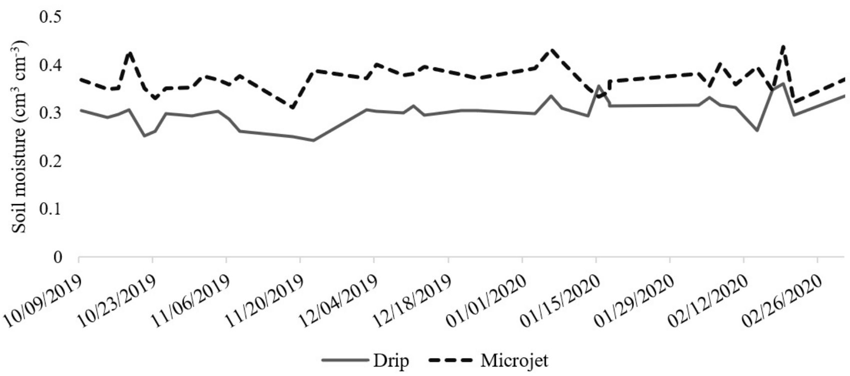

Figure 4. Average soil moisture at 0.1 m depth for the drip and diffuser microjet irrigation systems during the cycle of 'BRS Imperial' pineapple cultivar.

The irrigation system and the fertilizer application method had no effect on the percentage of adventitious and axillary roots. When studying the method of fertilizer application, Silva et al. (2021) also observed no variations between applications via fertigation and via soil for 'Pérola' pineapple.

The interaction between type of root enhancer and irrigation system was significant for the percentage of roots (Table 5). The application of root enhancer based on humic acids was significant for the growth of roots in the stalk with the microjet system and was significant for the growth of roots in the soil with the drip system. Soil moisture conditions under the microjet system (Figure 4) contributed to higher percentages of roots, which can be confirmed by the condition of irrigation without application of root enhancers.

Table 5. Means of the percentages of roots present in the stalk of the plant, in the 0-10 cm and 0-40 cm layers under the interaction between the type of root enhancer and the type of irrigation system.

	Plant Stalk		0-10 cm layer		0-40 cm layer	
	Microjet	**Drip**	**Microjet**	**Drip**	**Microjet**	**Drip**
Humic sub.	32.49 bB	46.05 aA	64.33 bA	50.06 bB	67.51 bA	53.95 bB
Phosphoric ac./amines	42.59 aA	29.24 bB	55.06 cB	64.37 aA	57.41 cB	70.75 aA
Without root enhancer	24.17 cB	45.26 aA	73.51 aA	51.48 bB	75.83 aA	54.74 bB

Equal lowercase letters in the same column do not differ from each other, and equal uppercase letters in the same row do not differ from each other by Tukey test at $p<0.05$.

The application of fertilizers at the base of the plant did not favor the use of any one of the root enhancers; however, for application via fertigation both root enhancers favored the growth of adventitious and axillary roots of the plant (Table 6).

Table 6. Means of the percentages of roots present in the plant stalk, in the 0-10 cm and 0-40 cm layers under the interaction between the type of root enhancer and fertilizer application method.

	Plant Stalk		0-10 cm layer		0-40 cm layer	
	Fertig.	**B. Plant**	**Fertig.**	**B. Plant**	**Fertig.**	**B. Plant**
Humic sub.	45.49 aA	33.05 aB	50.58 bB	63.80 aA	54.51 bB	66.94 aA
Phosphoric ac./amines	41.34 aA	30.49 aB	53.63 bB	65.81 aA	58.66 bA	69.51 aA
Without root enhancer	32.32 bA	37.11 aA	65.13 aA	59.86 aA	67.68 aA	62.89 aA

Equal lowercase letters in the same column do not differ from each other, and equal uppercase letters in the same row do not differ from each other by Tukey test at $p<0.05$.

The analysis of variance of the absolute daily growth rate based on the growth evaluations carried out in October 2019 and March 2020 detected the effect of interactions between irrigation systems and type of root enhancers and between fertilizer application method and type of root enhancers (Table 7). The fertilizer application method was not significant for the daily growth rates of number of leaves, leaf length and leaf area, regardless of irrigation system. The diffuser microjet system promoted a higher daily growth rate of leaf area, although with a lower rate of variation in the ‘D’ leaf length, which is due to the higher rate of variation in the number of leaves.

Table 7. Means of absolute daily growth rates of the number of leaves, ‘D’ leaf length and leaf area.

	Number of leaves ($n\ day^{-1}$)		‘D’ leaf length ($cm\ day^{-1}$)		Total leaf area ($cm^2\ day^{-1}$)	
	Microjet	**Drip**	**Microjet**	**Drip**	**Microjet**	**Drip**
Via fertigation	0.116 aA	0.105 aA	0.179 aB	0.202 aA	92.283 aA	75.727 aB
Base of the plant	0.108 aA	0.113 aA	0.195 aA	0.210 aA	103.700 aA	96.814 aA
Mean	0.109 A	0.112 A	0.187 B	0.205 A	97.992 A	86.271 B

Equal lowercase letters in the same column do not differ from each other, and equal uppercase letters in the same row do not differ from each other by Tukey test at $p<0.05$.

In the microjet irrigation system, a larger leaf area and wet soil extension were observed, and similar results have been found in the literature with other crops, such as ‘Prata’ banana (MARQUES et al., 2011) and orange (VELLAME et al, 2015). Maneesha et al. (2019) observed no statistical differences for ‘D’ leaf characteristics between treatments with fertigation and conventional application of fertilization, but found a greater number of leaves in the treatment with fertigation for ‘Giant Kew’ pineapple.

The interaction between types of root enhancers and irrigation system showed no statistical difference in the number of leaves and ‘D’ leaf length for the diffuser microjet system (Table 8). The number of leaves and the leaf area under application of root enhancer based on phosphoric acid and amines were lower when compared with the ones obtained with root enhancer based on humic substances and in the treatment without root enhancer under the drip system. The result that may be related to the dry mass of roots, especially adventitious roots, which were lower than the values obtained in the treatments with root enhancer based on humic substances and without the use of root enhancers.

Table 8. Means of number of leaves, ‘D’ leaf length and total leaf area under the interaction between the type of root enhancer and type of irrigation system.

	Number of leaves ($n\ day^{-1}$)		‘D’ leaf length ($cm\ day^{-1}$)		Total leaf area ($cm^2\ day^{-1}$)	
	Microjet	**Drip**	**Microjet**	**Drip**	**Microjet**	**Drip**
Humic sub.	0.114 a	0.126 a	0.187 a	0.197 a	103.525 a	87.389 ab
Phosphoric ac./amines	0.110 a	0.085 b	0.198 a	0.209 a	108.35 a	74.910 b
Without root enhancer	0.112 a	0.116 a	0.176 a	0.211 a	82.099 b	96.513 a

Equal lowercase letters in the same column do not differ from each other, and equal uppercase letters in the same row do not differ from each other by Tukey test at $p<0.05$.

Both root enhancers were significant under the microjet irrigation system. Thus, under the microjet system, the root enhancers contributed to a higher growth rate of leaf area, and the opposite was valid for the drip system condition (Table 8).

In the interaction between the type of root enhancer and fertilizer application method, the root enhancer based on phosphoric acid and amines led to lower leaf number under the application at the base of the plant and longer ‘D’ leaf length under the use of fertigation. The treatment without root enhancer resulted in the smallest leaf area when the root enhancer was applied at the base of the plant (Table 9).

Table 9. Means of absolute daily growth rates between Oct/19 and Mar/20.

	Number of leaves ($n\ day^{-1}$)		'D' leaf length ($cm\ day^{-1}$)		Total leaf area ($cm^2\ day^{-1}$)	
	Fertig.	**B. Plant**	**Fertig.**	**B. Plant**	**Fertig.**	**B. Plant**
Humic sub.	0.108 a	0.132 a	0.181 b	0.204 a	76.285 a	114.629 a
Phosphoric ac./amines	0.105 a	0.090 b	0.208 a	0.199 a	87.273 a	95.990 ab
Without root enhancer	0.118 a	0.110 ab	0.182 b	0.205 a	88.458 a	90.154 b

Equal lowercase letters in the same column do not differ from each other, and equal uppercase letters in the same row do not differ from each other by Tukey test at $p<0.05$.

The type of fertilizer application (by drip fertigation or at the base of the plant) did not contribute to significant differences in fruit circumference and mass for both irrigation systems. These average-dependent variables under drip irrigation were greater than the ones under microjet with fertigation. The same dependent variables did not show significant differences between both systems under microjet irrigation. There was no difference between fruit yields under drip irrigation for the two methods of fertilizer application. The application of fertilizer at the base of plant under micro jet irrigation resulted in larger yield (Table 10).

Table 10. Fruit circumference, whole fruit mass and yield, resulting from the interaction between the fertilizer application method and the type of irrigation system.

	Fruit circumference (cm)		Whole fruit mass (g)		Yield ($t\ ha^{-1}$)	
	Microjet	**Drip**	**Microjet**	**Drip**	**Microjet**	**Drip**
Via fertigation	33.3 aB	36.7 aA	811.8 aB	1087.2 aA	30.278 bB	41.817 aA
Base of the plant	33.9 aA	35.6 aA	992.3 aA	1046.7 aA	38.165 aA	40.260 aA
Mean	33.6 A	36.1 A	902.0 B	1067.0 A	34.221 B	41.038 A

Equal lowercase letters in the same column do not differentiate between each other, and equal uppercase letters in the same row do not differentiate from each other by the Tukey $p<0,05$ test of significance.

The larger average fruit circumference, mass and yield produced under fertigation with drip system occurred for plants with larger percentage of roots for microjet irrigation system at 0-0.40 m depth (Table 4). This may indicate that adventitious and axillary roots are very efficient compared with deep soil roots in the absorption of water and nutrients, since the percentage in the stalk was higher under the drip irrigation system.

The yield and fruit mass of 'BRS Imperial' pineapple irrigated by microjets was 26% and 22% higher with the application of fertilizers at the base of the plant (Table 10) when compared to the application by fertigation. The fertigation when applied by the diffuser microjet system showed deficiencies resulting from the problems of irrigation itself, like the larger water losses due to wind drift and the application of fertilizers over the ground with and without roots. The application at the base of plants assured all the nutrients within the stalk rooting-zone and soil around.

The drip system was statically better for the variables yield and fruit mass, a result that is even more significant when analyzing the irrigation water productivity, of 7.196 Kg m^{-3} and 18.443 Kg m^{-3}, and the crop water productivity, of 2.587 Kg m^{-3} and 3.758 Kg m^{-3}, for the microjet and drip systems, respectively. Souza et al. (2010), when evaluating the viability of 'Smooth cayenne' pineapple irrigated by a sprinkler system, observed irrigation water productivity of 6.714 kg m^{-3}, while Souza et al. (2012) found irrigation water productivity of approximately 12.0 kg m^{-3} for the same pineapple cultivar, but under drip irrigation. Similar results were found in the present study, in which water productivity by the drip system was approximately twice that of the microjet system.

When relating the irrigation system and the use of root enhancer, the fruit circumference, mass and yield from drip system was statistically larger than the ones from diffuser microjet system in all interactions (Table 11).

Table 11. Fruit circumference, whole fruit mass and yield, resulting from the interaction between the fertilizer application method and the type of irrigation system.

	Fruit circumference (cm)		Whole fruit mass (g)		Yield (t ha^{-1})	
	Microjet	Drip	Microjet	Drip	Microjet	Drip
Humic sub.	33.5 aB	36.6 aA	895.5 aB	1074.5 aA	34.442 aB	41.326 aA
Phosphoric ac./amines	33.9 aA	35.8 aA	926.5 aB	1084.7 aA	34.219 aB	41.721 aA
Without root enhancer	33.5 aB	36.0 aA	884.1 aB	1041.8 aA	34.002 aA	40.068 aA

Equal lowercase letters in the same column do not differ from each other, and equal uppercase letters in the same row do not differ from each other by Tukey test at $p<0.05$.

The use of root enhancers with the application of nutrients via fertigation caused differences between fruit masses (Table 12), with higher values for the application of root enhancer based on phosphoric acid and amines, compared to the root enhancer based on humic substances and the treatment without root enhancer application. In the application of fertilizers at the base of the plant, there were no significant results for the use of root enhancers.

Table 12. Crown length and fruit mass, resulting from the interaction between the type of root enhancer and fertilizer application method.

	Crown length (cm)		Fruit mass (g)	
	Fertig.	B. Plant	Fertig.	B. Plant
Humic sub.	17.4 aA	18.1 aA	918.0 abA	1052.0 aA
Phosphoric ac./amines	17.9 aA	18.8 aA	1016.1 aA	995.1 aA
Without root enhancer	17.1 aB	18.7 aA	914.4 bA	1011.4 aA

Equal lowercase letters in the same column do not differ from each other, and equal uppercase letters in the same row do not differ from each other by Tukey test at $p<0.05$.

Conclusions

The drip system promoted a greater root development in 'BRS Imperial' pineapple compared to the diffuser microjet system.

Much of the root system of 'BRS Imperial' pineapple is concentrated in the stalk and in the soil up to 0.1 m deep, and the drip system led to a higher percentage of root growth in the stalk compared to the diffuser microjet system.

The root enhancers promoted greater root growth in the stalk than in the soil. The use of the root enhancer based on humic and fulvic acids was not significant, while the use of root enhancer based on phosphoric acid and amines was significant for root growth only under the microjet system.

Application of fertilizers by spraying at the base of the plant promoted root growth and increased yield compared to the use of fertigation.

The drip system showed higher efficiency of crop and irrigation water productivity for 'BRS Imperial' pineapple.

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