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Water-retaining polymer and seedling type when planting irrigated coffee¹

Polímero hidro retentor e tipos de mudas na implantação de cafeeiros irrigados

Antonio Jackson Jesus Souza^{2*}, Rubens José Guimarães³, Anderson William Dominghetti³, Myriane Stella Scalco³ and Tiago Teruel Rezende³

ABSTRACT - The aim of this work was to evaluate the use of a water-retaining polymer on the initial growth of coffee plants for different levels of irrigation and types of seedling. The experiment was set up in pots with a clayey soil, in a greenhouse of the Sector for Coffee Production of the Federal University of Lavras, Brazil. The experiment was arranged in a randomised block design into sub-lots with three replications, giving a total of 48 experimental units. Four levels of irrigation (25%, 50%, 75% and 100% of the available water) were randomly assigned to the lots; the type of seedling (grown in bags or tubes) were randomly assigned to the sub-lots, and the use or not of the water-retaining polymer randomly assigned to the sub-sub-lots. In the treatments with water-retaining polymer, a dilution of 1.5 Kg of polymer to 400 litres of water was used at a dose of 1.5 litres of solution per plant. The following were evaluated at intervals of 60 days during the experiment (360 days from planting): stem diameter, plant height, leaf area, number of leaves and number of plagiotropic branches on the coffee plants. Hydrated water-retaining polymer favoured the growth of coffee plants under an irrigated system. Irrigation resulted in greater plant growth, with the seedlings grown in bags showing more growth than those grown in tubes.

Key words: Seedling containers. Implementation. *Coffea arabica* L.. Hydrogel.

RESUMO - Objetivou-se avaliar o uso do polímero hidro retentor no crescimento inicial de cafeeiros em diferentes níveis de irrigação e tipos de mudas. O experimento foi instalado em vasos com solo argiloso, em casa de vegetação do Setor de Cafeicultura, Universidade Federal de Lavras. O experimento foi conduzido em delineamento de blocos ao acaso com parcelas sub-subdivididas e três repetições, totalizando 48 unidades experimentais. Quatro níveis de irrigação (25%; 50%; 75% e 100% de água disponível) foram aleatorizados às parcelas; os tipos de mudas (formadas em saquinho e tubete) foram aleatorizadas às sub-parcelas; e a ausência ou presença do polímero hidro retentor foram aleatorizados nas sub-subparcelas. Nos tratamentos com uso do polímero hidro retentor utilizou-se a diluição de 1,5 kg de polímero em 400 litros d'água, para utilização da dose de 1,5 litros da solução por planta. Em intervalos de 60 dias durante a condução do experimento (360 dias a partir da implantação), avaliou-se o diâmetro de caule, altura de planta, área foliar, número de folhas e número de ramos plagiotrópicos dos cafeeiros. O polímero hidro retentor hidratado beneficiou o crescimento do cafeeiro em sistema irrigado. A irrigação promoveu maior crescimento das plantas, sendo que as mudas formadas em saquinhos apresentam maior crescimento que mudas em tubetes.

Palavras-chave: Recipientes de mudas. implantação. *Coffea arabica* L.. Hidrogel.

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INTRODUCTION

Coffee is one of the main products of international agribusiness; generating a large number of direct and indirect jobs, and distributing income throughout the production chain, especially to the families of coffee farmers and rural workers. Brazil is the world's largest coffee producer, and Minas Gerais is the state with the largest production, producing 26.64 million sacks of coffee in 2014, corresponding to 55.12% of all Brazilian production (CONAB, 2014).

Despite the importance of coffee to the country, farmers face difficulties in carrying out their activities, one of the main difficulties being implementation of the coffee crop.

Irrigation supplies water, enabling the full growth and development of the coffee plants. However, in regions with low water availability, or even in regions with satisfactory levels of precipitation, water deficits are seen throughout the year due to poor rainfall distribution. In 2014, in the south of Minas Gerais, the mean historical rainfall for January was 320 mm, but only 61 mm occurred during the period (CARVALHO; ADÃO, 2014).

An alternative way to help compensate for the poor distribution of rainfall or even optimize the availability of water in drier regions, may be the use of water-retaining polymers, which have the capacity to retain water during rainfall or irrigation, and make it available in times of water deficit. Polyacrylamide polymer (a hydro-retaining polymer) when hydrated, displays gelatinous characteristics, and is able to release water over time, reducing irregularities in the availability of water to plants (ZONTA *et al.*, 2009).

The best way to evaluate the effects of soil type, type of seedling container, and irrigation system on coffee plants, is by quantifying vegetative growth. Carvalho *et al.* (2010) noted a high positive correlation of vegetative characteristics with the initial productivity of coffee plants in different coffee-producing regions.

There is insufficient information in the literature concerning the effects of water-retaining polymer on different types of seedlings when planting coffee plants, especially regarding the use of the polymer in irrigated systems. The aim was to evaluate the effects of the availability of water for irrigation, the use of water-retaining polymer and the type of seedling (bag and tubes), when planting coffee.

MATERIAL AND METHODS

The experiment was conducted at the Sector for Coffee Production of the Federal University of Lavras

(UFLA), in the State of Minas Gerais, Brazil. Located at 21°15' S and 45°00' W, at an average altitude of 918 m (DANTAS; CARVALHO; FERREIRA, 2007).

The experiment was carried out in a randomised block design. For operational reasons, sub-divided lots were used with three replications. Irrigation levels were randomised across the lots (25%; 50%; 75% and 100% of the available water) the seedlings, grown in two types of container (bags and tubes), were randomised across the sub-lots, and the factor, water-retaining polymer (with and without), was randomised across the sub-sub-lots, giving a total of 48 experimental units.

Coffee seedlings were produced from seeds of the Acaia Cerrado MG-1474 cultivar at the site of the experiment. The seedlings grown in bags (B) (11x22 cm) used a standard substrate (300 L cattle manure, 700 L soil and 5 kg single superphosphate), and those in tubes (T) (120 mL), a commercial substrate (composted pine bark and vermiculite) with the addition of 1 g of slow-release fertiliser (15-10-10 NPK) per tube. After production, the seedlings were placed into pots to simulate planting in the field. The pots were of 20 litres for better control of irrigation. These were placed on benches 0.8 m above the ground at a spacing of 0.70 x 0.60 m. The soil used was a dystroferic Red Latosol (DfRL) (Table 1) as per the Brazilian system of soil classification (SANTOS, 2013).

Soil correction was carried out by raising the base saturation to 60% using dolomitic limestone with a PRNT of 87% mixed with the moist soil, which was piled up and covered with canvas for 26 days to react. Fertiliser application at planting and throughout the experiment, was performed following the recommendations of Faquin, Vale and Furtini Neto (2008).

For the treatments with water-retaining polymer, the solution was prepared in the ratio of 1.5 kg of the polymer to 400 litres of water, applying 1.5 litres of the solution to the planting hole when planting the seedlings, following the recommendations of Pieve *et al.* (2013).

For the pots with no polymer (the reference for setting irrigation levels) undisturbed soil samples were collected using a Uhland cylinder to characterise the water retention curve of the soil. The moisture (g g^{-1}), pressure or matric potential (kPa), and the soil-water characteristic curve were verified to create a spreadsheet to determine the amount of water to be applied in each irrigation treatment. From the soil-water characteristic curve, the volume of water needed to restore field capacity was determined (treatment of 100%), together with the reductions in this volume for establishing the other irrigation treatments (75%, 50% and 25%). Irrigation was carried out on Mondays and Thursdays by the manual application of

Table 1 - Physical and chemical analysis of the soil used in the experiment

SOIL	Clay	pH	P	K	Na	Ca	Mg	Al	H + Al	SB	(t)	(T)
Class	dag kg ⁻¹	(H ₂ O)	-----mg dm ⁻³ -----			-----cmol _c dm ⁻³ -----				-----cmol _c dm ⁻³ -----		
DfRL	65	6	2.6	41	-	4.1	0.4	0	3.2	4.6	4.6	7.8
SOIL	V	M	MO	Prem		Zn	Fe	Mn	Cu		B	S
Class	-----%		dag kg ⁻¹	-----mg L ⁻¹ -----						-----mg dm ⁻³ -----		
DfRL	58.6	0	3.6	11.0		2.5		19.1	3.4	0.8	0.2	14.9

the corresponding volume of water for each treatment, measured using a graduated cylinder.

Evaluations were made every 60 days for a total period of 360 days, giving a total of six periods of evaluation. The following growth variables were determined in the evaluations: stem diameter (SD) in mm, using digital calipers (mm) when collecting the plant; plant height (PH) in cm, from the base to the apical meristem, using a graduated rule; leaf area (AF) in cm², measured using a rule graduated in centimetres (multiplying the greatest length by the greatest width of one leaf from each pair, and then multiplying by the constant 0.667, multiplying by two, and finally summing the leaf area obtained for each pair, to get the total leaf area of the plant); and the number of leaves (NL), determined by counting true leaves greater than 2.5cm in length. Finally, the number of plagiotropic branches (NPB) was counted.

The collected data were tabulated, and tests for normality and homogeneity were performed. With the help of the SISVAR[®] statistical analysis software (FERREIRA, 2011), analysis of variance was carried out. The interactions for the water levels in each type of seedling, with or without the use of water-retaining polymer, were broken down when significant by regression analysis.

RESULTS AND DISCUSSION

In the first evaluation at 60 days, the effect from the interaction of irrigation level with type of seedling (I x S) was seen on stem diameter (SD) and plant height (PH). With the breakdown of the interaction, a significant effect from the bag container (B) could be seen on the SD and PH (Figure 1a and 1b). For SD an increasing linear trend was noted for increases in irrigation levels. Water supplied at 100% (100% of the available water) favoured a larger SD (Figure 1a). Determination of stem diameter is important in biometric evaluations, as Almeida *et al.* (2005) observed that the stem diameter

determines a higher survival rate for coffee seedlings in the field.

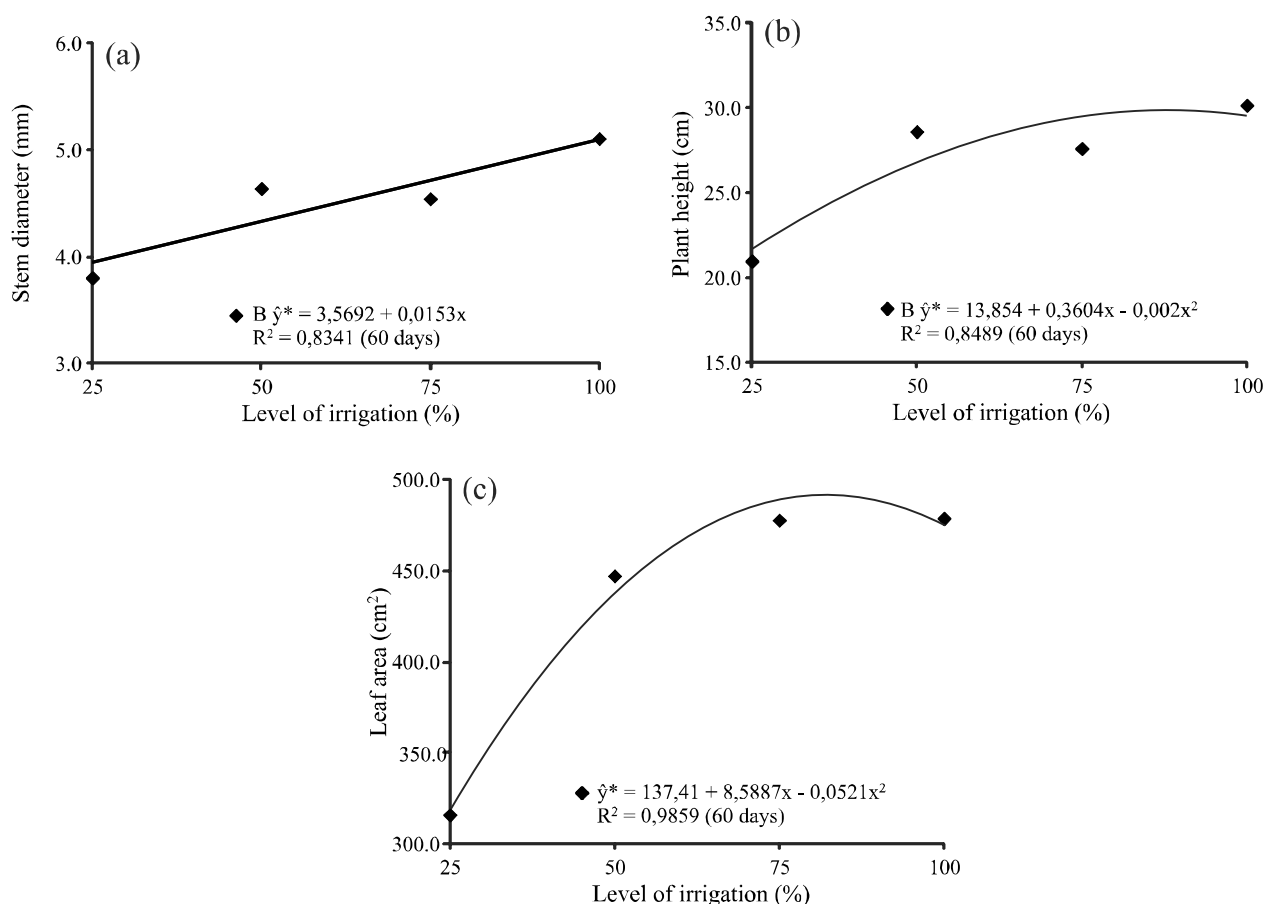
A quadratic trend was found for PH, with a peak at 90% of the irrigation level (Figure 1b). Greater plant heights were observed by Azevedo *et al.* (2002), when evaluating the levels of polymer and frequency of irrigation on the growth of coffee seedlings. Those authors noted that in the absence of polymer, the plant height was higher for a lower frequency of irrigation, i.e. with a greater supply of water per application, confirming the findings of the present work.

For leaf area (LA), only the effects of irrigation (I) were seen (Figure 1c). An irrigation level of 82% of the available water gave a maximum leaf area of 491 cm². At the irrigation level of 25%, it was found that the plants displayed 35.6% less development than that observed at the irrigation level of 82%. In general, one of the first responses of plants to water deficit is a reduction in leaf area, being either a result of leaf abscission, the production of smaller leaves, or even a reduction in the emission of new leaves (ATKINSON *et al.*, 1999).

With the number of leaves (NL), there was an effect from the type of seedling (S) only. Seedlings in bags (B) displayed a higher number of leaves (14) than those from tubes (T) (13) (Table 3), this difference is significant, being 7.14% greater, and reflecting in a larger area for the production of photoassimilates. According to Livramento (2010), the adequate supply of carbohydrates for the production of photoassimilates is directly influenced by the number of leaves.

For the characteristic, SD, an effect was seen from the interaction between irrigation and water-retaining polymer (I x G), where, in the breakdown at 120 days after planting, it was found that an increase in irrigation levels had a linear trend on the growth of the SD (Figure 2a). Alves *et al.* (2000) claim that coffee plants have more developed shoots with larger stem diameters, as irrigation tends to supply what is lost by evapotranspiration. At the largest supply of water to the coffee plant (levels

Figure 1 - Stem diameter (mm) (a), plant height (cm) (b) and leaf area (cm²) (c) at 60 days after planting, in the Acaia Cerrado MG-1474 coffee cultivar, for level of irrigation



*Significant difference by F-test at 5% probability within each period

of 75% and 100%), the difference in SD is small, with or without use of the polymer (Figure 2a). Pieve *et al.* (2013), evaluating stem diameter in coffee at 111 days after planting in the field, found no difference for the presence or absence of polymer during the rainy season, possibly due to the sufficient supply of water.

After 120 days, under conditions of water deficit (25% and 50% of the irrigation level), seedlings grown in the presence of the water-retaining polymer had a visually larger stem diameter when compared to those not grown with the product. Tohidi-Moghadam *et al.* (2009), studying the response of rapeseed to water stress and the application of water-retaining polymer, concluded that its use increased the performance of agronomic and physiological characteristics, attributing the supply of water that favoured photosynthesis and chlorophyll content to the application of the gel.

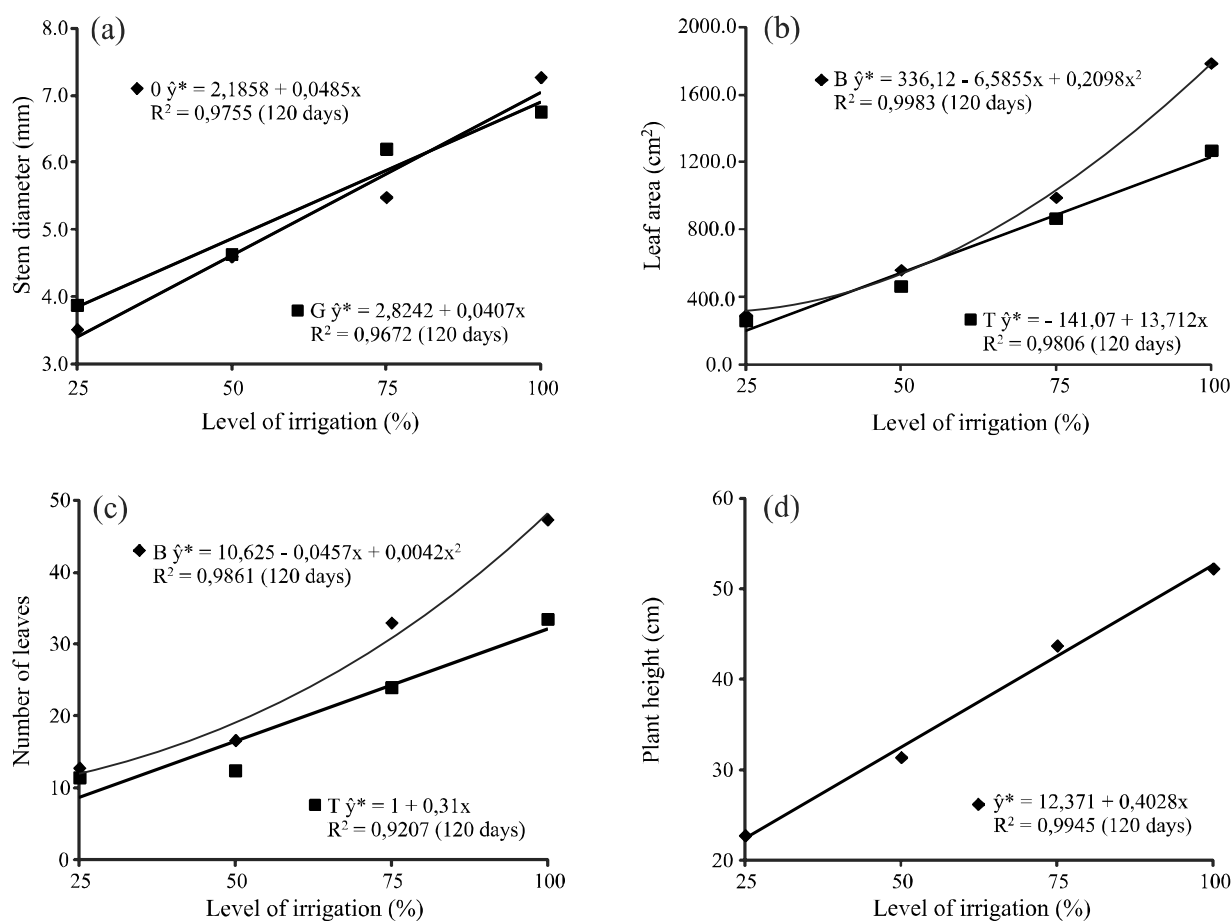
In the evaluation at 120 days after the beginning of the experiment, an effect was noted on LA and NL from

the interaction I x S. As the interaction was broken down, an effect from irrigation level was seen on LA (Figure 2b) and NL (Figure 2c), which were greater with the increase in irrigation levels for seedlings from the bags. In the case of the bags, there is possibly greater storage of the applied water, which may have led to an increase in the growth of leaves. For Atkinson *et al.* (1999), an increase in moisture provides an increase in leaf area and number of leaves.

At 120 days after planting, the PH was influenced with a linear trend, but only by the effects of irrigation. The greatest PH was found at a level of 100% (Figure 2d), the level of 25% resulting in an average increase of 22.44 cm in plant height. Increased plant growth was also found by Alves *et al.* (2000) when planting irrigated coffee.

For the number of plagiotropic branches (NPB) at 120 days, it was found that the coffee plants grown in bags had three branches and the seedlings grown in tubes had only two (Table 3). The faster growth of the seedlings in bags at 120 days was also seen by Vallone *et al.* (2010)

Figure 2 - Stem diameter (mm) (a), leaf area (cm²) (b), number of leaves (c) and plant height (cm) (d) at 120 days after planting, in the coffee cultivar Acaia Cerrado MG -1474, for level of irrigation



*Significant difference by F-test at 5% probability within each period

when evaluating the effect of container and substrate on the production of coffee seedlings.

With the evaluations carried out at 180 and 240 days after planting the coffee, a similar effect was found from the interaction I x B x G on PH (Figure 3a and 5a). Breaking down the this interaction for AP, a similar linear trend was found for height in the plants from bags and tubes, with or without polymer, since in the triple interaction the effect of irrigation on plant height was decisive. At 180 days after planting, each 25% increase in irrigation level caused a variation of 19.09, 27.70, 20.75 and 20.60 cm for the treatments, bag with no polymer (B0), bag with polymer (BG), tube with no polymer (T0) and tube with polymer (TG) respectively (Figure 3a). At 240 days after planting, each 25% increase in irrigation level resulted in a variation of 19.70, 30.14, 20.81 and 22.15 in PH for the treatments S0, SG, T0 and TG respectively (Figure 5a). This result can be attributed to the increased water retention of

those treatments using both polymer and container. The water-retaining polymer acts as a soil conditioner, in part resembling the presence of organic matter or clay in the soil. Oliveira *et al.* (2004), when working with sandy clay loam and clay soils, found an increase in water retention up to a matric potential of -1.0 MPa.

When breaking down the interaction between irrigation and type of seedling (I x S) for NL at 180 days, a significant effect was observed from irrigation. With the increase in irrigation levels a positive linear trend was seen, i.e. there was a greater number of leaves (Figure 3b). The result for NL at 180 days was similar to that observed at 120 days. In this case the difference between the seedling containers reached 18 leaves at 100% of the irrigation level.

At 240 days, it was found that seedlings grown in bags had a greater number of leaves (69) in relation to those grown in tubes (62) (Table 3). This greater number of leaves will possibly favour greater plant

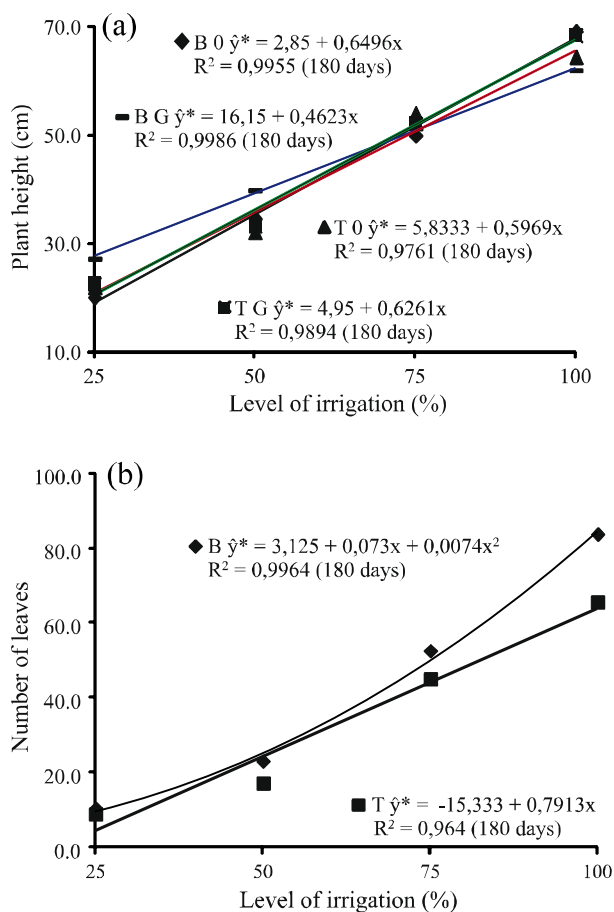
development in later stages, as noted by Santana, Oliveira and Quadros (2004) who, when evaluating the initial growth of coffee plants, found a difference between irrigation systems from 226 days after planting.

The SD at 180 and 240 days showed similar behaviour for irrigation (Figure 4a and 5b). A water deficit of 25% compromised development of the SD by 3.62 and 3.72 mm, at 180 and 240 days respectively. These results were less than those obtained by Scalco *et al.* (2002) for the same period, when evaluating planting densities on initial plant growth in coffee plants. The level of 100% favoured an increase in the SD, which after 180 and 240 days was 7.01 and 9.87 mm respectively. Similar results were found by Santana, Oliveira and Quadros (2004) for irrigated coffee plants at 181 days after planting, with a stem diameter of 7.7 mm.

The LA of the plants at 180 and 240 days displays similar behaviour for irrigation (I). A water deficit of 25% compromised the leaf area, which was only 276.5 and 260.5 cm², compared to the level of 100%, when it was 1527.4 and 2475.4 cm² at 180 and 240 days respectively (Figures 4b and 5c). This increase in LA can be explained by the greater availability of water, the phenomenon being due to the relationship between the size reached by the leaves and the moisture in the soil (FAVARIN *et al.*, 2002). Martins *et al.* (2006), in a study into the initial growth of conilon coffee under different levels of irrigation, point out that in treatments where less water was available, plant growth was impaired; the proper management of irrigation water is therefore necessary for good plant growth.

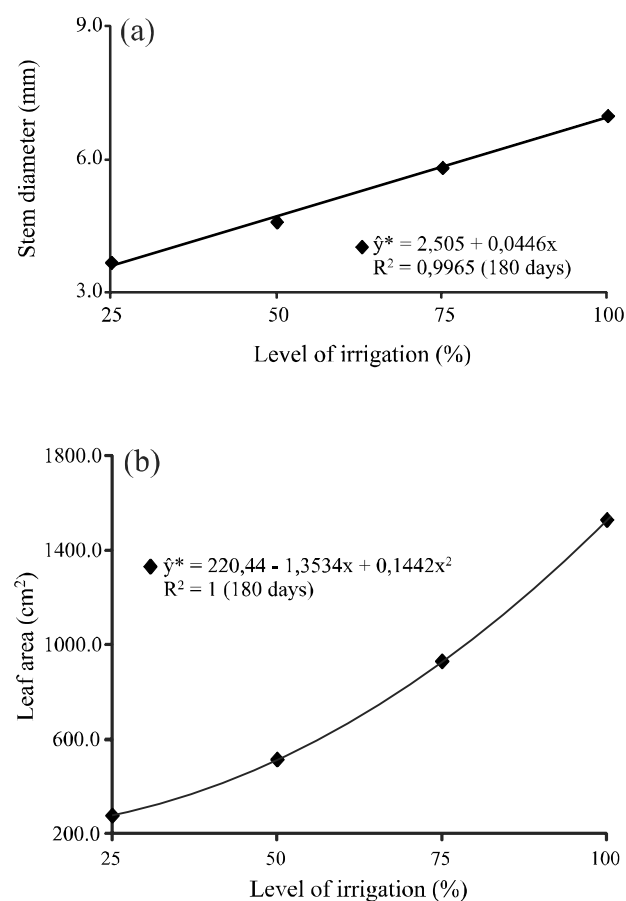
At 300 days after planting, there was an effect from the interaction I x B on NL. Breaking down the interaction,

Figure 3 - Plant height (cm) (a) and number of leaves (b) at 180 days after planting, in the coffee cultivar Acaia Cerrado MG -1474, for level of irrigation



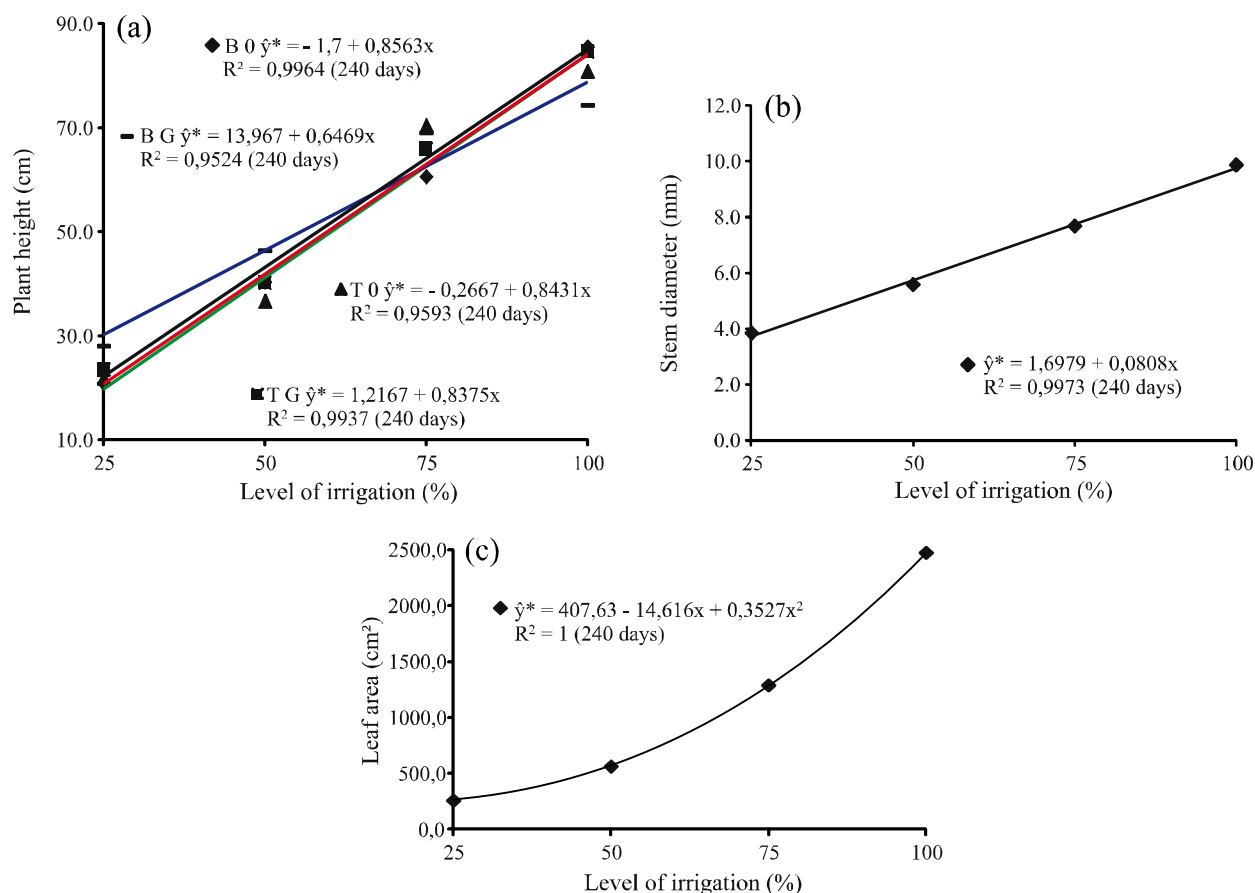
*Significant difference by F-test at 5% probability within each period

Figure 4 - Stem diameter (mm) (a) and leaf area (cm²) (b) at 180 days after planting, in the coffee cultivar Acaia Cerrado MG -1474, for level of irrigation



*Significant difference by F-test at 5% probability within each period

Figure 5 - Plant height (cm) (a), stem diameter (mm) (b) and leaf area (cm²) (c) at 240 days after planting, for the interactions (I x S) and (I x G), in the coffee cultivar Acaia Cerrado MG -1474, for level of irrigation



*Significant difference by F-test at 5% probability within each period

a significant effect from the irrigation level was found in both types of seedling in the regression analysis, showing a positive linear trend for NL with the increase in irrigation levels. Irrigation, as seen in previous periods, clearly interferes with the number of leaves. For each 25% increase in the applied irrigation level, an increase of 10 and 8 leaves was seen in the seedlings from the bags and tubes respectively (Figure 6a).

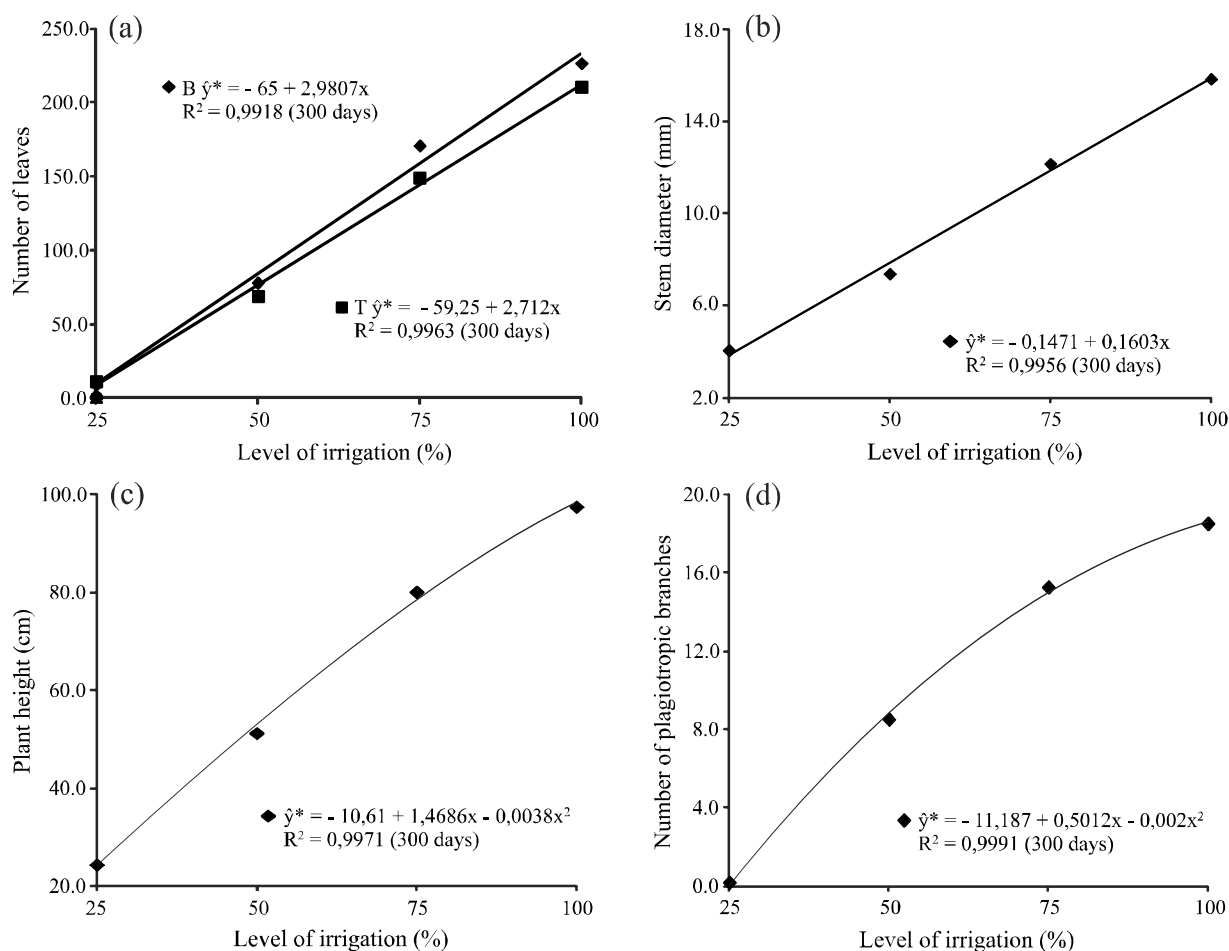
At 300 days after planting, stem diameter in the coffee plants was only influenced by the effect of irrigation (Figure 6b). With increases in the applied levels of irrigation, there were greater increases in SD. By comparing the maximum level of irrigation with irrigation carried out at half the level, there was a difference of 8.45 mm (Figure 6b). The increase in SD, was 46.6% for an increase of 50% in the level of irrigation; similar behaviour was observed in previous periods.

For leaf area at 300 days, an effect was seen from the water-retaining polymer (G); seedlings that received

an application of the product displayed a larger leaf area, i.e. 2913.9 cm², while without the water-retaining polymer the leaf area was 2557.4 cm² (Table 2). This increase in LA may promote greater plant development at later stages, as in the work by Azevedo *et al.* (2002), who noted satisfactory effects from the polymer on coffee plants, also with increases in leaf area.

By analysing LA at 300 days, greater development was also seen at 100% of the irrigation level (Figure 6c). Alves *et al.* (2000), evaluating irrigated and non-irrigated coffee, found that plants under water deficit grow less in height than plants under irrigation, as water stress can affect the metabolic processes of plant growth.

Analysing the number of plagiotropic branches (NPB) at 300 days, an increasing quadratic trend was also seen for this characteristic, for up to 100% of the irrigation level (Figure 6d), where it peaked. For Vale, Carvalho and Paiva (2006), the use of irrigation also increased the NPB

Figure 6 - Number of leaves (a), stem diameter (mm) (b), plant height (cm) (c) and number of plagiotropic branches (d), at 300 days after planting, in the coffee cultivar Acaia Cerrado MG -1474, for level of irrigation

*Significant difference by F-test at 5% probability within each period

Table 2 - Leaf area in cm² (LA) at 240 and 300 days, and stem diameter in mm (SD) at 360 days, in plants of Arabica coffee cultivar Acaia Cerrado MG-1474 in a clay soil

Polymer	LA 240 days	LA 300 days	SD 360 days
No Gel (0)	1700.55 B	2557.42 B	11.46 B
With Gel (G)	1826.51 A	2913.91 A	12.17 A

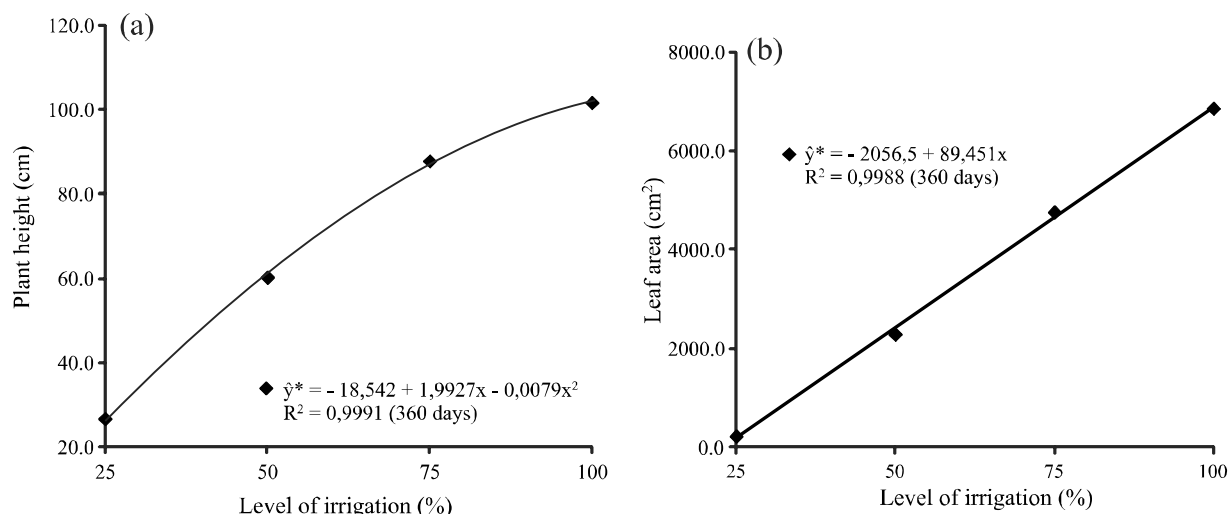
*Different letters in a column indicate a significant difference by F-test at 5% probability

per plant, which may increase the number of buds, thereby influencing production.

At the end of the experiment (360 days), an effect was found from irrigation (I) on plant height (PH), and leaf area (LA), with the highest levels of irrigation giving greater values for PH and LA (Figure 7a and 7b). Analysing the PH, an increasing quadratic trend was noted for increasing levels of irrigation. The difference between

the irrigation levels of 50% and 100% was 41.41 cm, i.e. at the level of 50%, plant height (Figure 7a) was 59% lower when compared to the level of 100%.

Analysing Figure 7b, it can be seen that there was a linear trend in the growth of LA for increases in irrigation level, with the largest growth, of 6,859 cm², occurring at the level of 100%. The gain in leaf area for each 25% level of irrigation was equal to 179.8 cm². A larger leaf area can

Figure 7 - Plant height (cm) (a) and leaf area (cm²) (b) at 360 days after planting, in the Acaia Cerrado MG-1474 coffee cultivar, for level of irrigation

*Significant difference by F-test at 5% probability within each period

Table 3 - Number of leaves (NL) at 60, 240 and 360 days, and number of plagiotropic branches (NPB) at 120 and 360 days, in plants of Arabica coffee cultivar Acaia Cerrado MG-1474 in a clay soil

Seedling type	NL 60 days	NL 240 days	NL 360 days	NPB 120 days	NPB 360 days
Tube (T)	13 B	62 B	149 B	2 B	11 B
Bag (B)	14 A	69 A	165 A	3 A	13 A

* Different letters in a column indicate a significant difference by F-test at 5% probability

promote greater productivity; Livramento (2010) points out that 20 cm² of leaf area is necessary for the formation of each coffee fruit.

At 360 days, the coffee seedlings that received the application of water-retaining polymer (G) displayed a greater SD; the value found for SD was 12.2 mm, while the seedlings that did not receive the product had an SD of only 11.5 mm (Table 2). Pieve *et al.* (2013), evaluating the dose and type of application of water-retaining polymer in coffee plants at 476 days after planting, found that applying the water-retaining polymer to the planting hole favoured a larger stem diameter in the plants, 15.4% greater than when the polymer was not used. A larger stem diameter is desirable, since according to Livramento (2010), plants that have more vigorous stems can accumulate greater quantities of carbohydrates, with a consequent increase in vegetative growth and reproductive development.

For the same period (360 days), the seedlings produced in bags and tubes showed differences in the number of leaves and plagiotropic branches. Seedlings

from the bags had 165 leaves and 13 plagiotropic branches, while seedlings from the tubes had 149 leaves and 11 plagiotropic branches (Table 3). A greater number of plagiotropic branches were also found in the field by Nasser, Gallo and Fonseca (2011) when evaluating the development of coffee plants at 325 days after planting.

CONCLUSION

1. Irrigation promotes greater growth in the coffee plant, which benefits from the use of water-retaining polymer when the crop is planted;
2. Seedlings produced in bags display greater growth than seedlings in tubes when planting the coffee crop.

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