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Growth and yield of yellow passion fruit under hydrogel and vegetal mulching doses

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Abstract

The yellow passion fruit is one of the most widely cultivated fruit crops in Brazil, with the Northeast region being particularly prominent. Despite being the largest national producer, water scarcity remains the primary limiting factor for expanding this crop in Brazilian semi-arid regions. Given this challenge, there is a need for soil management techniques that enhance water use efficiency by plants. This study aimed to evaluate the growth and production components of yellow passion fruit in soil treated with hydrogel and mulching from crop residues. The experiment was conducted using a randomized block design in a 5 × 2 factorial arrangement, corresponding to five hydrogel doses (0, 0.5, 1.0, 1.5, and 2.0 g dm^{-3} of soil) in soil with and without mulching derived from Brachiaria plant residues. The analyzed variables included plant height, stem diameter, number of branches and leaves, number of fruits, yield per plant, average fruit mass, and yield. Yellow passion fruit growth was enhanced with a hydrogel dose of 1.1 g dm^{-3}, and yield improved with doses ranging from 0.65 to 2.0 g dm^{-3} in the second harvest. Soil with mulching from Brachiaria plant residues increased the yield of yellow passion fruit, particularly in the second harvest.

Keywords: biometric measurements, fruit production, soil cover, *Passiflora edulis L.*, water-retaining agent

Introduction

Brazil stands out as the world's largest producer and consumer of yellow passion fruit (*Passiflora edulis Sims*) (Talma et al., 2019). In 2022, the estimated national production was 697,859 tons over a harvested area of 45,602 hectares (IBGE, 2023). The state of Paraíba holds a modest position, ranking 12th nationally and 6th in the Northeast region (IBGE, 2023). This situation highlights the state's potential for expanding the production of this crop, as indicated by the production levels reported by Aguiar et al. (2017) and Cavalcante et al. (2018a).

In tropical semi-arid regions with hot and dry climates, potential evapotranspiration rates exceed precipitation for most of the year, leading to water deficits for plants (Um et al., 2019). Water scarcity in arid and semi-arid areas impairs the biometric and productive behavior of crops and even limits agricultural production (Ding et al., 2021; Guedes et al., 2023). This issue necessitates the use of irrigation techniques to sustain crop production in the region (Borges et al., 2019).

Water-retaining polymers or hydrogels, based on polyacrylamide, have been used in agriculture to reduce soil water losses in the root absorption zone (Patra et al., 2022). Hydrogels improve soil physical and chemical properties, increasing water storage and availability (Navroski et al., 2016) and reducing nutrient losses through leaching from the root absorption zone (Abdallah et al., 2019; Sousa et al., 2021).

Over the last decade, interest in the effects of water-retaining polymers on soil and plants has increased (Cavalcante et al., 2018b), as recent studies describe how hydrogels improve water retention capacity and reduce nutrient losses (Monteiro Neto et al., 2017). However, there is a need to define the appropriate dosage for application in crops, including yellow passion fruit, as the dose may vary depending on soil type and species

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(Narjary et al., 2012; Filho et al., 2018).

In semi-arid conditions, water availability in the root zone becomes a critical factor for production; thus, mulching can be an alternative to improve agricultural cultivation, as it keeps the soil cooler and more humid, reduces competition from spontaneous plants, and minimizes water evaporation from the soil surface, thereby increasing water availability in the root zone (Uchôa et al., 2018; Gabriel et al., 2018; Júnior et al., 2020).

This study aimed to evaluate the growth and yield of yellow passion fruit cultivated in soil with hydrogel and mulching from Brachiaria plant residues in the Curimataú micro-region of Paraíba, a semi-arid region in Brazil.

Material And Methods

The experiment was conducted from September 2016 to June 2018 at Sítio Macaquinhos, located in the municipality of Remígio, Paraíba, Brazil. According to Köppen's classification, the region's climate is As', characterized by hot and humid summers with rainfall concentrated between March and July (Alvares et al., 2013). The municipality is georeferenced at the geographic coordinates 7° 00' 1.95'' South latitude, 35° 47' 55'' West longitude from the Greenwich Meridian, and an altitude of 562 meters.

The experimental design was a randomized block design in a 5 × 2 factorial arrangement with three replications, corresponding to hydrogel doses of 0.0, 0.5, 1.0, 1.5, and 2.0 g dm^{-3} in soil with and without mulching from plant residues. The mulching was derived from dehydrated Brachiaria grass (*Brachiaria decumbens* L.), applied at a thickness of 0.08 m in a 1 m diameter circumference covering an area of 0.78 m², with the plant stem at the center of the pit (Freire et al., 2011). The mulch was chemically characterized at the beginning and end of the experiment, and the results are presented in **Table 1**.

During the experiment, monthly data on rainfall and Class "A" pan evaporation were collected. Temperature and relative humidity data were recorded using a Datalogger (model HT-70) installed at the center of the experimental area, as shown in **Figure 1**.

The soil in the experimental area, according to the criteria of the Brazilian Soil Classification System (EMBRAPA, 2018), was classified as a dystrophic Regolithic Neosol, presenting, at a depth of 0.0-0.4 m, the following chemical and physical attributes related to fertility (EMBRAPA, 2017), as shown in **Table 2**.

The pits were dug with dimensions of 0.40 × 0.40 × 0.40 m, spaced 3 m apart between rows and plants. From the total volume of soil removed from the

Table 1. Characterization of the chemical attributes of the mulch derived from *Brachiaria decumbens* L., analyzed at the beginning and end of the experiment

Chemical Attributes	Before	Last
N (g kg^{-1})	10.21	16.86
P (g kg^{-1})	2.23	1.22
K (g kg^{-1})	12.72	4.32
Ca (g kg^{-1})	4.11	11.59
Mg (g kg^{-1})	3.02	2.31
S (g kg^{-1})	2.23	1.66
B (mg kg^{-1})	25.46	20.22
Cu (mg kg^{-1})	7.53	9.77
Fe (mg kg^{-1})	138.81	1.212.42
Mn (mg kg^{-1})	46.68	119.34
Zn (mg kg^{-1})	57.02	144.50
Organic Carbon (g kg^{-1})	418.54	368.33
C/N	40:1	22:1

Nitrogen (N) – Kjeldahl method by wet digestion; Phosphorus (P) – Mehlich 1; Potassium (K) – Flame photometer; Calcium (Ca) – Atomic absorption spectrophotometer at a wavelength of 422.7 nm; Magnesium (Mg) – Atomic absorption spectrophotometer at a wavelength of 285.2 nm; Sulfur (S) – Atomic absorption spectrophotometer at a wavelength of 400.0 nm; Boron (B) – UV-VIS spectrophotometer at a wavelength of 460 nm; Copper (Cu) – Atomic absorption spectrophotometer at a wavelength of 324.7 nm; Iron (Fe) – UV-VIS spectrophotometer at a wavelength of 508 nm; Manganese (Mn) – Atomic absorption spectroscopy with air-acetylene flame; Zinc (Zn) – Atomic absorption spectroscopy with air-acetylene flame; Carbon/Nitrogen ratio (C/N) – Wet oxidation method.

Table 2. Chemical attributes related to soil fertility and physical attributes before the installation of the experiment

Chemical Attributes	Value	Physical attributes	Value
pH (H_2O)	6.20	Sand (mm)	822
MOS (g kg^{-1})	7.30	Silt (mm)	81
P (mg dm^{-3})	13.00	Clay (mm)	97
K^+(mg dm^{-3})	0.14	Ada (g kg^{-1})	27
Ca^{2+}(cmol$_c$ dm^{-3})	0.78	GF (%)	72.16
Mg^{2+}(cmol$_c$ dm^{-3})	0.65	Ds (g cm^{-3})	1.40
Na^+(cmol$_c$ dm^{-3})	0.04	Dp (g cm^{-3})	2.66
SB (cmol$_c$ dm^{-3})	1.57	Pt (%)	47.76
H^++Al^{3+}(cmol$_c$ dm^{-3})	1.68	Ucc - 0.010 MPa (g kg^{-1})	107
Al^{3+}(cmol$_c$ dm^{-3})	0.00	Upmp - 1.500 MPa (g kg^{-1})	58
CTC (cmol$_c$ dm^{-3})	3.25	Adi (g kg^{-1})	49
V (%)	48.31	Textural class	Loamy sand

SB = Sum of exchangeable bases (Ca^{2+} + Mg^{2+} + K^+ + Na^+); CTC = Cation exchange capacity [SB + (H^+ + Al^{3+})]; V (%) = Base saturation value (SB/CTC) × 100; MOS = Soil organic matter; Ada = Clay dispersed in water; GF = Flocculation degree; Ds = Soil density; Dp = Particle density; Pt = Total porosity; Ucc = Moisture at field capacity; Upmp = Moisture at the permanent wilting point; MPa = Megapascal; Adi = Available water (Ucc - Upmp); P = Phosphorus - Mehlich-1; K = Potassium - Mehlich-1; Na^+ = Sodium - 1 mol/L KCl; Ca^{2+} = Calcium - 1 mol/L KCl; Mg^{2+} = Magnesium - 1 mol/L KCl; H^+ + Al^{3+} = Hydrogen + aluminum - 0.5 mol/L calcium acetate; Al^{3+} = Aluminum - 0.5 mol/L calcium acetate; MOS – separation in water.

pits (64 dm³), 20 dm³ was separated from the first 20 cm of the pit for preparing the mixtures for each dose of the hydroabsorbent polymer. The polymer used was Hydroplan®-EB/HyA, with particles ranging from 0.3 mm to 1 mm, anionic ionic characteristic, neutral pH of adsorbed water, bulk density of 0.8 g cm^{-3}, 60% absorption time of 30 minutes, composed of a copolymer of acrylamide (C_3H_5NO) and potassium acrylate ($C_3H_3KO_2$). After homogenizing the soil with the mass of each polymer dose, the mixture was returned and incorporated with the volume of soil from the surface layer (0.00 – 0.20 m) to prepare the 64 dm³ for each pit.

In the first 0.2 m of soil, 20 dm³ of cattle manure was incorporated, along with a mixture containing 15 g pit^{-1} of calcitic lime (CaO = 47%, MgO = 3.4%, PRNT = 82%) and 9 g pit^{-1} of agricultural gypsum (CaO = 26%, moisture = 8%, total P_2O_5 = 0.65%) to increase the percentage of soil base saturation to 70%, as recommended for the yellow passion fruit crop (Borges & Souza, 2010). The soil was irrigated for 30 days to solubilize the lime and gypsum

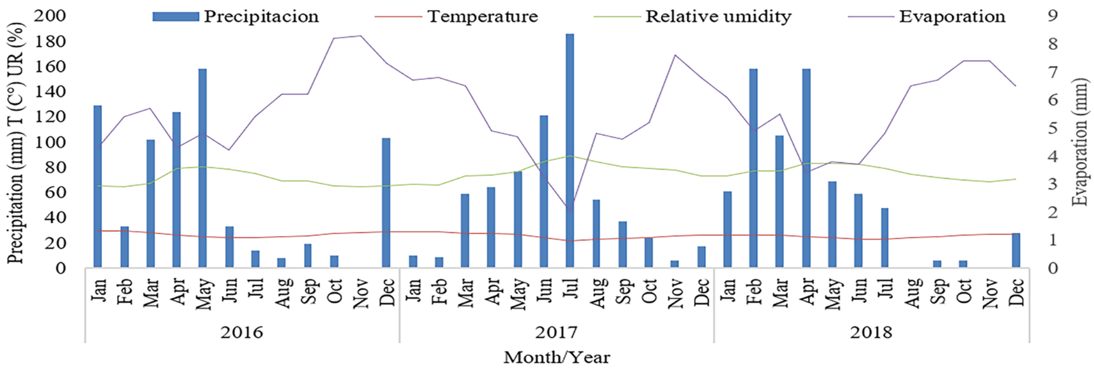

Figure 1. Monthly average values of precipitation, temperature (T), relative humidity (RH), and Class "A" tank evaporation during the years 2016, 2017, and 2018, collected at the experimental center.

mixture. Thirty days before planting, the soil phosphorus content in the pits was increased from 13 to 30 mg dm^{-3} by incorporating 27.1 g pit^{-1} of single superphosphate (20% P_2O_5, 20% Ca, 12% S).

Transplanting occurred on 09/13/2016, when the seedlings had four fully expanded leaf pairs and an average height of 25 cm. The system used to support the plants was a trellis type, with a height of 2.3 m, consisting of a 12-gauge smooth wire installed at the top of the stakes (Cavalcante et al., 2018b).

Starting 30 days after transplanting (DAT), monthly top-dress fertilization was applied with nitrogen (urea, 45% N) and potassium (potassium chloride, 60% K_2O and 50% K) in a 1:1 N and K ratio, applying 5, 10, and 15; 15 g of N and K, respectively, at 60, 90, and 120 DAT, and after 120 DAT, monthly until the end of the 2016/2017 harvest. At 330 DAT, 20 g of N and 20 g of K were applied, totaling 170 g of N and K per plant throughout the period and 380 and 340 g per plant per year, respectively, of urea and potassium chloride. Phosphorus fertilization began at 60 DAT, every two months, applying 12 g per plant of P_2O_5 in the form of single superphosphate, totaling five applications until the end of the harvest, corresponding to 60 g per plant per year of P_2O_5 or 300 g per plant per year of single superphosphate. NPK fertilization in the 2017/2018 harvest followed the doses provided from 120 DAT in the 2016/2017 harvest, considering the root system duly established.

Irrigation was performed when the plants showed typical symptoms of water deficiency. Before irrigation, the volumetric soil moisture value in the 0-0.20 m layer was obtained using a portable digital soil moisture meter, ECH$_2$OCheck-EC 3212. The potential evapotranspiration (ETc) was used for irrigation, corresponding to the product of reference evapotranspiration (ET_0) and the crop coefficient (Kc) of yellow passion fruit, with values of 0.64 during initial growth (from transplanting to 58 DAT), 1.13 during crop formation to early flowering (59 to 114 DAT), and 1.25 from flowering to the end of the harvest (115 to 150 DAT), as recommended by Freire et al. (2011). In the 2017/2018 harvest, the last two Kc values from the 2016/2017 period were used.

The growth variables evaluated were plant height, measured with a graduated tape measure in centimeters from the base of the stem to the apical meristem at 60 DAT; stem diameter 5 cm above the soil, measured with a Digimess® digital caliper with 0.01 mm precision; and the count of the number of leaves and productive branches at 120 DAT. The production variables in the 2016/2017 and 2017/2018 harvests were the number and average weight of fruits, production per plant obtained by the product of the number and average weight of fruits, and yield, quantified by multiplying the production per plant by the planting density (1,111 plants ha^{-1}), with repeated samples over time.

The data were subjected to variance analysis using the F-test ($p < 0.05$). The means for the presence and absence of mulching in the 2016/2017 and 2017/2018 harvests were compared using the F-test at a 5% probability, which is conclusive for two factors from the same source of variation. The means for the hydrogel doses were analyzed by regression using the R statistical software (R Core Team, 2017).

Results and Discussion

Among the variables evaluated, the interaction between the hydroabsorbent polymer and soil mulch had significant effects on leaf and productive branch emission in yellow passion fruit (**Table 3**). Height growth responded to the effects of polymer doses, and the stem diameter of yellow passion fruit cv. BRS GA1 was influenced by soil mulch. Michoma et al. (2023) found similar results when using a hydroretentive polymer (hydrogel) and plastic mulch, where the treatment showed the highest average height in yellow passion fruit. These findings also align with observations of growth and development in yellow

Table 3. Summary of variance analysis, based on the mean square values, for plant height (PH) and stem diameter (SD), number of leaves (NL), and number of branches (NB) of sour passion fruit under hydrogel doses (H) in soil with the application of mulch with plant residues (M)

SV	DF	Mean Square			
		PH	SD	NL	NB
Hydrogel (H)	4	1763,21**	22,46^{ns}	16.492,5**	14,28^{ns}
Linear Regression	1	487,35^{ns}	1,66^{ns}	9.753,75**	3,75^{ns}
Quadratic Regression	1	5684,29**	51,85^{ns}	31.281,00**	447,28^{ns}
Mulching (M)	1	346,80^{ns}	83,33**	27.240,50**	700,83**
H × M	4	380,21^{ns}	8,16^{ns}	19.805,61**	183,58*
Residue	20	333,76	10,26	949,73	31,63
Total	29	-	-	-	-
CV (%)		8,86	14,18	12,58	15,61

SV = Source of variation; DF = Degrees of freedom; CV = Coefficient of variation; ns = not significant; * = significant at 5% probability; ** = significant at 1% probability.

passion fruit seedlings under irrigation and hydrogel addition to the substrate (Carvalho et al., 2013; Tofanelli et al., 2016).

Plant height growth increased to a maximum of 223.18 cm at the estimated maximum dose of hydrogel polymer, 1.1 g dm^{-3} of soil. Plants subjected to doses above this value experienced inhibition in the growth of the main stem within 60 days of transplanting to the pruning of the main stem. During the formation of yellow passion fruit seedlings, thus at a younger age (70 days after sowing), hydrogel stimulated plant height growth up to a dose of 3 g dm^{-3} (Carvalho et al., 2013).

A similar response was reported by Fagundes et al. (2015) and Tofanelli et al. (2016) when observing height growth in passion fruit seedlings, both with increasing doses of hydrogel up to 2.0 g dm^{-3} of substrate, respectively, at the ages of 60 and 80 days from sowing to the point of field transplantation. In this context, the application of hydrogel at the determined concentration (1.1 g dm^{-3}) becomes beneficial for height growth in yellow passion fruit by allowing a greater water reserve to meet the crop's needs, as water is an important factor for cell expansion and consequently, vegetative growth (Ma et al., 2019).

The reduction in plant height under the hydrogel dose of 3 g dm^{-3} compared to 1.1 g dm^{-3} (**Figure 2**A) may be a response to the difference in age between seedlings and adult plants, as well as the addition of 20 dm^{3} of organic matter in the form of cattle manure, which also increases water storage and availability to plants (Yost & Hartemink, 2019; Zhou et al., 2020), reducing the need for hydrogel polymer.

Therefore, it is possible that concentrations above 1.1 g dm^{-3} of hydrogel retain more water than necessary, causing a lack of oxygenation in the roots and resulting in water stress, which reduces vegetative growth. This phenomenon was observed by Jiménez et al. (2019), who reported that hypoxia in the root zone reduces the growth of the tropical forage grass *Urochloa humidicola* under high nutrient conditions, but not under low nutrient conditions.

The soil mulch from plant residues inhibited the stem diameter of yellow passion fruit (Figure 2B), causing a 13.75% loss. These data differ from the literature, which generally shows positive results of soil mulch on plant growth (Gabriel et al., 2018; Murad et al., 2019; Alves et al., 2021).

In the soil without mulch, increasing doses of hydrogel inhibited leaf emission in plants by 109 leaves per unit increase in the dose of the hydroretentive polymer, resulting in a 56% loss between plants with 0 and 2.0 g dm^{-3} of the hydroretentive polymer (**Figure 3**A). On the other hand, the combination of mulch with the polymer stimulated leaf emission from 133 to 278 leaves between plants in the soil without and with 1.1 g dm^{-3} of hydrogel.

It was also observed that doses above 1.1 g dm^{-3} of the hydroabsorbent polymer impaired leaf emission in yellow passion fruit. This behavior is similar to that found in plants subjected to excess water in the soil, where flooding contributes to a lack of oxygen, harming root growth and function (Souto et al., 2024). Consequently, there is a reduction in functional leaf area caused by chlorosis, necrosis, leaf drop, stomatal closure, and chlorophyll degradation (Benkeblia, 2021; Ivanov et al., 2022). In this context, doses above 1.1 g dm^{-3} may have caused hypoxia in the roots, reducing the number of leaves in yellow passion fruit, as observed by Fischer et al. (2023).

The number of productive branches in the plants at 120 DAT, in both soil without and with mulch, did not fit any regression model based on hydrogel doses and showed average values of 40.86 and 31.20, respectively (Figure 3B). The branches of plants in soil without mulch exceeded those in soil with mulch by 24%. As observed with stem diameter, the emission of productive branches was also inhibited by soil mulch. This result is consistent with that found by Faria et al. (2020), where *Passiflora edulis* plants demonstrated reduced vegetative growth under excess soil water caused by mulch. This inhibition is due to excess water, which induces morphophysiological changes to stimulate acclimation and tolerance to adverse conditions (Matos et al., 2018).

According to **Table 4**, the interaction between hydrogel × mulch × harvest season significantly influenced the production components expressed by the number of fruits (NF), average fruit mass (AFM), production per plant (PP), and yield (Y). The responses of the plants related to the hydrogel × mulch × harvest season interaction are in

Table 4. Summary of variance analysis, based on the mean square values, for the number of fruits (NF) and average fruit weight (AFW), production per plant (PP), and yield (Y) of sour passion fruit in soil with hydrogel doses (H) and the application of mulch with plant residues (M) in two consecutive Season (S)

SV	DF	Mean Square			
		NF	AFW	PP	Y
Hydrogel (H)	4	187,7**	477,2**	17,41**	22,58**
Season (S)	1	1050,3**	4420,6**	358,00**	422,15**
Mulching (M)	1	489,7**	50,4^{ns}	31,19**	43,90**
H × S	4	63,6*	798,0**	10,31**	12,95**
H × M	4	734,7**	673,7**	33,56**	44,19**
S × M	1	173,4**	1765,9	1,58ns	1,82ns
H × S × M	4	274,7**	1926,6**	29,90**	37,27**
Residue	40	17724,66	6355,26	89,15	101,36
Total	59	-	-	-	-
CV(%)		23,41	11,93	20,99	20,94

SV = Source of variation; DF = Degree of freedom; CV = Coefficient of variation; ns = not significant; * significant at 5% probability; ** = significant at 1% probability.

line with Cavalcante (2018b), who concluded that the interaction between hydrogel × irrigation levels, except for the number of harvested fruits, had significant effects on the other production components of yellow passion fruit.

The increase in hydrogel doses up to 1 g dm^{-3} in soil without mulch, regardless of the 2016/2017 (first season) and 2017/2018 (second season) harvests, inhibited fruit emission in the plants. Although this outcome differs from Carvalho et al. (2013) and Fagundes et al. (2015), who concluded that hydrogel stimulates the formation of yellow passion fruit seedlings, it aligns with Cavalcante et al. (2018b), who found that the number of fruits was reduced from 41 to 36 fruits in plants without and with 1.0 g dm^{-3} of hydrogel, respectively. It is also evident that, in general, treatments with doses above 0.5 g dm^{-3} of the polymer outperformed plants in soil with mulch in both seasons (**Figure 4**).

This behavior contrasts with that observed for stem diameter (Figure 2B) and productive branches (Figure 3B) in soil without mulch, either alone or in combination with hydrogel, which promoted increases in these variables.

In the first season (2016/2017), increasing hydrogel doses in soil without mulch led to an inhibition of 26 fruits, resulting in a 31% loss between plants in soil without and with 2 g dm^{-3} of hydrogel. In the same season, soil mulch increased the number of fruits from 42 to 82, inducing a 95.2% gain between plants in treatments without and with 1.2 g dm^{3} of hydrogel (Figure 4A).

Similarly, in the second season, increasing doses of the hydro-absorbing polymer in soil without mulch resulted in a reduction of 20 fruits per plant, corresponding to a 17.1% loss between plants in soil without and with 2 g dm^{3}.

In the same season, mulch increased the number

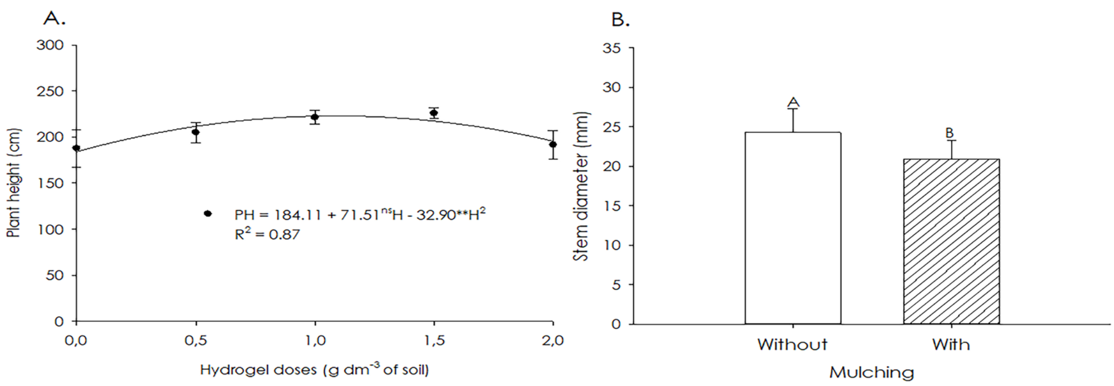

Figure 2. Height of yellow passion fruit under hydrogel doses (A) and stem diameter in soil without and with mulch (B), at 60 days after transplanting (DAT)

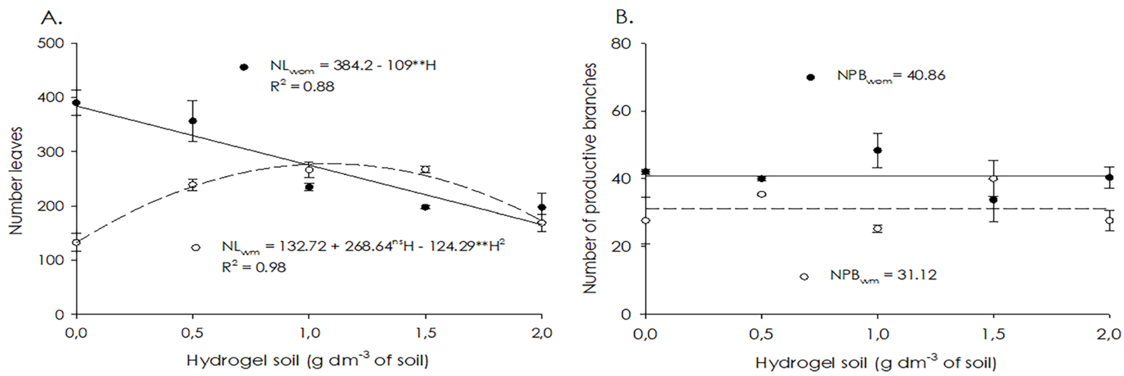

Figure 3. Number of leaves (A) and productive branches (B) of yellow passion fruit under hydrogel doses in soil without (—) and with (- - -) mulch

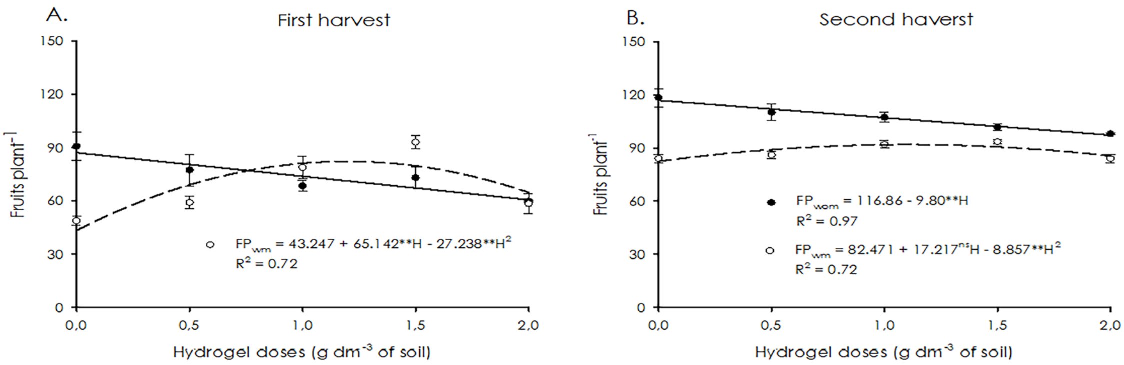

Figure 4. Number of yellow passion fruit harvested in the first (A) and second (B) harvest, according to hydrogel doses, in soil without (—) and with (- - -) mulch.

of fruits per plant from 82 to 92, promoting a 12.2% increase between plants in soil without and with 1.1 g dm^{-3} of hydrogel (Figure 4B). Comparatively, more fruits were harvested in the second season than in the first; it is also evident that the values surpass the averages of 41 and 36 fruits per plant harvested by Cavalcante et al. (2018b) in irrigated yellow passion fruit plants in soil without and with 1.0 g dm^{-3} of hydrogel.

The use of high doses of hydro-absorbing polymer may have induced water stress caused by excess water, resulting in reduced vegetative growth, with smaller and less vigorous leaves. Consequently, there was lower flower and fruit production, leading to fewer fruits per plant, corroborating the findings of this study. Fruit production is directly affected by the overall health of the plant, which, when stressed or with roots damaged by excess soil moisture, tends to produce lower quality flowers and fruits (Jitsuyama et al., 2019).

The average fruit mass in response to hydrogel doses, except for plants grown in soil without mulch in the second season, did not fit any regression model, regardless of the presence of mulch (**Figure 5**).

In the first season, plants in soil without mulch produced fruits with an average mass of 244 g, exceeding by 6.6% the mass of fruits from plants in mulched soil (Figure 5A). Conversely, in the second season, plants grown in mulched soil produced fruits with a higher average mass of 254 g at the estimated maximum dose of 0.65 g dm^{-3} of the hydro-absorbing polymer, a 17.6% increase compared to the 216 g of fruits harvested from plants in soil without mulch (Figure 5B). Comparatively between seasons, the average fruit mass decreased from 244 to 216 g from the first (2016/2017) to the second season (2017/2018) and increased from 228 to 254 g from the first to the second season, respectively for plants in soil without and with mulch.

The fruit masses ranging from 228 to 244 g and 216 to 254 g between the 2016/2017 and 2017/2018 seasons indicate that the fruits meet the internal Brazilian consumer requirements for fresh yellow passion fruit, which demands fruits with an average weight exceeding 190 g (Santos Rufino et al., 2020).

In Acre, fruits from passion fruit grown in different soil types with mulch yielded a mass of 145 g in sandy soil with 75% mulch coverage of the plant area (Uchôa et al., 2018), which is lower than the results obtained in this study. In Paraíba, the average fruit mass was 192.25 g as reported by Cavalcante et al. (2018a) for yellow passion fruit plants fertilized with potassium chloride and calcitic lime, which is less than observed in this study. Macedo et al. (2019) achieved an average fruit mass of 220 g in plants irrigated with saline water at different spacings, which is also lower than observed in this study, and both studies used the yellow passion fruit accession “Guinezinho.” However, the average fruit mass in this study was below the 324 g reported by Aguiar et al. (2017) for BRS GA1 yellow passion fruit plants in soil with bovine biofertilizer.

The average fruit mass results suggest that the use of plant mulch improves water availability in the soil. Thus, its use reduced soil water evaporation, maintaining the moisture essential for proper growth and satisfactory fruit production of yellow passion fruit. Furthermore, the decomposition of the mulch adds organic matter to the soil, improving its structure and water retention capacity (Araújo et al., 2022), which benefits root growth and development in the soil. Mulch, by keeping the soil moist for a longer period, reduces water stress in yellow passion fruit plants, ensuring continuous access to the necessary water for fruit development and mass gain (Souto et al., 2023).

The individual fruit production per plant, in relation to hydrogel doses, showed different behavior between plants in soil without mulch and similar behavior among plants in soil with *Brachiaria decumbens* mulch, respectively in the first and second seasons (**Figure 6**).

In soil without mulch, increasing hydrogel doses

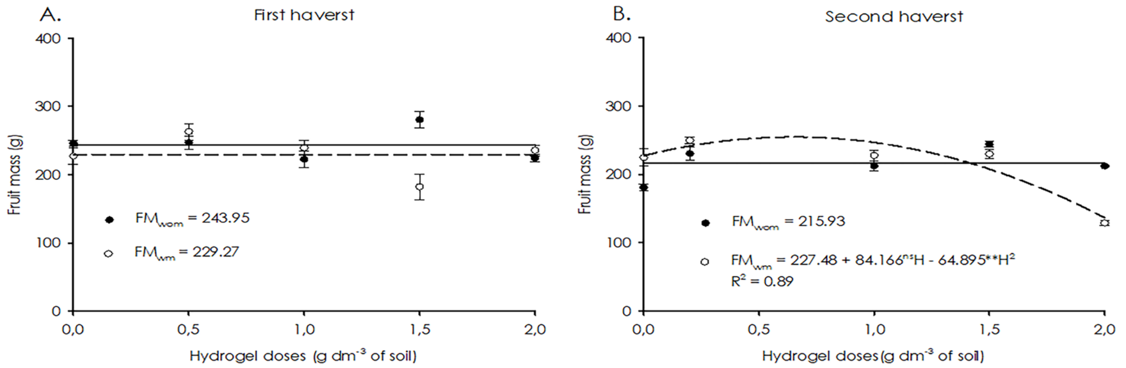

Figure 5. Average mass of yellow passion fruit, as a function of hydrogel doses, in soil without (—) and with (- - -) mulch, in the first (A) and second (B) harvest.

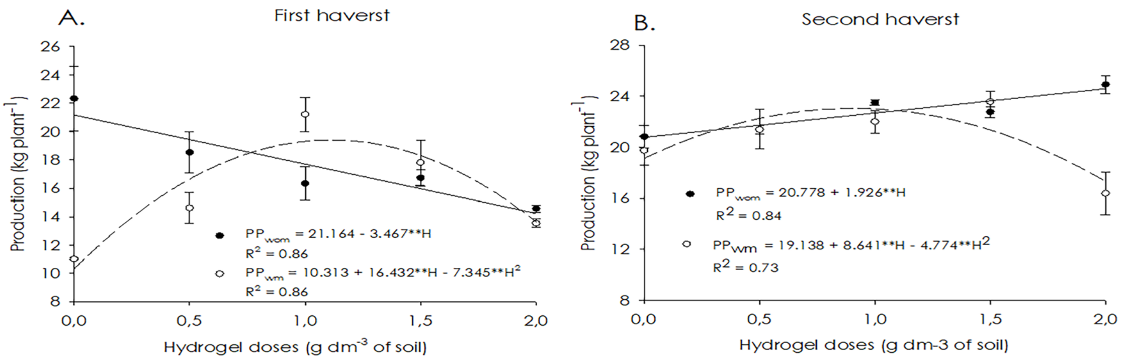

Figure 6. Production per plant of yellow passion fruit, as a function of hydrogel dose, in soil without (—) and with (- - -) mulch, in the first (A) and second harvest (B).

up to 2.0 g dm^3 reduced the production per plant from 21.16 to 14.16 kg $plant^{-1}$, resulting in a 33.1% loss in the first season, but increased it from 20.33 to 23.92 kg $plant^{-1}$, with a 17.7% gain, in the second season (Figure 6). In the same seasons, in soil with mulch, hydrogel increased production from 10.31 and 19.14 to 19.39 and 23.05 kg $plant^{-1}$, respectively, with increases of 88.1% and 21.2% between plants in soil without and with 1.1 and 0.9 g dm^{-3} of hydrogel, in the first and second seasons.

The application of hydrogel increases the water retention capacity in sandy soils of semi-arid regions, thereby stimulating plant yield. In this sense, the polymer acts as a “mini reservoir” of water in the soil, which is gradually released due to the difference in water potentials between the plants and the atmosphere, creating a gradient for water flow and influencing the water balance (Berry et al., 2018). Additionally, it reduces leaching losses through dissolution and enhances the absorption of some nutrients provided by fertilizers (Fagundes et al., 2015), improving the growth and yield of yellow passion fruit.

In the second season, the polymer stimulated the increase in plant production of yellow passion fruit up to doses of 1.4 and 0.9 g dm^3, with values of 24.5 and 23 kg $plant^{-1}$, respectively, for soil without and with mulch (Figure 6B). Relating to the maximum estimated values in the second season, the application of mulch did not reduce the plants' productive capacity, showing less than 1% loss. The high production in the second season may be related to the greater concentration of rainfall during this period (Figure 1), which, combined with the hydrogel’s capacity to release water more slowly and the nutrients incorporated into the soil, increased the productive capacity of the crop (Yan et al., 2018).

Similar results to the production per plant were observed in yield in the first season (**Figure 7**A). In plants grown in soil without mulch, yield decreased linearly by 3.81 t ha□¹ per unit increase in hydrogel dose, with a 32% loss between doses of 0 and 2.0 g dm^3. In plants in soil with mulch, yield increased up to a dose of 1.2 g dm^3, reaching 21.6 t ha^{-1}, with reductions beyond this dose. In the second season, fruit yield increased linearly by 2.08 t ha^{-1} per unit increase in hydrogel dose, reaching a maximum value of 26.8 t ha^{-1} at a dose of 2.0 g dm^{-3} (Figure 7B). In plants grown in soil with mulch, yield of yellow passion fruit increased up to a dose of 0.9 g dm^3, with a value of 25.5 t ha^{-1}.

The results found by Uchôa et al. (2018), which showed better yield with mulch covering 78% of the area, with an average of 5.182 t ha^{-1}, are lower than those observed in this study.

Vegetal mulching enhances nutrient cycling

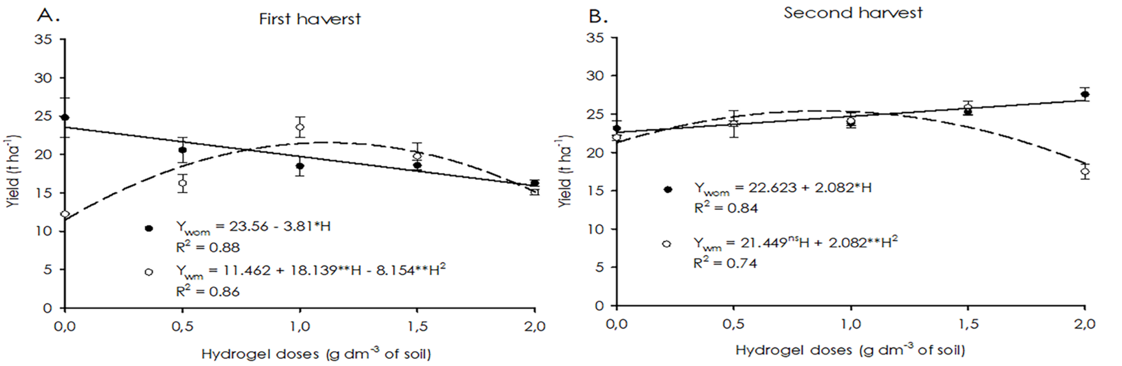

Figure 7. Yield of sour passion fruit, as a function of hydrogel doses, in soil without (—) and with (- - -) mulch in the first (A) and second harvest (B).

(Table 1), as the decomposition of organic matter in the mulch releases essential nutrients into the soil, providing a continuous source of natural fertilizers for the plants (Sun et al., 2021). This can improve the nutrition of yellow passion fruit and consequently increase fruit production by supplying the crop with essential nutrients for yield. Additionally, with the incorporation of hydrogel into the soil, nutrient losses from the decomposition of the mulch were reduced, allowing for greater uptake by the plants (Sun et al., 2022), which resulted in higher passion fruit yield in both seasons.

Conclusions

The dose of 1.1 g dm^{-3} of hydrogel improves the growth characteristics of yellow passion fruit plants.

The number of fruits increased with the use of mulching with Brachiaria grass residues combined with hydrogel application at doses of 1.2 and 1.1 g dm^{-3} in the first and second seasons, respectively.

The average fruit mass was increased with the application of a dose of 0.65 g dm^{-3} of hydrogel and the use of vegetal mulching in the second season.

The doses of 1.10 g dm^{-3} in the first season and 0.90 g dm^{-3} in the second season, combined with the use of vegetal mulching, enhanced the production per plant.

The yield of yellow passion fruit plants was higher in the first and second seasons, respectively, with the application of doses of 1.2 and 0.90 g dm^{-3} and the use of vegetal mulching.

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