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CORRELATIONS BETWEEN GROWTH AND PRODUCTION VARIABLES OF TWO COFFEE CULTIVARS FERTIRRIGATED BY MICROIRRIGATION

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ABSTRACT

This work aimed to address the correlations between growth and production variables of coffee cultivars fertigated by microirrigation. The experiment was conducted in experimental area of the Technical Irrigation Centerof the State University of Maringá. The coffee seedlings were planted at a spacing of 2.0 meters between rows and 1.0 meters between plants. The localized drip irrigation system was used so that the drippers were installed at 0.2 meters from the plants and were 0.40 m apart at the planting line and 2 m apart. The treatments applied to the plants of each coffee cultivar (Obatã and IAPAR-59), in this work, were formed by combining the four doses of NPK, with three crops (not irrigated, irrigated and fertigated), with a total of 24 treatments, with four repetitions, with ten plants, representing one repetition. In this experiment, a completely randomized design was adopted, with subdivided plots. The determination of simple correlations and partial correlations between growth and production variables was carried out using the Genes statistical software. Through partial correlations it was possible to verify the relationship between the growth and production variables of the plants, since it was highly significant in the irrigated and fertigated crops of the cultivars.

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INTRODUCTION

Among the crops of agronomic interest, the coffee culture, one of which has greater prominence in the national agricultural scenario. According to CONAB (2020), the production achieved in the 2018/2019 harvest was 49.31 million bags, while the productivity achieved was 27.20 bags per hectare. Such performances represent a drop of 17.8% in relation to the 2017/2018 crop. This performance can be explained by the fact that the coffee culture is characterized by suffering the effect of biannuality, that is, the culture alternates years of great performance with years of low performance. A cycle of large grain production is accompanied by a cycle of low production due to the fact that a large amount of nutrients absorbed by the plant is transported and participates in the fruit production process. As a consequence, the plant at the end of the harvest becomes worn out, needing to restore its nutritional status and in this way in the next cycle the nutrients absorbed are used primarily to restore the vegetative status of the plant (MATIELLO, *et al*., 2015). According to Fernandes *et al*. (2016), Irrigation aims to meet the water demand of plants in critical periods, and it is necessary to apply it in quantity and at the correct time. Its use allows areas previously considered marginal for the production of Arabica coffee to become suitable for cultivation, in addition to promoting an increase in the production of crops already installed. In addition, irrigation methods allow water to be supplied to crops on a regular basis, contributing to the production of quality grains. According to Frizzone *et al*. (2012), the term microirrigation is a substitute for the English term trickle because it cannot be translated into other languages such as French, Spanish and Portuguese. In several countries there is a preference for the term localized irrigation due to the fact that a small fraction of the soil near the root region of the crop is irrigated. Microirrigation has the advantages of allowing water applied with low flow and pressure in regions close to the root system of crops. In addition, it allows chemicals like fertilizers to be applied as well. The use of fertilizers for irrigation water is called fertigation. Such measure provides cost reduction, since the operations of fertilization and application of water are carried out simultaneously. Several fertilizers can be applied to irrigation water, from formulated to even fertilizers that contain a higher percentage of a certain nutrient. Nitrogen and potassium fertilizers have greater solubilization in irrigation water. However, phosphate fertilizers deserve special attention in relation to their handling, since they can contribute to the clogging of pipes (BERNARDO *et al*. (2019); FRIZZONE *et al*. (2012)). Correlations are understood as the relationship between two variables that can be quantitative, qualitative, discrete and continuous. The value of the correlations is between - 1 and 1, so that, the closer this correlation is to 1, it is said that the correlation is highly positive, that is, the great performance of a variable can be explained by the great performance on the other, that is, there is a great dependence between the variables. However, the closer the correlation is to -1, it is stated that the correlation is highly negative, that is, the great performance of one variable is explained by the poor performance of the other, that is, one variable negatively influences the behavior of the other. (BUSSAB & MORETTIN, 2017; FERREIRA, (2018)).

For Cohen (1988), correlation values between 0.10 and 0.29 can be considered small; scores between 0.30 and 0.49 can be considered as average; and values between 0.50 and 1 can be interpreted as large. Dancey and Reidy (2005) point to a slightly different classification: r = 0.10 to 0.30 (weak); r = 0.40 to 0.6 (moderate); r = 0.70 to 1 (strong). Correlations within a parametric approach can be simple or partial. The simple correlation deals with the association between two variables of interest, without any kind of restriction. However, the partial correlation allows the study of the association between two variables, isolating the effect from the others (CRUZ *et al*., 2012). Starting from the presented, this work had for objective to approach the possible existing associations between growth and production variables of two coffee cultivars irrigated by microirrigation.

MATERIALS AND METHODS

This work was carried out in an area of the Technical Irrigation Center (CTI) of the State University of Maringá, in Maringá - PR, whose geographical coordinates are 23º25′ south latitude and 51º57′ west longitude. The relief has an average difference in level of 6%, which can be considered homogeneous and smoothly wavy. The climate of the area is of the Cfa Mesothermal Humid type, characterized by abundant rains in the summer and dry winters, according to Koppen. Average annual rainfall reaches 1500 mm. The average minimum and maximum temperatures reach 10.3ºC and 33.6ºC, respectively. The average annual temperature is 21.8ºC and the average relative humidity is 66%. Planting took place in December 2017. The coffee seedlings of cultivar Obatã and cultivar IAPAR-59 were planted with a spacing of 2.0 m between rows and 1.0 m between plants. Such an arrangement characterized a dense system. The soil in the area belongs to the class Nitossolo Vermelho Distroférrico typical with moderate Horizon A, clayey texture, subperennial forest phase (EMBRAPA, 2018). With the crop newly formed and aiming to guarantee uniform “catching” of the seedlings, irrigation was carried out through the drip irrigation system until the differentiation of treatments that took place in August 2018. For the operations of cultural treatments and phytosanitary control, the recommendation of MATIELLO *et al*. (2015). The self-compensating emitters of the Goldentrip brand installed on the line operated with nominal flow and operating pressure of 1.2 L h^{-1} and 10 m.c.a, respectively. The drippers were installed at a distance of 0.2 m from the stem of the plants, on the soil surface so that the wet surface could form a continuous strip along the planting line. The drippers were 0.40 meters apart and 2.0 meters between them. The recommendation for doses of N, P and K was based on MATIELLO *et al*. (2015).

The recommendation for doses of N, P and K was based on Matiello *et al*. (2015), which indicate the dose of 150 kg ha^{-1} for N and K_2O, which corresponds to the percentage of 100%. In addition to this dose, lower doses (75 kg ha^{-1}) and higher doses (225 and 300 kg ha^{-1}) were tested, which are equivalent to the percentages of 50%, 150% and 200%, respectively. For P, the dose corresponding to the 100% percentile is 30 kg ha^{-1} of P_2O_5. Thus, lower (15 kg ha^{-1}) and higher (45 and 60 kg ha^{-1}) doses were also evaluated, which correspond to the percentage changes of 50%, 150% and 200%, respectively. The treatments applied to the plants of each coffee cultivar (Obatã and IAPAR - 59), in this work, were formed by combining the four doses of NPK, with three crops (not irrigated, irrigated and fertigated), with a total of 24 treatments, with four repetitions, with ten plants, representing one repetition. In this experiment, a completely randomized design was adopted, with subdivided plots. The doses of NPK formed the plots, by lot, so that each formed a sector of the experiment area. Subsequently, within each sector, the subplots were made up of rows of plants, which received, by drawing lots, the three crops (not irrigated, irrigated and fertigated). Each experimental unit was made up of a group of ten plants, selected randomly, in the planting lines, with the peripheral plant lines in the experimental area as a border, and the three initial and final plants of each line.

They were used as sources of nitrogen, phosphorus and potassium, in fertigated crops, calcium nitrate, monomamonic phosphate and potassium nitrate. In the conventional fertilization used, in irrigated and non-irrigated crops, the commercial formulation 20-05-20 was used. Plants conducted in fertigated crops received doses of N, P and K, through injection, in the main line of the irrigation system, before the filtration system. A 0.5 hp centrifugal pump with a Noryl® impeller was installed as an injector. This promoted the suction of the solution, composed of water and fertilizers, from a reservoir, with a capacity of 150 L. The fertigation time was 30 minutes.

The variables studied in the study were obtained according to the procedures described below:

- stem diameter: measured with a digital caliper at a height of 10 cm from the ground;

- crown diameter: measured perpendicular to the planting lines, using a measuring tape fixed to a 3/4 ”PVC tube;
- plant height: measured with a measuring tape attached to a 3/4 ”PVC tube, from the neck to the apical bud of the orthotropic branch of the plants;
- total number of plagiotropic branches: direct counting plant by plant;
- •length of the first primary plagiotropic branch: the first primary plagiotropic branch was selected and marked on each plant; measuring tapes were used for the measurements;
- Productivity: The harvest took place in April 2019, so that productivity was measured in the four experimental units for each treatment. For this, the coffee harvested was drained on a cloth and, subsequently, weighed to evaluate the coffee mass in coconut, harvested in each plant. Soon after, samples were taken and the mass correlation of coffee in coconut to clean coffee was performed. Then, the average production of each experimental unit was obtained, which were converted into kilograms per hectare, using a factor related to the plant stand, which in this case was 5000 plants per hectare. These data were converted into the number of processed bags (60 kg) per hectare.

To quantify the degree of association between the production components, simple and partial correlation estimates between the evaluated characteristics were obtained. Simple correlations were estimated using equation 1 (CRUZ *et al.*, 2012), while partial correlation coefficients estimates were obtained using equation 2 (CRUZ *et al.*, 2012).

$$r_{xy} = \frac{COV_{(xy)}}{\sqrt{\sigma_x^2 * \sigma_y^2}} \quad (1)$$

On what:

COV (x, y) = covariance between characteristics x and y;

= variance of characteristic x,
= variance of characteristic y.

$$r_{xy,z} = \frac{r_{xy} - r_{xz} * r_{yz}}{\sqrt{(1 - r_{xz}^2) * (1 - r_{yz}^2)}} \quad (2)$$

Where:

rxy.z = partial correlation between the characteristics x and y excluding the effect of z,
rxy = simple correlation between x and y,
rxz = simple correlation between x and z,
ryz = simple correlation between y and z.

The determination of simple correlations and partial correlations between growth and production variables was performed using the statistical software Genes (CRUZ, 2013). The significance of the coefficients of simple and partial correlations was assessed by the t test, at 5% and 1% probability (CRUZ, *et al.*, 2012).

RESULTS AND DISCUSSION

No significant partial correlations were found between the variables of growth and production in the non-irrigated crops of the coffee cultivar IAPAR-59. However, in irrigated and fertigated crops, significant partial correlations were detected, and this is best observed through Table 1. In non-irrigated crops, it was not possible to establish any type of partial correlation between the studied variables. However, in the irrigated crops of cultivar IAPAR-59, the partial correlation between productivity and total number of plagiotropic branches was significant and positive, the largest being considering the removal of the effect of the crown diameter (r = 0.8042). Several research papers show that the number of plagiotropic branches indirectly influences productivity due to the potentialization of bud production (CARVALHO, *et al*, 2006) and in this case it can be said that the diameter of the crown has a great effect on this correlation, so that when it was isolated there was a greater expression of the correlation between productivity and the number of plagiotropic branches.

Table 1. Partial correlations between growth and production variables in non-irrigated, irrigated and fertigated crops of the coffee cultivar IAPAR – 59

PARTIAL CORRELATIONS	CROPS		
	NOT IRRIGATED	IRRIGATED	FERTIRRIGATED
rPROD X DCOPA, NTRP	-0,1681NS	0,7237**	0,9218*
rPROD X DCAULE, NTRP	-0,1375NS	-0,5721*	0,9633**
rPROD X NTRP, DCAILE	0,3450NS	0,5359*	0,9927**
rPROD X NTRP, DCOPA	0,1874NS	0,8042*	0,9202*
rPROD X DCAULE, DCOPA	0,2610NS	-0,7348**	0,9844*
rPROD X DCOPA, DCAULE	-0,3968NS	0,5856*	0,9311*

PROD: productivity, DCAULE: stem diameter, DCOPA: crown diameter, NTRP: total number of plagiotropic branches, * and ** - significant at 5 and 1%, respectively by t test, NS - Not significant at 1 and 5% of probability by the T test.

Table 2. Correlations between the growth and production variables of the plants of the coffee cultivar Obatã conducted in not irrigated crops

	PROD	ALTP	NTRP	CPRP
PROD	1	0,014^{NS}	0,0023^{NS}	-0,2589^{NS}
ALTP	0,014^{NS}	1	0,8107**	0,0800 ^{NS}
NTRP	0,0023^{NS}	0,8107**	1	-0,1294 ^{NS}
CPRP	-0,2589^{NS}	0,00796 ^{NS}	-0,1294 ^{NS}	1

PROD - Productivity, ALTP - Height of Plants, NTRP - Total number of plagiotropic branches, CPRP - Length of the first plagiotropic branch, * and ** - significant at 5 and 1%, respectively by t test, NS - Not significant at 5% probability by the t test.

In fertigated crops, all the correlations between production and growth variables were significant and high, which allows us to affirm that a high productive performance is associated with a high performance of the growth variables. In this case, the greatest expression of the correlation between productivity and the total number of plagiotropic branches occurred with the removal of the effect caused by the stem diameter.

This behavior is consistent with the observation of other authors. According to PEREIRA *et al*. (2007), the greater the growth of plagiotropic branches, the greater the productive potential of the next crop, due to the presence of a greater number of nodes, consequently, a greater number of inflorescences. In fertigated environments, there is a high availability of water and nutrients for the crops and this may have allowed the coffee cultivar IAPAR - 59 to express its greatest productive potential. In fertigation, fertilizers are applied directly to the region with the highest root concentration in doses appropriate to the needs of the crop at each stage of its phenological cycle (COELHO and SILVA, 2005). No significant simple correlations were found between the height and productivity of the Obatã coffee cultivar in non-irrigated crops, however, the height of plants has a significant positive correlation with the variable total number of plagiotropic branches, which is best evidenced by observing the Table 2. In the irrigated crops of the coffee cultivar Obatã it was possible to find significant positive correlations by the t test, that is, the productivity of the plants is influenced by the total number of plagiotropic branches. In addition, plant height is also influenced by this variable. These conclusions can be verified by looking at the data in Table 3 below. In fertigated crops of the coffee cultivar Obatã, it was not possible to verify the influence of height on productivity. However, significant simple correlations were detected in the association between plant height and number of plagiotropic branches, as well as, in the plant height association length of the first plagiotropic branch, as can be seen in Table 4 below. It is possible that the other variables have had some effect on productivity. Higher plant heights are associated with a greater number of plagiotropic branches.

Such finding may be associated with greater distribution of nutrients, since they are provided in a more soluble form, a fact that contributes to reducing the reaction time of the soil and at the same time providing its action on the plant. The result obtained in this analysis was different from that found by Medina Filho, Bordignon and Carvalho (2008) who, when studying growth and productivity data of arabica coffee cultivars, concluded that there was a simple positive and significant correlation between productivity and the number of plagiotropic branches. Assis *et al*. (2014), studying the relationship between the height of coffee plants and the number of plagiotropic branches in a crop production cycle concluded that the correlations found for the study of the two variables were not significant, differing from the result found in this work (r = 0 , 6974 *), which can be seen in Table 4 above. With partial correlations, it is possible to study the association between two variables, isolating the effect from the others. In the study of the partial correlations between height and productivity, the effect of the total number of plagiotropic branches and the length of the first plagiotropic branch was removed. The correlations between height and productivity were significant, so that they were high in fertigated crops, as can be seen in Table 5.

Table 3. Correlations between the growth and production variables of the plants of the coffee cultivar Obatã conducted in irrigated crops

	PROD	ALTP	NTRP	CPRP
PROD	1	0,1038 ^{NS}	0,3377*	0,1489 ^{NS}
ALTP	0,1038 ^{NS}	1	0,6846**	0,0786 ^{NS}
NTRP	0,3377*	0,6846**	1	0,0145 ^{NS}
CPRP	0,1489 ^{NS}	0,0786 ^{NS}	0,0145 ^{NS}	1

PROD - Productivity, ALTP - Height of Plants, NTRP - Total number of plagiotropic branches, CPRP - Length of the first plagiotropic branch, * and ** - significant at 5 and 1%, respectively by t test, NS - Not significant at 5% probability by the t test.

Table 4. Correlations between the growth and production variables of the plants of the coffee cultivar Obatã conducted in fertigated crops

	PROD	ALTP	NTRP	CPRP
PROD	1	0,2514 ^{NS}	0,0172 ^{NS}	-0,0146 ^{NS}
ALTP	0,2514 ^{NS}	1	0,6974**	0,3285*
NTRP	0,0172 ^{NS}	0,6974**	1	0,0086 ^{NS}
CPRP	-0,0146 ^{NS}	0,3285*	0,0086 ^{NS}	1

PROD - Productivity, ALTP - Height of Plants, NTRP - Total number of plagiotropic branches, CPRP - Length of the first plagiotropic branch, * and ** - significant at 5 and 1%, respectively by t test, NS - Not significant at 5% probability by the t test.

Tabela 5. Partial correlations between height and productivity in the cultivars of the coffee cultivar Obatã

CROPS	$r_{PROD\ X\ ALT,\ NTRP}$	$r_{PROD\ X\ ALT,\ CRP}$
not irrigated	0,2063 ^{NS}	0,2953 ^{NS}
irrigated	0,9968**	0,9493**
fertigated	0,9044**	0,9993**

PROD: productivity, ALT: plant height, NTRP: total number of plagiotropic branches, CRP: length of the first plagiotropic branch, **: significant at 1% probability by t test, NS: not significant at 1% probability by test t.

Higher heights are associated with higher productivity only in fertigated crops, so that the partial correlation obtained between the two variables was greater when the effect of the length of the first plagiotropic branch was removed. It is possible that this growth variable had a greater effect in the study of the simple correlation between height and productivity, which may not have allowed the detection of a possible association between productivity and height. The expression of this correlation may have been greater due to the practice of fertigation that may have provided an environment with greater availability of readily soluble nutrients for the plants. SOUZA *et al*. (2003) state that the height of plants is influenced by the environment in which plants grow and develop. Similar results were found by CARVALHO *et al*. (2010).

Conclusion

The results obtained in this work allow us to state that irrigation and fertigation can provide greater productivity compared to non-irrigated crops. Among several factors, the association between variables can explain these differences. The partial correlation allowed to elucidate in more detail the associations existing between the variables of growth and production, since the possible effects exerted by other variables are removed. This behavior occurred in the analysis of data from cultivar IAPAR-59 and cultivar Obatã. In some cases, the association between variables was not detected in the simple correlation, but it was found in the partial correlation. The correlation between height and productivity can be detected through the study of partial correlations, and taller plants are more productive, considering the fertigated crops of the cultivar Obatã. One of the factors that affects productivity is height, but this cannot be seen in simple correlations, since, in this case, the association between two variables is influenced by other variables.

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