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Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(3): 1462-1471. OPEN ACCESS

A correct combination of pruning, spacing and organic fertilizer improve development and quality of fruit in watermelon cultivar: Case of Ecuadorian littoral

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Empirical planting techniques, little knowledge of appropriate pruning methods, and the continued use of synthetic fertilizers can trigger low productivity features, and consequently poor fruit quality in watermelon cultivation. The present investigation was aimed to determine these objectives: a) the best crop performance by using three spacing, b) two types of organic fertilizers and c) two types of pruning on the development and quality of fruit. The three factors were studied under the followings: 1) spacing factor (SF) including 1 m x 2.5 m, 1 m x 3 m, 2.5m x 2.5 m, 2) pruning (PF) including 1 and 2 axes, and

3) Organic fertilizers (OF) including earthworm humus and Biol elaborated from biological waste. The best behavior for the fruit length and perimeter variables was linked to the spacing 1 m x 2.5 m, and to the 2-axis pruning. Likewise, with the 2-axis pruning, fruits with higher sweetness were obtained, represented in Brix Grades. These results allow to recommend the use of the two organic fertilizers: biol and humus respectively as potential elements for the vegetable nutrition of watermelon crop, guaranteeing an adequate quality of fruits, but overall avoiding the use of chemical fertilizer.

Keywords: *Citrullus vulgaris,* pruning, fertilizer, agriculture

INTRODUCTION

Watermelon (*Citrullus vulgaris* L.) belongs to the genus of cucurbits and is a creeping plant. Its cultivation is rainfed and irrigated (Mármol, 1998; Manzano et al., 2016; Boualem et al., 2016). It is one of the most important crops in the world (Renner et al., 2017). It originated from Old World agriculture, which was domesticated in Africa, and later spread around the south of Europe (Mediterranean zone), Middle East, America, and India (Pérez et al., 2015). This plant produces one of the fruits that can reach a weight higher than ≈7 kg, as basically most of its fruit is composed of water (≈90%). It has low calories and contains antioxidant substances such as lycopene (Laínez Orrala, 2009). There are different varieties of watermelon, with different characteristics that determine the fruit quality (Renner and Schaefer, 2016; Suárez-Hernández et al., 2017) and its successful conditions in the national, regional and international markets (Canales, 1998; FAO, 2011; Barba and Suris, 2015).

Watermelon cultivation in the world has faced a registered important increase (Pérez *et al*., 2015). In Ecuador, watermelon production has developed since the 1970s. In general, around 8 million hectares are occupied by agricultural crops in Ecuador, of which ≈2000 ha have been established as watermelon monoculture cultivation with a production of 25,818 t (MAGAP, 2012; INEC, 2013). According to the Ecuatorian Agricultural Census, the main zones are almost completely distributed on the coast. According to the FAO (2007), watermelon average yield in Ecuador between 1997 and 2001 was ≈17,171 kg ha^{-1} per year, with that average Ecuador is not among the most watermelon exporting countries in the region. However, it is a promising market of watermelon in Ecuador that has had a significant increase in recent years.

Some authors have described the importance of watermelon production, highlighting the variety (Pardo et al., 1997; Ciupureanu et al., 2016; das Chagas et al., 2016), and carrying grafts (Petropoulos et al., 2014). In some other studies, the graft carrier does not show any relationship with watermelon production, but it does the sequence in the cut of fruits (Camacho and Fernández, 2000), chemical fertilization (Orrala, 2015), organic fertilizers (González et al., 2015), and so on.

Fertilizers can be organic and chemicals of commercial origin (Idrovo and Quilambaqui, 2008), and are showed in different states (solid, liquid, and gaseous). Currently, most farmers use commercial chemical fertilizers (Colla et al., 2011; Barba et al., 2015). However, the use of chemical fertilizers causes imbalances on the soil and on the organism populations that interact in/with the environment and the quality of the fruits, which generates distrust in the consumers (Charles and Martín, 2015). For the above described, the use of organic fertilizers is very crucial. Among those organic fertilizers are Biol and humus, which comes from the humification process (Douchaufour, 1975; Vásquez and Maravi, 2017; Méndez et al., 2017). They are commonly used by farmers because of their easy production and their availability from both private and state companies (Soto, 2003; Kaufman et al., 2004; Pacheco et al., 2017). Therefore, it is crucial to expand the knowledge of the benefits of using organic fertilizers in crop production (Salazar et al., 2003; Strik et al., 2017) for small farmers.

Watermelon is a multibranched plant; it emits many stems that can reach up to 4 meters. Therefore, pruning has been considered as an alternative that reduces energy expenditure on stems, leaves and fruits. On the contrary, this energy can be invested in other parts of the plant (Balliu and Sallaku, 2017). This practice aims to stimulate fruit growth (Zapata et al., 1989), and a greater aeration of plant. Another agricultural strategy discussed, is the spacing factor (SF) of sowing which allows to increase productivity (Camacho, 1993). In this sense, different spacing per hectare have been described, depending on the ploidy of plants (i.e. diploid or triploid) (Resende and Costa, 2003; Walters, 2009; Feltrim et al., 2011), or sown surface (Pérez et al., 2015).

It is necessary to undertake research that outputs knowledge of a technical criterion (Segura et al., 2017): using efficient and rationally pruning, spacing and organic fertilizers, to regulate the production of safe and competitive fruits in the market. These types of results should be available to the farmers (Muñoz et al., 2014) to maximize the usefulness of research. This background justifies the realization of this research, which evaluated the following objectives: a) determining the best growing behavior by using three spacing, b) comparing two types of organic fertilizers and c) studying two types of pruning on the development and quality of watermelon fruit.

MATERIALS AND METHODS

Study location

The present investigation was carried out at the "La María" farm of the State Technical University of Quevedo (UTEQ). It is located at 7.5 Km of the Quevedo – El Empalme road, Los Ríos province, at the geographic coordinates of 1º 2' 30'' of southern latitude and 79º 28' 30 ''of western longitude, at 74 meters above sea level. The predominant climate in the area is humid tropical, with an average temperature of 24.8 ºC. Rainfall is usually around 2,200 millimeters per year, being the rainiest season, from January to May, and the driest season, from August to November. The relative humidity is 84%. The topography is irregular (35%) and flat (65%). The soil texture is clear, with good drainage and an optimum pH (6.5 - 7.0).

Plant material, factors and experimental development

The American sweet hybrid, which has a life cycle of 70-75 days and a smooth epicarp with a dark green appearance, was used. The three factors of the study were: 1) spacing (SF) (1 m x 2.5 m, 1 m x 3 m and 2.5 m x 2.5 m), 2) pruning (PF) (1 axe and 2 axes) and 3) Organic fertilizers (OFF) (earthworm humus and Biol). The characteristics of experimental plots are detailed in Table 1.

Table 1. Characteristics of the experimental plots in field.

Item	Value
Number of factors	3
Total number of treatments	12
Number of replicates	3
Number of plots	36
Dimension of plots	3.0 x 10.0 m, 3.0 m x 12.0 m, 7.5 m x 10.0 m
Plot area	30 m^2, 36 m^2, 75 m^2
Spacing	1.0 m x 2.5 m, 1.0 m x 3 m, 2.5 m x 2.5 m
Number of rows per plot	4
Number of useful rows	2
Form of parcels	Rectangular
Block area	36m^2, 432 m^2,900 m^2
Total test area	1692 m^2

In order to sow the seeds in the nursery, a soil substrate, sawdust, and organic fertilizer were used. The nursery plants remained 12 days, of which they were covered with a black polyethylene film for the first 72 hours to increase temperature, decrease evaporation and augment CO_2 concentration. Two passes of harrow in two directions from 25 to 30 cm depth approximately were done for preparation of farm soil, until the soil was well fluffy and ready to sail in beds, where the plants were transplanted 12 days after planting.

It took 5-6 days from sowing in trays to seed germination. Flowering started between 25 and 28 days after sowing, until it became a complete flower after 35 or 40 days. Forty days after sowing the watermelon plants began to develop their creeping stems, giving rise to buds that brought the fruit set in the female flowers. The plant guides went to the bed center and were not allowed to remain inside the irrigation rows. The guides were kept until before flowering step. Pruning was carried out 21 days after sowing to prevent diseases (Reche, 1988). Humus application was done during the transplant section based on a dose of 350 kg ha^{-1} and Biol application at a dose of one Liter per pump at 18th day. The humus was stable, in accordance with the nutritional request and without extraneous materials (Brinton, 2000). Uneven curves were made on the ground to apply irrigation by furrows. Irrigation was permanently done at intervals of once per week (INIAP, 1987), and sometimes at increased intervals (2 times weekly) from the fruit development to maturity, that is, in the stages of growth and flowering (ICA, 1983). For weed control, the commercial herbicide "H1 Super" (Fluazifop-P-butyl) was used in a dose of 610 cc ha^{-1}, complemented by manual weeding to keep the crop free of weeds. For preventing and controlling pests and diseases, Piriclor and Captan (commercial names), fungicide and pesticide were applied respectively into the hole at the time of transplant. As a complement, weed-free cultivation was maintained to avoid the incidence of Virosis. The fruit cutting was performed once a week when they were ripe, according to the harvest indicators, to achieve an optimum quality grade. The harvested fruits were placed on the edge of the rows in the same position that they were before harvest, avoiding supporting them on the apical end.

Development, quality of fruit, experimental design and statistical analysis

The variables studied were the followings: 1) length of the fruit, measured from the tendril of peduncle to the posterior terminal part of fruit; 2) the central perimeter of fruit; 3) fruit weight expressed in kilograms taken from 10 fruit randomly per each plot and per each treatment 4) brix grade determined by measuring the total sucrose ratio dissolved in watermelon juice, for which a refractometer was used (MAGFOR, 2005). The measured grade unit was parts per 100. As an example, A 12º Brix solution has 12 g sugar (sucrose) per 100 g liquid, or, in other words, 12 g sucrose and 88 g of water in 100 g of solution.

A Random Complete Blocks (RCB) with a factorial arrange of 3x2x2 and distributed in three repetitions was used. The data were organized in a matrix using the calculation template of Microsoft Excel, to be later analyzed with the statistical software INFOSTAT (Di Rienzo *et al*., 2011). Bartlett and Shapiro-Wilk statisticians were made for all the variables, in order to verify the homoscedasticity (variances) and normality (residuals) of the data, respectively. For the multiple comparisons of means, the Tukey multiple range test was applied (P <0.05). For the graphic representation, the commercial type software SigmaPlot11.0.Ink Exact Graphs was used, manufactured by Systac Software.

RESULTS AND DISCUSSION

Fruit length (cm) and perimeter (cm)

The best results for the two variables length (cm) and perimeter (cm) of fruits were observed for the SF 1.0 m x 2.5 m, with which, the fruits obtained 29 and 65 centimeters in average of length and perimeter correspondingly (P < 0.05, Table 2). These results differ from what observed by Mármol (1998), who described that very close spacing have disadvantage of covering soil surface very early and even on occasions before the female flowers have developed, since these appear from the fifth or sixth conjuncture. Therefore, according to Barba et al., (2015), farmers use higher planting densities. With respect to PF, it occurred for the 2-axis pruning, and higher averages for the fruit perimeter (cm) for 2-axis were presented than those with 1-axis (P < 0.05, Table 2). Marini (2009) points out that these differences are related to the fact that pruning techniques can increase certain agronomic and productive characteristics due to the elimination of excess floral and vegetative buds, encouraging growth of new shoots with more vigorous abundant floral buds that all can translate to low economic incomes.

For OFF, any statistical differences were not shown (P < 0.05, Table 2, Figure 1↓).

However, there was a slight numerical increase in the fruit length with the humus-based fertilizer (28 cm, Table 2, Figure 1 ↓). According to Filipek-Mazur et al., (2015) humus or vermicompost increases the levels of organics matter in soil, improving the microbiological activity and therefore the assimilation of nutrients, while the plant is improved and protected naturally from the attack of plague insects and diseases.

Table 2. Effect of SF, PF and OFF on fruit length (cm) and fruit perimeter. Averages with the same letters do not show statistical differences, according to the F test (P<0.05).

Factors	Fruit length (cm)	Fruit perimeter (cm)
SF		
1.0 m x 2,5 m	29,00 a	65,00 a
1.0 m x 3,0 m	27,00 b	62,00 b
2,5 m x 2,5 m	27,00 b	62,00 b
PF		
1 axis	27,00 a	62,00 b
2 axis	28,00 a	64,00 a
OFF		
Humus	28,00 a	63,00 a
Biol	27,00 a	63,00 a
CV%	7,29	2,28

PF: Pruning factor; SF: Spacing factor; OFF: Organic fertilizer factor

Fruit weight (kg) and brix grades

Significative differences were shown for the variable weight of fruit (kg) with respect to SF and PF, highlighting SF 1.0m x 2.5m, and 2 axes pruning, which reached a greater weight each one respectively (5.79kg, P <0.05, Table 3). Our results differ from the averages reported by Alvarado and Alfredo (2017), who found fruits with an approximate weight of 7.5 kg in watermelon plants without pruning treatment, using an average of 5 guides per plant and diatonic phosphate fertilization (18-46-0). In the same manner, it occurred with the results reported by Lomas Rosales (2017), who obtained fruits with weight of 5.21 and 6.65 kg without pruning, and with pruning of 1 secondary guide, respectively. Interesting results regarding PF also were described by Seabra Júnior et al., (2003) who observed that increasing the number of fruits per plant reduces their size, which means that PF has a great effect on plant production. In a general way, these outcomes suggest that an adjustment of the plant physiological activity is produced by PF effect (Costas *et al*., 2005). When pruning, leaving flowers (hermaphrodites) that guarantee fruiting, the nutrients and energy are redistributed, which allow achieving the conformation of ideal fruits desired in the market (Díaz-Alvarado and Monge-Pérez, 2017).

Table 3. Effect of SF, PF and OFF on fruit weight (kg) and brix grades. Averages with the same letters do not show statistical differences, according to the F test (P < 0.05).

Factors	Fruit weight (kg)	Brix grade
SF		
1 x 2,5	5,79 a	8,87 a
1 x 3	5,15 b	9,00 a
2,5 x 2,5	5,35 b	8,49 a
PF		
1 axis	5,07 b	8,73 a
2 axis	5,79 a	8,84 a
OFF		
Humus	5,57 a	8,86 a
Biol	5,29 a	8,71 a
CV%	15,82	2,67

PF: Pruning factor; SF: Spacing factor; OFF: Organic fertilizer factor

For the same fruit weight variable (kg) there were no significant differences for OFF (Table 3), the same occurred with Brix grade, however, a slight numerical difference (not statistical) was obtained with the use of fertilizer based on humus. This allows to elucidate that both organic fertilizers could be well used by watermelon producers guaranteeing a good fruit quality (quantified in Brix grade), additionally, avoiding the excessive use of synthetic chemicals that cause a hazard on the health of the farmers, and all this making to the production more friendly with the environment (Villamar-Torres et al., 2018). According to MAGFOR (2005) "the quality grades of watermelon are determined by the sweetness of their pulp", this distinction between Brix grades is based mainly on the concentration of sucrose. The content of Brix grade is constituted by a large percentage (80-95) of sugars dissolved in cell juice (Osterloh et al., 1996). To conclude, our results agree with the range of good quality fruits cited by Morán (2001), who describes that ranges between 8.5 to 11.5 Brix grades are excellent for consumption and for national and international trade. Higher indexes of Brix grades are related to a higher content of soluble solids, or earthworm humus, because it raises the contents of total soluble solids (Brix grades) (Charles and Martín Alonso, 2015).

Interactions: SF vs PF vs OFF

In Figure 1, the interactions for the four variables with the three factors under study are shown. We found that the combination spacing of 1 x 2,5 m + 2 axis + humus-based organic fertilizer reached the higher average in all the variables. These outcomes agree with those found by González et al., (2015) who observed that the fertilizer based on humus generates a positive impact on the agronomic characteristics of plant height, stem thickening and fruiting. According to Charles and Martín Alonso (2015), the contributions of N, P and K (in doses of 150, 24 and 1.5 (t ha^{-1}) respectively) of earthworm humus have a positive effect on plant. Chamorro et al., (2017) reported that there is a competence between each plant that share a same space on ground; consequently, several physiological requirements are not fulfilled, becoming a negative factor, which generates a reduction of agronomic and physiological features as survival, growing, individual yield and fruitfulness.

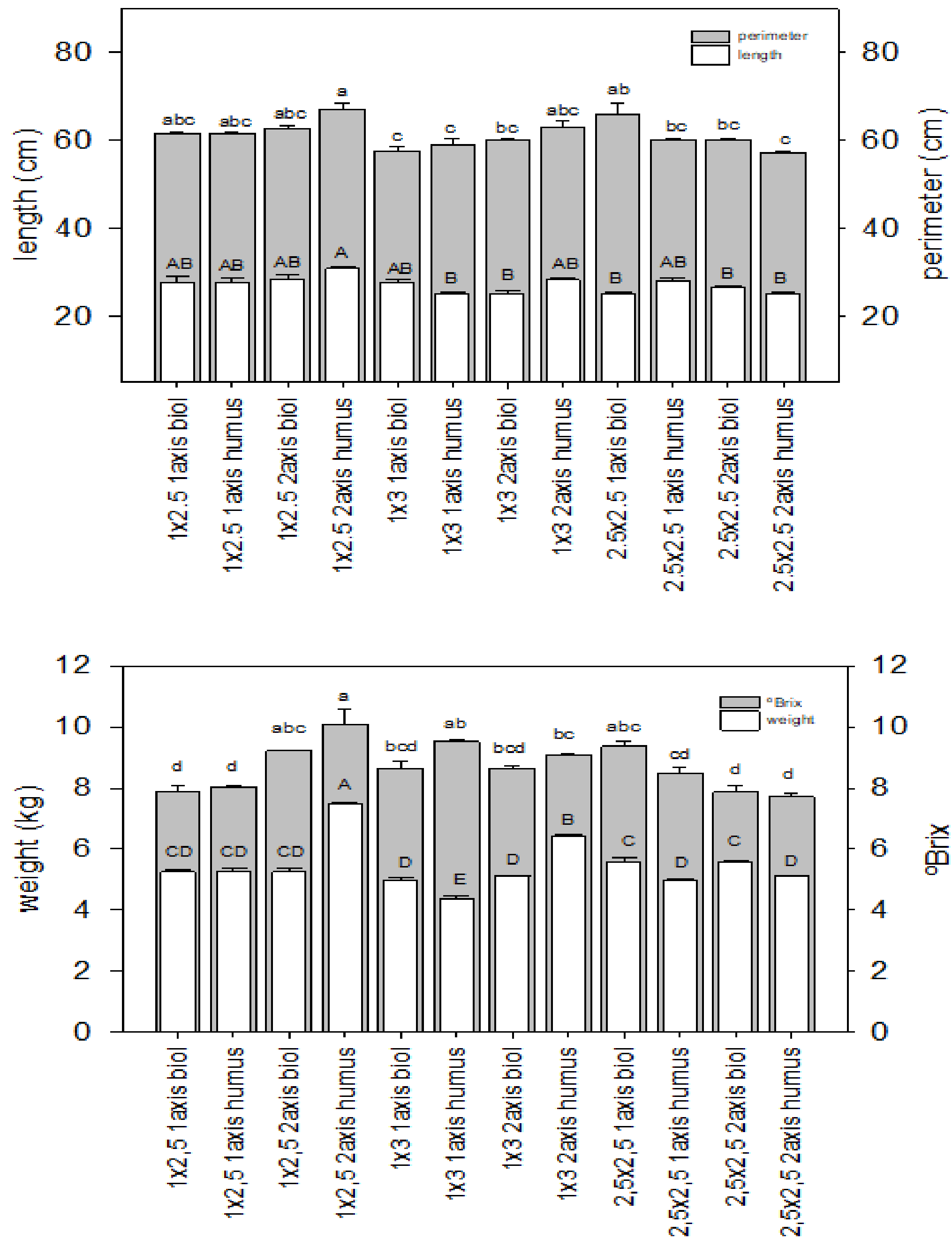

Figure 1. Effect of the interactions of spacing, pruning and organic fertilizers on the weight and Grade-brix of fruits respectively. Different letters between the treatments under study show statistical differences (P <0.05

CONCLUSION

The results of sampled plots show that fruit development and quality was affected overall by the three factors and for almost all the variables under study, highlighting the treatment originated from the combination of spacing of 1 x 2,5 m + 2 axis + humus-based organic fertilizer. The effect of the fertilization organic is inherent on the fruit development and quality. Our results are within of permitted range regarding to the scale of brix grades that considers if the fruits quality are apt for consumption and for national and international trade. All this, illustrates the possibility of a change in the management system of watermelon cultivation, mainly for small farmers in this zone of Ecuador because it represents an excellent alternative to avoid the use of synthetic fertilizers that can signify a lowest fruit quality and probably not appetizing in the markets by the consumers.

CONFLICT OF INTEREST

We declare that we have no competing interests.

ACKNOWLEGEMENT

The authors JCMR and Diego Ortega want to express their sincere gratitude to the Professor. Pedro Rosero Tufiño and the alma mater Universidad Técnica Estatal de Quevedo (UTEQ) for all the support during this investigation. In the same way, to Marlene Rengifo Z., Fabiola Guevara O. and Victor Muñoz Z. for all their support in the logistics during the project. Finally, to Silvana Vélez Q, by the support, as well as for the transcription from original document and elaboration of some tables of the manuscript.

AUTHOR CONTRIBUTIONS

Julio Muñoz-Rengifo and Ronald Villamar-Torres[1]are contributed as first author. JCMR and DOG designed and carried out the experiments, as well as the data collection. JCMR, ROVT, JMV, LGC and BTN, did the statistical analysis and wrote the manuscript. SMJ, BCM, AMM and JCO checked English proof, statistical analysis and adjusted the manuscript to the journal format. Finally, all authors contributed with critics on the data, checked and corrected the final version of the manuscript.

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