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PRODUCTIVITY OF IRRIGATED JAMBU UNDER SOIL-WATER STRESSES AND NITROGEN DOSES

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KEYWORDS

Acmella oleracea (L.) R.K., tensiometry, dripping, nitrogen fertilization.

ABSTRACT

Jambu (*Acmella oleracea* (L.) R.K.) is a short-cycle leafy vegetable from the Amazon region, which needs an adequate availability of water and nutrients, mainly nitrogen, to obtain a rapid mass increase. This research aimed to study the effect of different soil-water stresses and nitrogen doses on jambu cultivation in the state of Pará. The experiments were conducted at the Igarapé-Açu experimental farm of the Federal Rural University of Amazonia (UFRA). The Jamburana variety was used in a 10 × 10 cm spacing, using a randomized block design in a 4 × 4 factorial scheme with three replications. Each plot had a dimension of 0.4 × 0.5 m (0.2 m^2), totaling 20 plants in 4 rows, but only the plants of the central rows were useful. Treatments consisted of four soil-water stresses (12, 18, 24, and 30 kPa) as an indication of the irrigation time (critical stress), using drip irrigation, and four nitrogen doses (0, 50, 100, and 150 kg ha^{-1}). The use of soil-water stress of 12 kPa associated with nitrogen fertilization at a dose of 150 kg ha^{-1} is recommended for better development and production of jambu under the conditions this experiment was conducted.

INTRODUCTION

Jambu is an unconventional vegetable native to the Amazon region, originating in the Amazon basin, belonging to the family Asteraceae, with extreme importance in the regional cuisine and for medicinal purposes in the treatment of various diseases (Gusmão & Gusmão, 2013).

In addition, Barbosa et al. (2016) stated that spilanthol, a substance found in jambu, has aroused the interest of pharmaceutical and cosmetic markets due to its biological activities such as analgesic, antinociceptive, antioxidant, anti-inflammatory, antimutagenic, anti-wrinkle, antifungal, bacteriostatic, insecticidal, antimalarial, anti-larvicidal against *Aedes aegypti* and *Helicoverpa zea* neonates, and anti-molluscicide. It can be absorbed through the skin, endothelial intestine, oral mucosa, and blood-brain barrier.

Vegetable production and quality may be limited by water deficit at certain times of the year (August to December) or high rainfall (January to July) due to the high variability of precipitation in the region (Pacheco & Bastos, 2008).

Water is one of the determining factors for food production and has a direct influence on agricultural production, being important to perform the ideal water replacement in order to obtain high productivity rates (Dutra et al., 2018). Thus, irrigation is one of the agricultural practices that provide production in regions with low water availability and increased production per area where this technique is already used.

However, the increased use of irrigation in agricultural systems has been causing environmental problems due to the misuse of this technique, mainly related to waste of water, making it necessary to manage irrigation properly (Foley et al., 2011). Knowing the irrigation time and the ideal quantity of water to be applied to each crop is essential to prevent water stress and increase productivity, in addition to minimizing the waste of water and nutrient leaching and maximizing water use efficiency (Azevedo et al., 2014; Aviz et al., 2019).

In order to obtain the ideal water depth and achieve satisfactory productivity, Valeriano et al. (2016) and Araújo et al. (2018) evaluated lettuce and arugula productivity,

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respectively, submitted to different irrigation depths and observed maximum production values close to the replacement factor of 100% of the evapotranspiration. Geisenhoff et al. (2016) also studied lettuce productivity subjected to different soil-water stresses and found a maximum productivity value at a stress of 12 kPa, but with higher water use efficiency with intermediate stresses of 34 and 45 kPa, reaching 579.87 and 471.71 kg ha^{-1} mm^{-1}, respectively.

However, in addition to water availability as a key factor in achieving high productivity, nutrition is also another indispensable factor in vegetable production. Leafy vegetables have a direct effect of nitrogen on plant growth and, consequently, productivity (Mota et al., 2016; Rezende et al., 2017; Farias et al., 2015; Vieira Filho et al., 2017).

Rodrigues et al. (2014) found a significant difference of jambu production in Pariqueira-Açu, São Paulo, Brazil, as a function of nitrogen doses; the treatment with the highest dose showed a 90% increase for fresh matter production in relation to the treatment with the total omission of this element. Borges et al. (2014) analyzed the productivity of jambu cultivars influenced by organic and mineral fertilization and found maximum values of 2.98 kg m^2 using mineral fertilizer at a dose of 69.9 g m^2 of nitrogen.

Thus, this study aimed to evaluate the effect of different soil-water stresses and nitrogen doses on the productivity of drip-irrigated jambu in Igarapé-Açu, PA, Brazil.

MATERIAL AND METHODS

The experiment was carried out in Igarapé-Açu, northeast region of the state of Pará, Brazil, from July to September 2016 under field conditions and consecutive plantations at the Experimental Farm of the Federal Rural University of Amazonia (UFRA), which has geographical coordinates of 1°07′48.47″ S and 47°36′45.31″ W, with an altitude of 54 m.

The local soil is classified as a sandy textured dystrophic Yellow Argisol. The mean soil density was 1.60 g cm^{-3}, and the results of the fertility and particle size analysis of the experimental area were obtained from a composite soil sample collected at a depth of 0–0.2 m (Table 1).

TABLE 1. Soil physical and chemical properties of the experimental area.

Particle size			**Chemical analysis**							
Sand	Silt	Clay	pH H_2O	OM	N	P	K	Na	Ca	Mg
g kg^{-1}				g kg^{-1}	%	mg dm^{-3}			cmol$_c$ dm^{-3}	
801	19	180	5.9	13.76	0.07	37	19	30	2.1	0.9

Plowing and harrowing were carried in the area and then, beds with 0.2 m height and an area of 0.25 m^2 were made. Liming was not necessary because the base saturation was within the ideal range for cultivation (70–80%). Fertilization was performed based on soil chemical analysis and following the recommendation by Cravo et al. (2007). Triple superphosphate was applied during the preparation of the pits, with a dose to provide 100 kg ha^{-1} of P_2O_5. Topdressing fertilization was split into three applications and performed at 10, 17, and 24 days after seedling planting. Fertilizers used in the area were potassium chloride at a dose of 120 kg ha^{-1} of K_2O and the nitrogen at doses of 0, 50, 100, and 150 kg ha^{-1} of N, as established in the treatments.

The experimental design was a randomized block design in a 4 × 4 factorial scheme, with three replications. Treatments consisted of four soil-water stresses (12, 18, 24, and 30 kPa) and four nitrogen doses (0, 50, 100, and 150 kg ha^{-1}).

The cultivar Jamburana, which has a cycle of approximately 70 to 80 days, was used. Seedlings were obtained from family producers of Igarapé-Açu and produced in 128-cell Styrofoam trays filled with organic compost with good phytosanitary characteristics. Transplanting was performed at 31 days after sowing. The spacing used was 10 × 10 cm, with plots with dimensions of 0.4 × 0.5 m (0.2 m^2), totaling twenty plants arranged in four rows of five plants. Central plants were considered useful (useful area with 10 plants).

After transplanting, plants were irrigated for 10 days to a better adaptation to field conditions. During this period, an irrigation depth of 3.19 mm was applied per day, with no stress measurement.

Manual weeding procedures were carried out in the beds and with a hoe between beds to control weeds. There was no incidence of pests and diseases during the experimental period. Harvesting was performed at 77 days after planting.

Irrigation was performed using pressure-compensating dripline hoses of additive polyethylene, with inline emitters spaced at 20 cm, flow rate of 1.2 L h^{-1} each, nominal diameter of 16 mm, working pressure of 6 mWC at the end of the hose. Drip hoses were connected to polyethylene bypass lines (DN 16), which were connected to PVC pipes (DN 50; PN40), which, in turn, were connected to the main line via electrically operated solenoid valves via the controller installed on the control head. A 5000 L water tank was used for the irrigation system to store the water used in the experiment. Also, a 1.5 hp electric pump, a 120 mesh disc filter, and a pressure regulating valve, set to work with up to 6 mWC inserted into the main pipe outlet, were used.

Critical stress was determined using two puncture tensiometer devices installed for each stress established in the treatments (12, 18, 24, and 30 kPa), together with a dose of 100 kg ha^{-1} of nitrogen, which was the recommended fertilizer dose. These tensiometers were installed at a depth of 15 cm, being positioned between two plants in the plant row, and indicated the time to irrigate. Stress measurements were performed once a day in the morning (9:00 h) using a digital puncture tensiometer with a sealing rubber inserted on its top.

Irrigations were performed when the tensiometer mean reached the critical stress established in the treatments, always seeking to raise soil moisture to its field capacity, corresponding to a stress of 10 kPa (0.240 cm^3 cm^{-3}).

Irrigation management was based on the soil-water characteristic curve obtained at a depth of 0–20 cm (Figure 1), following the methodology of Andrade Junior et al. (2007), being then adjusted by the van Genuchten (1980) model.

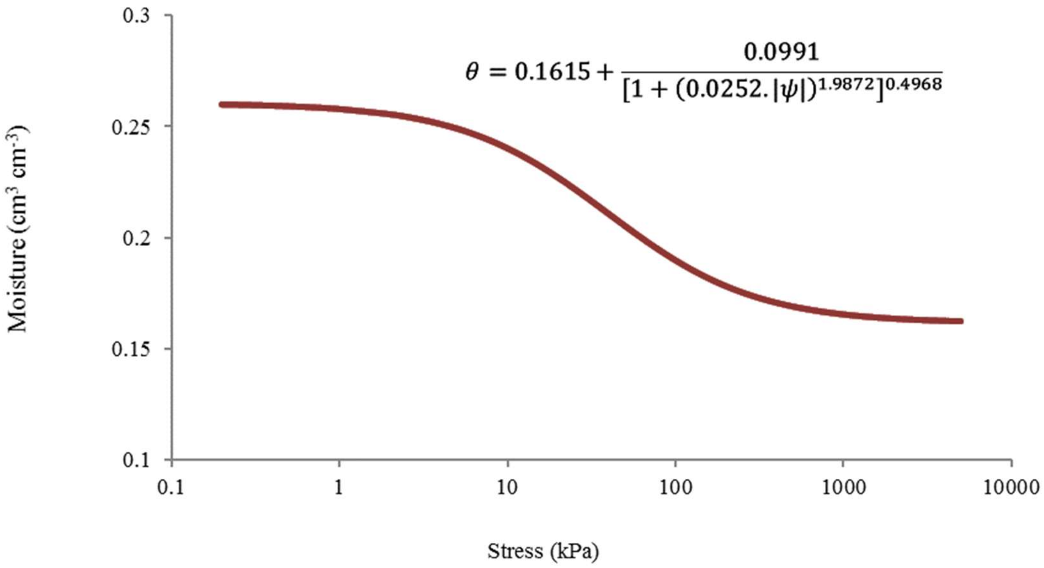

FIGURE 1. Soil-water retention curve.

The distribution uniformity coefficient (DUC) and application efficiency were calculated after the irrigation system was installed, following the methodology proposed by Calgaro & Braga (2008).

Considering the effective depth of the root system equal to 20 cm (Gusmão & Gusmão, 2013), the net irrigation depth was calculated by [eq. (1)].

$$NID = (\theta cc - \theta current).z \quad (1)$$

Where:

NID is the net irrigation depth (mm);

θcc is the soil moisture at field capacity (cm^3 cm^{-3});

θcurrent is the soil moisture at the time of irrigation (cm^3 cm^{-3}), and

z is the effective depth of the root system (mm).

Then, the gross irrigation depth was calculated by [eq. (2)].

$$GID = \frac{NID}{Ea.DUC} \quad (2)$$

Where:

GID is the gross irrigation depth (mm);

Ea is the application efficiency, and

DUC is the distribution uniformity coefficient for the water of the irrigation system.

Subsequently, the irrigation system working time was calculated by [eq. (3)] in order to perform the water replacement in the treatments.

$$T = \frac{GID.A}{e.qa} \quad (3)$$

Where:

T is the irrigation system working time of each treatment aiming to increase the moisture to field capacity (h);

A is the area occupied per plot (m^2);

e is the number of emitters per plot, and

qa is the mean flow of emitters (L h^{-1}).

Temperature, air humidity, and precipitation data were collected from a Vantage pro2 automatic weather station installed in the experimental area.

The response variables plant height (PH), shoot fresh matter (SFM), productivity (PROD), and water use efficiency (WUE) were analyzed to evaluate the effect of soil-water stress and nitrogen doses.

Plant height was measured at the time of harvest, being determined from the plant collar using a measuring tape. The shoot fresh matter was determined using a precision scale shortly after harvest. Productivity was estimated in g m^{-2} by multiplying the shoot fresh matter by plant population in one square meter, while water use efficiency was obtained by dividing the productivity obtained per area by the total water depth applied in each treatment.

The data were subjected to analysis of variance and means compared by the Tukey test at 5 and 1% probability. A regression analysis was performed when there was significance.

RESULTS AND DISCUSSION

During the experiment, the mean daily air temperature and humidity were 27.8 °C and 71.1%, respectively. During this period, temperature ranged from 21.3 to 33.9 °C, while humidity ranged from 41 to 93%. These data show a variation of more than 12 °C in temperature and more than 50% in humidity throughout the experiment. According to Gusmão & Gusmão (2013), jambu grows well in hot and humid climates, with temperatures ranging from 25 to 35 °C, relative humidity around 80%, and 2,600 hours of sunlight annually, being one of the few vegetables not harmed by excessive rainfall. Thus, the experiment was conducted under ideal conditions for proper crop development.

Water depths applied before and after treatment differentiation, as well as precipitations during the experimental period, total water supplied to the crop until harvest, number of irrigations, mean irrigation frequency, and daily water demand during treatment differentiation are shown in Table 2.

TABLE 2. Soil-water stress at a depth of 0.15 m, water depth applied before (Begin.) and after (Irrig.) treatment differentiation, precipitation (Prec.), total water depths (Total), number of irrigations (NI), and mean irrigation frequency (IF), daily water demand (WD).

		Water depth (mm)					
Stress	Begin.	Irrig.	Prec.	Total	NI	IF (day)	WD (mm/day)
12 kPa	31.9	36.98	109.2	178.08	24	1.46	3.96
18 kPa	31.9	29.49	109.2	170.59	14	2.5	3.79
24 kPa	31.9	13.79	109.2	154.89	4	8.75	3.44
30 kPa	31.9	12.52	109.2	153.62	3	11.67	3.41

The data in Table 3 showed a linear behavior in relation to water consumption per treatment, similar to that observed by Geisenhoff et al. (2016) in an experiment with drip-irrigated lettuce with different stresses, in which the total applied depth decreased as the soil-water stress increased.

An interaction was observed between the factors stress and nitrogen dose (Table 3) for the shoot fresh matter, productivity, and water use efficiency. No significant difference for height was observed for the interaction between these factors, but there was an isolated effect only for nitrogen dose.

TABLE 3. Summary of analysis of variance for plant height (PH), shoot fresh matter (SFM), productivity (PROD), and water use efficiency (WUE) of jambu plants as a function of soil-water stresses and nitrogen doses in Igarapé-Açu, Pará, Brazil.

Source of variation	DF	F-value			
		PH	SFM	PROD	WUE
Stress	3	2.0462ns	127.9796**	127.9796**	52.4037**
Nitrogen	3	5.0501**	274.7800**	274.7800**	268.5446**
Stress × nitrogen	9	0.3788ns	11.7051**	11.7051**	8.3287**
Blocks	2	2.9448ns	3.0270ns	3.0270ns	2.8160ns
Residual	30				
CV%		15.74	6.03	6.03	6.04

**Significant at 1% probability; *significant at 5% probability; ^{ns}not significant.

According to the analysis of variance, there was an interaction between factors, showing a linear behavior in which the total applied water depth influenced nitrogen absorption. For shoot fresh matter, productivity, and water use efficiency, treatments submitted to a stress of 12 kPa and nitrogen dose of 150 kg ha^{-1} had higher means when compared to the others, occurring a reduction in the variables as stresses increase.

Water depths and nitrogen doses influenced jambu development, evidencing the need for an ideal amount of water and nutrient to obtain a good crop development. Soil moisture maintained close to field capacity favored nitrogen use efficiency. Considering that water is the means of transport of nutrients to plants, the management that provided the highest amount of water and lowest irrigation frequency promoted the reduction of nitrogen losses by leaching and kept the soil consistently moist, which favored biomass accumulation.

Jambu showed a positive response to the increase of nitrogen doses, evidencing its importance in leafy vegetables. Nitrogen at a dose of 150 kg ha^{-1} provided a high increment of fresh matter under all soil-water stresses, with a higher response of nitrogen fertilization at lower soil-water stresses.

Fresh matter production showed linear behavior for interaction between the factors soil-water stress and nitrogen dose, and the treatment with maximum fresh matter production consisted of the combination between the stress of 12 kPa and nitrogen dose of 150 kg ha^{-1}, reaching a value of 39.0 g plant^{-1} (Figure 2). These results showed that plants subjected to this treatment absorbed more nitrogen because soil moisture remained close to the field capacity, which favored the mass flow, soil aeration, solubilization, and nutrient availability (Marouelli et al., 2014).

Fresh matter decreases as soil-water stress increases, regardless of the used nitrogen dose. This effect is due to the difficulty that the plant has to absorb the water retained in the soil colloid at higher stresses, requiring higher energy expenditure.

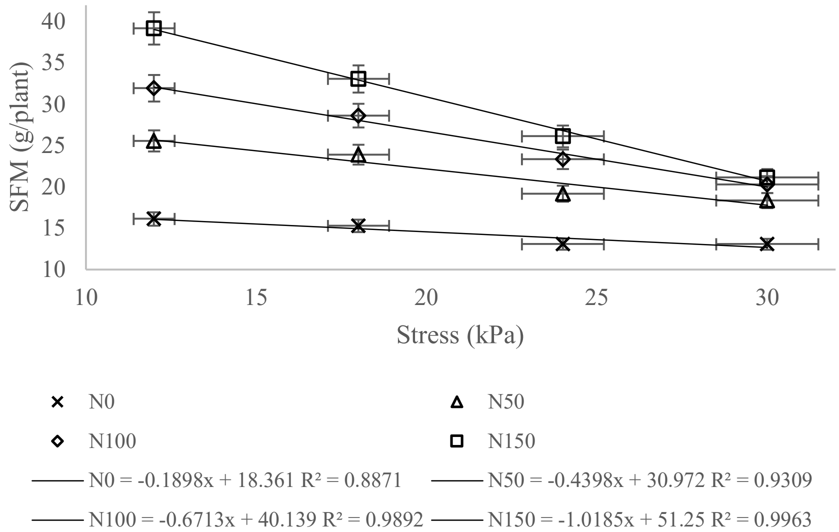

FIGURE 2. Jambu shoot fresh matter (SFM) as a function of different soil-water stresses (12, 18, 24, and 30 kPa) and nitrogen doses (0, 50, 100, and 150 kg ha^{-1}). Igarapé-Açu, PA, Brazil, 2017.

The result of fresh matter found in this study presented behavior similar to that found by Silva et al. (2013), who worked with beet under different soil-water stresses and found a linear model for fresh matter production, with a maximum value at stress closer to field capacity (15 kPa). Rodrigues et al. (2014) evaluated the influence of nitrogen and phosphorus fertilization on jambu production and found maximum fresh matter production (leaves and flowers) of 4,012.4 g m^2 at a dose of 112.5 kg ha^{-1} of nitrogen. These results confirm that water and nutrient availability is fundamental for the increase of fresh matter in jambu.

Plant height varied significantly only for the factor nitrogen doses and had a quadratic behavior (Figure 3). The regression analysis showed that the maximum height was found at a nitrogen dose of 57.13 kg ha^{-1}, resulting in the height of 15.46 cm, from which the increased nitrogen doses led to a decrease in plant height. These results are different from those found by Favoreto & Gilbert (2010), who observed that jambu could reach around 20 to 40 cm in height. Borges et al. (2014) and Souto et al. (2018) studied fertilization in the jambu crop and obtained higher plant height than that found in this study, with values of 37.36 and 35.42 cm, respectively.

Similar to fresh matter, the variable productivity was significantly affected by the interaction between factors and showed linear behavior, reaching a maximum value of 39 t ha^{-1} at a stress of 12 kPa and nitrogen dose of 150 kg ha^{-1} (Figure 4). The treatment with 12 kPa favored the use of nitrogen fertilization by jambu plants, which responded with maximum productivity at the highest dose. The treatment with soil-water stress of 12 kPa maintained the soil close to field capacity, demonstrating behavior similar to the results found by Geisenhoff et al. (2016) with lettuce and Lima Junior et al. (2012) with carrots, who performed irrigation management based on the soil and obtained maximum productivity at stresses close to field capacity.

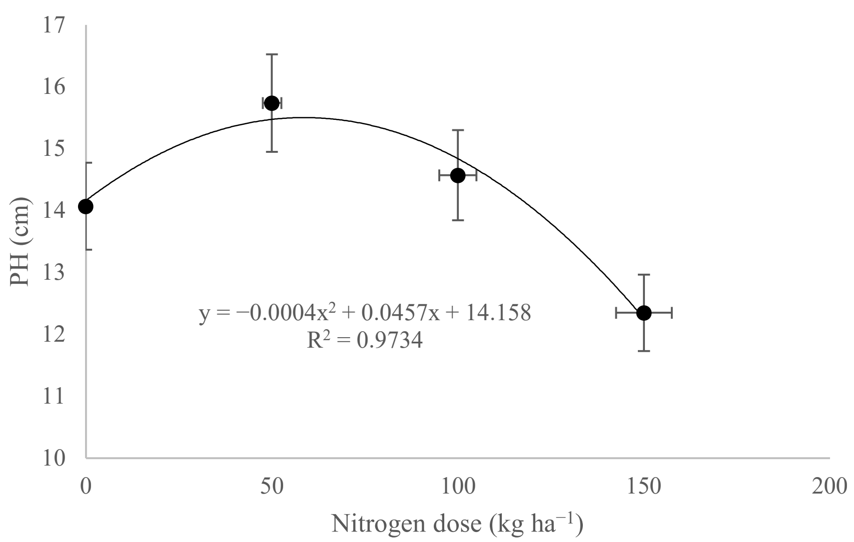

FIGURE 3. Height of jambu plants as a function of different nitrogen doses (0, 50, 100, and 150 kg ha^{-1}).

Jambu production is benefited by the stress that maintains soil moisture close to field capacity. It is in accordance with Gusmão & Gusmão (2013), who stated that jambu occurs naturally under humid conditions, being an important factor for its development.

Soil moisture in the treatment with the stress of 12 kPa was maintained by applying low water depths with low irrigation frequency, which favored photoassimilates absorption and soil aeration, and hence better vegetative development. Nitrogen dose of 150 kg ha^{-1} provided better results when associated with the stress of 12 kPa. It is possibly due to an increase in the split of water supply to the plant, which may have favored nutrient absorption and decreased losses by leaching. Productivity reduction as stress increases may be related to a higher amount of water applied at each irrigation time, as the leaching process may be favored under these conditions.

Borges et al. (2014) found productivity of 29.8 t ha^{-1} using a nitrogen dose of 69.9 g m^2. This productivity was lower than that found in this study, but a higher amount of nitrogen fertilizer was used to conduct the experiment. The difference in productivity between studies may be related to the planting density adopted by Borges et al. (2014), as the fresh matter cited was higher than that found in the present study.

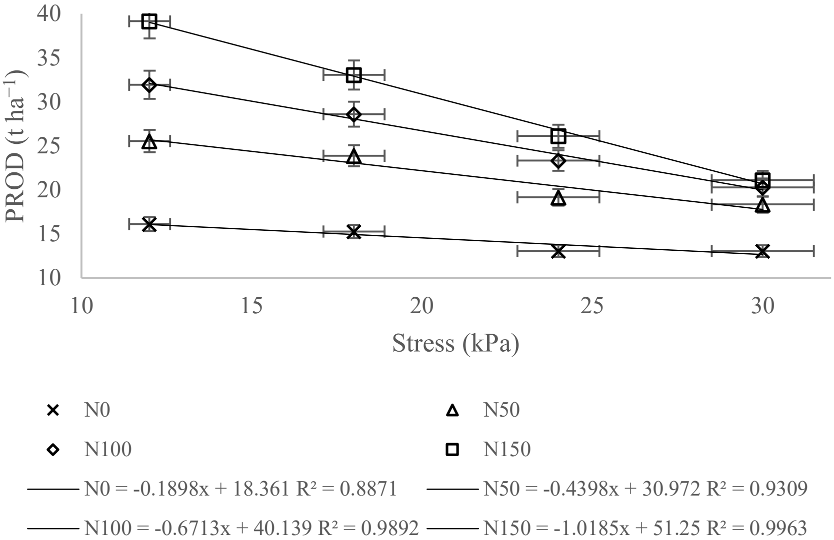

FIGURE 4. Jambu productivity as a function of different soil-water stress (12, 18, 24, and 30 kPa) and nitrogen doses (0, 50, 100, and 150 kg ha^{-1}).

The nitrogen dose of 150 kg ha^{-1}, which allowed the maximum productivity found in this study, is higher than that recommended by Cravo et al. (2007), showing that leafy vegetables under tropical, climate, and soil conditions present higher water and nutritional requirements.

Water use efficiency is a variable that shows the relationship between water production and water consumption. This variable showed a decreasing linear behavior as soil-water stress increased (Figure 5). The maximum value obtained for water-use efficiency was 220.8 kg ha^{-1} mm^{-1}, obtained with a stress of 12 kPa, which had the highest total irrigation depth, and a nitrogen dose of 150 kg ha^{-1}. The other stresses combined with fertilization of 150 kg ha^{-1} had lower water use efficiencies, i.e., stresses of 18, 24, and 30 kPa reached 193.6, 166.3, and 139.0 kg ha^{-1} mm^{-1}, respectively.

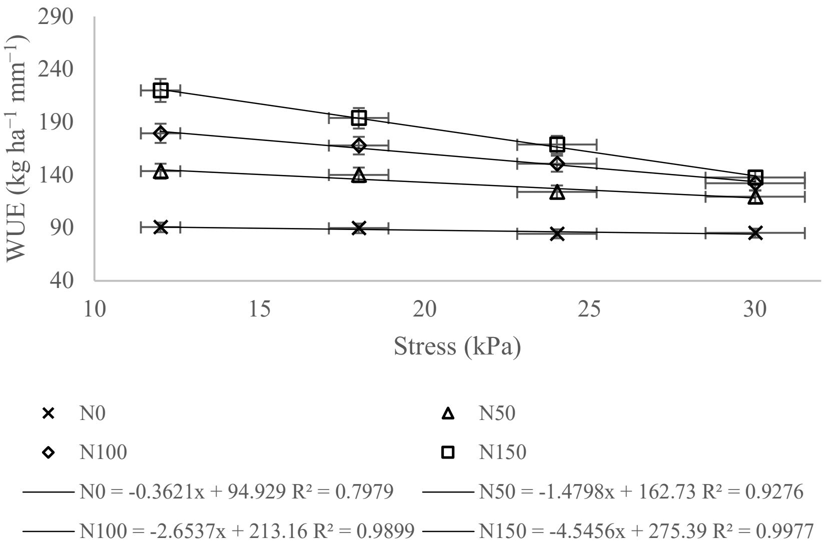

FIGURE 5. Water use efficiency of jambu shoot fresh matter as a function of different soil-water stresses (12, 18, 24, and 30 kPa) and nitrogen doses (0, 50, 100, and 150 kg ha^{-1}).

Water use efficiency is a strategy for the rational use of water resources. However, jambu productivity decreased as the total applied water depth decreased. This behavior shows the positive response of jambu to an increase in the applied water depths. Similar to the results found in this study, Silva et al. (2013) evaluated water-use efficiency in beet cultivars under different soil water stresses and Sahin et al. (2016) evaluated lettuce production submitted to different irrigation levels and found that the efficiency in water use reduced with a reduction of the applied water depths.

CONCLUSIONS

The use of the soil-water stress of 12 kPa associated with nitrogen fertilization at a dose of 150 kg ha^{-1} is recommended for better development and production of jambu under the conditions this experiment was conducted.

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