ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

VARIÁVEIS DE CRESCIMENTO, FISIOLÓGICAS E DE PRODUÇÃO DA BANANEIRA IRRIGADA POR GOTEJAMENTO E MICROJATOS DIFUSORES SOB MANEJO DE ÁGUA PELO SECAMENTO PARCIAL DA ZONA RADICULAR

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1 RESUMO

A bananicultura é uma atividade de grande relevância socioeconômica no semiárido brasileiro, onde a escassez hídrica exige estratégias de irrigação eficientes. Nesse contexto, técnicas com redução do volume aplicado têm se destacado por possibilitar maior eficiência no uso da água sem comprometer a produtividade. O presente estudo teve como objetivo avaliar o crescimento, parâmetros fisiológicos e a produção da bananeira cv. Prata sob diferentes sistemas de irrigação no Norte de Minas Gerais. O delineamento experimental foi em blocos casualizados, com quatro tratamentos, quatro repetições e seis plantas por parcela: (a) GOT100 – gotejamento com duas linhas laterais e irrigação simultânea; (b) GOT50 – gotejamento com duas linhas laterais, alternância da irrigação a cada três dias e aplicação de 50% da lâmina; (c) MJATO45 – duas linhas laterais com dois microjatos de 45 L h^{-1} por planta; e (d) MJATO30 – duas linhas laterais com dois microjatos de 30 L h^{-1} por planta. Os resultados mostraram relação positiva entre altura e circunferência do caule, além de efeito significativo da interação tratamento × período para condutância estomática e temperatura foliar. O sistema com microjatos difusores aliado ao PRD, com alternância de três dias do lado da irrigação, mostrou-se mais eficiente no uso da água, com potencial para produtividades superiores às geralmente alcançadas na bananicultura.

Palavras-chaves. *Musa* ssp, sistemas de irrigação, manejo da irrigação, fruticultura.

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GROWTH, PHYSIOLOGICAL, AND PRODUCTION VARIABLES OF BANANA IRRIGATED BY DRIP AND DIFFUSE MICROJETS UNDER PARTIAL ROOTZONE DRYING MANAGEMENT

Recebido em 16/04/2024 e aprovado para publicação em 19/08/2024
DOI: http://dx.doi.org/10.15809/irriga.2024v29p306-316

2 ABSTRACTS

Banana cultivation is highly economically important in the semiarid regions of Brazil, where water scarcity demands efficient irrigation strategies. In this context, techniques involving reduced irrigation volumes have improved water use efficiency without compromising yield. This study aimed to evaluate the growth, physiological parameters, and production of 'Prata' banana plants under different irrigation systems in northern Minas Gerais, Brazil. The experiment followed a randomized block design with four treatments, four replications, and six plants per plot: (a) GOT100 – drip irrigation with two lateral lines and simultaneous application; (b) GOT50 – drip irrigation with two lateral lines, alternating irrigation every three days with the application of 50% of the calculated water depth; (c) MJATO45 – two lateral lines with two microsprinklers of 45 L h^{-1} per plant; and (d) MJATO30 – two lateral lines with two microsprinklers of 30 L h^{-1} per plant. The results revealed a positive relationship between plant height and stem circumference, in addition to a significant treatment × period interaction effect on stomatal conductance and leaf temperature. The system using microsprinklers combined with partial rootzone drying (PRD), with three-day alternation of the irrigated side, was more efficient in terms of water use, with potential yields above those generally obtained in banana production.

Keywords: *Musa* ssp, irrigation systems, management irrigation. fruit growing.

3 INTRODUCTION

The banana tree is one of the fruit trees with the highest water demand during its growing season, which can vary from 8,000 to 15,000 m³ of water per hectare, depending on the cultivar and evapotranspiration demand. Thus, to irrigate 10,000 hectares of banana trees, the volume withdrawn from water sources can reach 80 to 150 million m³ per annual cycle (Coelho *et al*., 2020). Excessive water use in agriculture, especially in drought-prone regions, compromises availability for human consumption, reduces food production, and generates economic and environmental impacts, such as unemployment and shortages. Mitigating these effects involves adopting technically appropriate irrigation strategies that balance maintaining productivity with reducing pressure on water resources.

Water scarcity and high evaporation pose critical challenges to agriculture in semiarid environments (Rosa *et al*., 2020; Bai *et al.,* 2022). In this context, sustainable banana (*Musa* spp.) production has become fundamental for regional development and environmental preservation. Deficit irrigation strategies, such as the partial root zone drying (SPZR) technique, have shown promise for increasing water use efficiency without compromising production (Kourgialas; Koubouris; Dokou, 2019). SPZR consists of keeping half of the root system exposed to dry soil, while the other half receives irrigation. This can be done alternately, with periodic changes on the irrigated sides (Loveys *et al.,* 2000; Kang; Zhang, 2004), or fixed, maintaining permanently dry and humid zones (Talluto *et al*., 2008).

Positive results of this technique have been reported in different crops. In orange groves in northern Iran, the application of 50% or 75% full water, with lateral alternation, did not reduce yield or fruit quality (Shahabian; Samar; Emdad, 2012). In another study, orchards subjected to water depths equivalent to 50% and 100% of crop evapotranspiration (ETc) presented increases in yield of up to 20% (Consoli *et*

al., 2017). For banana trees, the alternation interval was found to be decisive, with 7 days resulting in better performance than 14 and 21 days (Coelho *et al.,* 2019).

The application of water to parts of the root system is a common practice in fruit trees and is made possible by systems such as drip irrigation, microsprinklers, and microjet diffusers. In drip irrigation, the wetted volume of the soil is more restricted than that in microsprinklers, maintaining greater moisture, albeit concentrated near emitters (Lima *et al*., 2023). Despite this, in semiarid regions, high irrigation frequencies and larger wetted surface areas can increase evaporation losses, reducing drip efficiency. Given this context, this study aimed to evaluate the growth, physiological parameters, and production of banana cv. Prata under different irrigation systems, comparing the use of microjet diffusers to drip irrigation under SPZR conditions with alternating irrigation every three days.

4 MATERIALS AND METHODS

The experiment was conducted over two years, covering two cycles of the banana cultivar Prata, in an experimental area of the Minas Gerais Agricultural Research Corporation (EPAMIG), North China, as shown in Figure 1. The soil of the experimental area, whose physical attributes are presented in Table 1, was classified as a medium-textured dystrophic Red–Yellow Latosol. The local altitude is 516 m, with a latitude of 15°47'29" S and longitude of 43°17'88" W. The average annual rainfall is 750 mm, and the local climate is classified as Aw (tropical savanna) according to the Köppen-Geiger classification (Alvares *et al*., 2013). The rainy cycles corresponding to the experimental period recorded precipitation of 1,070.4 mm between 2021 and 2022 and 748 mm between 2022 and 2023. The average air temperature observed in the same period was 24.9 °C.

Figure 1 of the study area.

Source. Lima (2022).

Table 1. Physical-hydric characteristics of the soil in the experimental area.

Prof.	Sand	Silt	Clay	Dens. Soil	Humidity (cm ^{3} cm $^{-3}$) at tension (kPa)				
(m)	kg kg $^{-1}$			kg dm $^{-3}$	10	33	100	300	1500
0–20	434	264	302	1.54	0.2626	0.2423	0.2210	0.2031	0.1938
20–40	434	229	337	1.66	0.1698	0.2640	0.2448	0.2269	0.2058

Prof. = Depth; Dens. Soil = soil density.

The banana cultivar Prata was evaluated in the third and fourth production cycles, with a spacing of 2.5 × 2.0 m (2,000 plants per hectare). The irrigation systems used were as follows: Microjet40, with microjets with a flow rate of 45 L h^{-1}; Microjet30, with microjets with a flow rate of 30 L h^{-1}; in the latter case, two microjets were positioned per plant, one beyond and one below the plant in the row, each connected to a lateral line (two lateral lines per row of plants); and the drip system, with two lateral lines containing 4 L h^{-1} emitters spaced every 40 cm, with four emitters per plant.

Randomized blocks, with four treatments and four replicates, containing six plants per treatment: (a) GOT100 – drip irrigation with two lateral lines and simultaneous irrigation on both sides of the row; (b) GOT50 – drip irrigation with two lateral lines, with alternating irrigation between the sides of the row every three days, applying 50% of the calculated gross water depth; (c) MJATO45 – two lateral lines with two microjets of 45 L h^{-1} per plant; (d) MJATO30 – two lateral lines with two microjets of 30 L h^{-1} per plant. In the microjet treatments, irrigation was used with the irrigated side alternating every three days, with the application of 50% of the calculated gross water depth.

gs), expressed in mmol H_2O m^{-2} s^{-1}, and leaf temperature (°C) readings were taken with a porometer model SC $^{-1}$ (Decagon Devices) in the morning and afternoon, on the third leaf (from the apex to the base), in plants exposed to the soil. The growth variables evaluated were the number of leaves, plant height, pseudostem diameter, and leaf area. Plant height was measured from the ground to the youngest leaf, known as the "candle leaf". The pseudostem diameter was obtained from the circumference 0.20 m above the ground with a flexible tape measure. The leaf area was estimated via the equation developed by Zucoloto, Lima, and Coelho (2008).

To evaluate production, the following parameters were measured: bunch weight, stalk weight, number of bunches, number of fruits per bunch, average fruit weight (g), average fruit length (cm), and average fruit diameter (cm). The average fruit weight was assessed immediately after harvest via a precision scale. The average length and diameter were obtained by measuring the median fruit length of the second bunch via a tape measure and caliper. The data were subjected to analysis of variance (ANOVA), preceded by the F test, and when significant, the means were compared via Tukey's test at 5% probability via SISVAR statistical software (Ferreira, 2003).

5 RESULTS AND DISCUSSION

Analysis of variance for growth variables revealed significant effects only for mean plant height and pseudostem circumference, indicating differences between treatments. With respect to plant height, greater values were observed in the GOT100 and GOT50 treatments (Table 2). In a study by Lima (2022), using the partial root zone drying (SPZR) technique in

banana crops, similar results were obtained, with a 50% reduction in the applied volume. For pseudostem circumference, the treatment that presented the lowest value was MJATO30. The drip system treatments, both with full irrigation depth and with a 50% reduction and alternating the irrigated side of the row every three days, did not differ in terms of the mean plant height or pseudostem circumference.

The mean plant height in the drip treatments did not differ significantly from that in the 45 L h^{-1} microjet treatment. The mean pseudostem circumference was greater for the drip and full irrigation treatments, followed by the drip treatment with a 50% reduction and alternating irrigation every three days. The latter did not differ from the 45 L h^{-1} microjet treatment with a three-day alternation. The results show that the use of the 45 L h^{-1} microjet diffuser system did not differ from the use of the full drip irrigation system with two lateral lines per row of plants in terms of leaf number, leaf area, or plant height. Similarly, it did not differ from the means observed for the drip system, with a 50% reduction in the water depth and alternating irrigation every three days on the irrigated side (Table 2).

For the leaf area variable, no significant differences were identified between the treatments. This result is in line with the data reported by Coelho *et al*. (2021), who also investigated the use of SPZR, although in the Grande Naine cultivar, a 50% reduction in the gross blade and seven-day alternation were applied.

There are few studies addressing the application of SPZR with alternations every three days. However, studies that alternated every seven days, as cited by Coelho *et al.* (2020), revealed that this frequency presented greater safety in the adoption of the technique on the basis of both growth and productivity data for the BRS Princesa and Grande Naine cultivars.

Table 2. Averages of the number of leaves, plant height, pseudostem circumference and leaf area of irrigated banana plants.

Treat	Nº leaves	Plant height	Circumference	Leaf area
GOT100	14.8 a	3.5 to	29.8 a	14.0 a
GOT50	15.2 to	3.4 a	28.8 ab	13.7 a
MICRO30	15.2 to	3.2 b	26.4 c	12.7 a
MICRO45	14.8 a	3.3 ab	27.4 bc	13.7 a
CV (%)	15.9	7.1	10.2 21.9	

Averages followed by the same letters in the same column do not differ from each other according to the Tukey test at 5% significance.

Analysis of variance revealed a significant effect ($p < 0.05$) of the interaction between treatment and period on the physiological variables stomatal conductance (Gs) and leaf temperature in the afternoon (Table 3). The average stomatal conductance observed in both shifts was within the range reported by Thomas and Turner (2001) when studying gas exchange in banana plants of the cultivar 'Grand Naine', which varied between 250 and 500 mmol m^{-2} s^{-1}. Plants subjected to a 50% reduction in crop evapotranspiration depth (ETc), with an alternation frequency of three days (GOT50), as well as those irrigated with microjets with a flow rate of 30 L h^{-1} (MJATO30), with alternation every three days, presented, in the afternoon, a more pronounced reduction in Gs than did plants irrigated with 100% ETc, which maintained higher values.

This study corroborates the results obtained by Lima (2022), who used partial root zone drying (SPZR) with 50% water depth reduction and three-day alternation, observing significant variations in Gs at

different times of the day. A similar behavior was reported by Santos *et al*. (2021) when the SPZR technique was applied to papaya crops with reduced water depth. As observed by Mahouachi (2009), these reductions in stomatal conductance are attributed to the increased vapor pressure deficit between the leaf and the air (DPVleaf -air) during the hottest times of the day. This phenomenon requires greater water transport to the leaves, which is not always efficiently supplied by root absorption, especially between 2 and 3 PM. This limitation mainly affects plants under the SPZR with three-day alternations (in the case of GOT50) and those irrigated with a lower hourly water depth per area (in the case of MJATO30). In general, in both shifts, the treatments with microjet irrigation systems presented relatively high average stomatal conductance, indicating a relatively high transpiration rate. This trend was also reported by Melo *et al*. (2009), when evaluating gas exchange in banana plants under fertigation.

Table 3. Averages of stomatal conductance and temperature of banana leaves under water management by the SPZR in microjet and drip systems.

	Gs (mmol s^{-1} cm^2)		Leaf temperature (^{o} C)	
Treatments	**Morning**	**Afternoon**	**Morning**	**Afternoon**
GOT100	437.5 aA	419.7 aA	30.1 bB	34.7 bA
GOT50	409.5 bA	323.7 bB	34.5 aB	37.7 aA
MICRO30	417.5 abA	351.2 abB	31.3 bB	35.1 bA
MICRO45	446.3 aA	423.1 aA	31.1 bB	35.3 bA
CV 1%	16.62		9.38	
CV2%	14.22		7.14	

Averages followed by the same letters, capital letters in the row and lower case in the column, do not differ from each other according to the F test ($p<0.05$).

With respect to the production data from the third cycle, the analysis of variance revealed a significant effect of the treatments only on the number of bunches and the number of fruits (Table 4). The number of bunches was greater in the treatments with 30 and 45 L h^{-1} microjets, which consequently resulted in a greater number of fruits. This increase in the number of bunches and fruits observed in the microjet treatments compensated for the smaller lengths, diameters, and average weights of the fruits, resulting in higher absolute values of bunch and bunch yields than those obtained with the drip system, although the analysis of variance did not indicate a significant effect of the treatments on these variables.

Table 4. Production variables of the third cycle of Prata banana with irrigation water management by partial drying of the root zone under drip and microdiffusers

Treatment	Curl product	Produce bunches	Number bunches	Number fruits	Buy. fruit	Diam fruit	Fruit weig ht
	(t ha $^{-1}$)	(t ha $^{-1}$)	for bunch	for bunch	cm	mm	g
GOT. 50%	37,479 a	34.832 a	8.5 b	114.3 c	19.2 years	3.7 to	149 a
GOT. 100%	36,087 a	33,444 a	8.8 b	133.9 b	19.7 years	3.4 a	145 a
MICRO30	38,504 a	35,585 a	9.5 ba	142.2 ba	18.7 years	3.5 to	137 a
MICRO45	41,297 a	37.875 a	10.0 to	151.0 a	18.7 years	3.4 a	139 a
CV %	10.4	13.2	7.6	9.2	4.2	4.8	3.9

Averages followed by the same letters in the same column do not differ from each other according to the Tukey test at 5% significance.

Banana production averages in microjet systems were within or above commercially acceptable values. Compared with drip irrigation, the larger wetted area provided by microjets contributed to a greater number of bunches and fruits. The results demonstrate the viability of microjet systems with flow rates of 30 and 45 L h^{-1} in managing irrigation via partial root zone drying, suggesting that these systems constitute a viable alternative to drip irrigation in the application of this technique, as confirmed by the data obtained in the fourth banana cycle (Table 5).

According to Cruz (2012), when studying the effects of different irrigation depths on the growth and production of banana genotypes, the author reported an average of 126.2 fruits in the Princesa cultivar. Similarly, Lédo *et al*. (2008) reported an average of 123.7 fruits, both lower than the averages obtained in this study in the treatments with 100% drip irrigation, 30 L h^{-1} microjet and 45 L h^{-1} microjet (Table 4). Santana Júnior *et al*. (2011), when analyzing the productivity of the banana tree 'Prata Gorutuba', which is irrigated by different localized irrigation systems, reported a bunch productivity of approximately 37.82 t ha^{-1} in the treatment with a microsprinkler with a flow rate of 53 L h^{-1}—the same productivity achieved with the microjet of 45 L h^{-1} in this study (Table 4). This highlights the economic advantage of the lower flow rate microjet, which maintains productivity.

The average productivity of Prata banana plants under water management with partial drying of the root zone, a 50% reduction in the water depth and alternating irrigation every three days via drip irrigation, was greater, in absolute terms, than the productivity under full irrigation. However, this difference was not statistically significant. This result in the third cycle contrasts with the decrease in productivity observed by Almeida *et al. (2024), when the same technique was used with 'Prata* Gorutuba ' banana. In the fourth cycle (Table 5), the data obtained in this study confirm the results of Almeida *et al.* (2024), in which productivity under a 50% reduction was statistically lower than that under full irrigation. In the fourth cycle, the effect of the treatments was significant only for the productivity of bunches and hands (Table 5).

Table 5. Production variables of the fourth cycle of Prata banana with irrigation water management by partial drying of the root zone under drip and microdiffusers

Treatment	Curl product	Produce bunches	Number bunches	Number fruits	Buy. fruit	Diam. fruit	Fruit weight
	(t ha^{-1})	(t ha^{-1})	for bunch	for bunch	cm	mm	g
GOT. 50%	28.00 b	26.13 b	9th	132 a	18.1 a	3.5 to	134.2 a
GOT. 100%	49.72 a	46.60 a	10 to	157 a	19.0 a	3.6 to	151.3 a
MICRO30	45.34 a	42.31 a	10 to	160 a	19.0 a	3.6 to	142.1 a
MICRO45	45.89 a	42.54 a	10 to	161 a	19.1 a	3.6 to	140.8 a
CV %	16.3	16.8	6.8	12.5	6	3.5	11.8

Averages followed by the same letters in the same column do not differ from each other according to the Tukey test at 5% significance.

The results indicate that the use of microjet diffusers is more efficient than the use of drip systems in terms of water management by partially drying the banana root zone, considering the average productivity of both bunches and bunches at the two flow rates evaluated (30 and 45 L h^{-1}). Productivity above 40 t ha^{-1} is highly significant, as it exceeds the values generally observed in the banana market, characterizing a banana plantation with full and uniform development, especially since it is the fourth production cycle.

6 CONCLUSION

Using the drip system, plants subjected to a 50% reduction in water depth based on ETc, as well as those irrigated by microjets with a flow rate of 30 L h^{-1}, both with a three-day alternation frequency, presented a more pronounced reduction in stomatal conductance than did plants subjected to 100% ETc, which maintained higher values. Compared with the drip system, the microjet system presented greater average stomatal conductance, regardless of the time of day.

Until the third cycle of the 'Prata' banana tree, irrigation management by partial drying of the root zone, using a drip system with a reduction of up to 50% of the water depth and alternating every three days, resulted in a productivity similar to that obtained with full irrigation.

The irrigation system with microjet diffusers demonstrated efficiency in applying the technique of partial drying of the root zone over three alternating days and was able to provide higher productivity than the drip system, with values above those commonly found in the banana market.

7 ACKNOWLEDGMENTS

The authors would like to thank the Brazilian Agricultural Research Corporation (EMBRAPA), the Minas Gerais Agricultural Research Corporation (EPAMIG), and the Federal University of Recôncavo da Bahia (UFRB) for their technical support, laboratory infrastructure, and field assistance, which were essential for this study. They would also like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES) for the financial support and scholarships that made this research possible.

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