

Interactive effect of soil mulching and ISAREG model based irrigation on watermelon production

ABSTRACT

Even with the growing scenario of water scarcity, in the Northeastern semi-arid region, the irrigation management is still not properly managed, resulting in the waste of scarce water resources in the region. The ISAREG model has been used in several countries, being able to assist in the simulation of irrigation. In addition, the ISAREG model quantifies irrigation depths at different percentages of storage, increasing irrigation efficiency. Another way to reduce water loss in agriculture is through the use of soil cover, which is a simple technology and whose benefits over crop production and productivity are irrefutable. Added to this is the fact that interactions among these applications can amplify the effects. The objective of this study was to compare the irrigation propositions generated from ISAREG model with the actual irrigation management adopted by the farmers of the Jaguaribe - Apodi Irrigation District, Brazil. In addition, field experiments were performed to assess the influence of different irrigation and soil cover conditions on fruit development and yield of watermelon. These field experiments were performed after field surveys with farmers in a randomized complete block design with subdivided plots and four replicates. The treatments consisted of the combination of four irrigation propositions (three ISAREG propositions: M1 = 100%, M2 = 80% and M3 = 60% of Available Water Capacity in Soil, and M4, irrigation depth used by irrigators), and four subplots, the uncovered soil (C0), covers with rice husks (C1), with white mulching (C2) and with black mulching (C3). The data were subjected to analysis of variance, and when significant, regression analysis, averages test and trend graphs were performed. The irrigation depths of 365.2 mm and 410 mm with a black mulching resulted in the highest numbers of fruits per plant (1.6). From the results, it was concluded that the farmers do not practice the correct management of the irrigation, because the farmers irrigated more water to a greater irrigation depth as indicated by the ISAREG model (100% of the Available Water Capacity in Soil) throughout the watermelon cultivation. In general, plants irrigated with 100% of available Water Capacity and on soils covered by rice husk and white mulching showed better productivity.

Keywords: deficit irrigation; software; *Citrullus lanatus*; crop productivity.

1. INTRODUCTION

New strategies for the management of water resources in cultivated areas, especially in the semi-arid region are essential where water is limited and wasted resource. As a consequence, a technical problem of water supply is already perceived that will be aggravated by different human activities, making it necessary to use water in a controlled manner in agriculture [1]. In addition, in the semi-arid region of Northeastern Brazil where the irrigation is not properly managed crop yields are low and more water than those required by crops is used resulting in the waste of the scarce water resources of the region.

As a solution, the rational management of irrigation aims, among others, to maximize the efficiency of water use, maintaining favorable conditions for soil moisture and plant health taking into consideration the climatic conditions of the agroclimatic region, as well as the crop characteristics. Rational water management aims to supply water to the crops at the right time and amount [2]. In addition, high crop yields can be obtained by maintaining soil moisture at suboptimal field capacity levels [3].

One of the alternatives to avoid water wastage is the use of computational software used in irrigation management that calculates water requirements based on climate, soil and crop data [2]. As an example, the ISAREG model, which is a simulation software for soil water balance, developed at the

Higher Institute of Agronomy, in Portugal, which is able to deal with capillary ascension and percolation through the root zone.

The ISAREG model has been used as a new technology in irrigation management in several regions, being able to assist in the simulation of irrigation depth in order to maintain soil moisture in different percentages of the maximum storage [4, 5].

Another way to reduce the use of water resources in agriculture is through the use of ground cover. This is a simple technology, but the benefits for crop development and production are irrefutable, especially in situations of water scarcity, reducing the frequency of cultural practices and the production costs.

Several authors prove the benefits of this technique: a) it improves the quality of the products, like the production of strawberry, pumpkin and watermelon; b) it increases the productivity of crops; c) it extends the time of water availability in the soil; d) it reduces soil temperature variations; e) it reduces the development of weeds; e, f) it reduces or eliminates the possibility of erosion by blocking the direct impact of rainfall and provides savings in the costs of agricultural production [6].

In addition, the interaction between these technologies can increase agricultural productivity and reduce the use of water resources. It is possible that the irrigation depth dimensioned by the ISAREG model to maintain the bare soil at 80% of the available soil water capacity may be enough to keep the soil under rice husk at 100% of the available soil water capacity, due to less evaporation under this condition.

This study was aimed to compare the irrigation patterns generated using ISAREG model with the actual irrigation practices adopted by the farmers of the Jaguaribe - Apodi Irrigation District, Brazil. Further, we evaluated and analyzed the fruit development and crop productivity of watermelon under the different irrigation and soil cover conditions. The interactive effects of these practices on the water resource economics were also determined.

2. MATERIAL AND METHODS

The research was carried out in the Research and Extension Unit of the Federal Institute of Education, Science and Technology - IFCE, in Limoeiro do Norte-Ceará (05°06'38 "S; 37°52'21" W; 145.95 m), in the Irrigation District Jaguaribe–Apodi, Brazil.

The local climate is BSw'h', semi-arid, according to Köppen's climatic classification, with the following average conditions: relative humidity (66.1%), rainfall (717.1 mm) and air temperature of 26.9 °C.

Two consecutive experiments were carried out with the watermelon. All the methodologies and analyzes performed were identical for the 2 cycles, except for the irrigation depth simulated by the ISAREG model. The duration of the experiment was 6 months.

The input data used in the ISAREG model were: field capacity humidity; permanent wilting point; Phenological stages of the crop (1st stage - from planting to first irrigation, 2nd stage - beginning of vegetative growth, 3rd stage - total cover and flowering, 4th stage - fruit formation, 5th stage - leaf senescence and 6th phase - harvest and end of the cycle); water availability factor (f) and effective depth of the root system (Z), both for each phenological phase. Also, the model required data on irrigation management, in which three (3) were calculated by ISAREG (Irrigation with deficit - 60%, 80% and 100% of available soil water capacity) and the other one consisted of the mean leaf of 6.3 mm.dia⁻¹, during the watermelon cycle, practiced by the farmer of DIJA. This irrigation management was the fourth irrigation condition added to ISAREG.

Watermelon seeds (*Citrullus lanatus* var. *Crimson sweet*) were obtained from an agricultural store.

The experiment was carried out in a randomized complete block design with subdivided plots and 4 replicates (4 x 4 x 4, totaling 64 subplots). The treatments consisted of the combination of 4 irrigation propositions (three propositions of the ISAREG model and one irrigation management used by the producers named M1, M2, M3 and M4), which constituted the plots, and 4 subplots, with 3 conditions of soil coverage with rice husk (C1), with white mulching (C2) and with black mulching (C3), and

subplot 4, the soil without cover (C0). The white mulching and the black mulching were made of plastic material, obtained in agricultural store.

The irrigation propositions by the ISAREG model were: M1, the optimal irrigation management (irrigation depth proposed for daily soil maintenance in its maximum storage capacity, 100% of available water capacity, without percolation, for an uncovered soil); M2, proposal of daily irrigation for maintenance of storage of uncovered soil water, around 80% of available water capacity; M3, proposal of daily irrigation for maintenance of storage of uncovered soil water, around 60% of available water capacity; and the M4 treatment represented the daily irrigation depth used by local irrigators.

The crop spacing was 2.0 m x 0.5 m, each sub-plot with 6 plants, with 6.0 m² (2.0 m x 3.0 m). The analyzed variables were obtained in the area occupied by 4 plants in the center of the planting row.

There was a borderline between the lines with treatment, making nine lines (9.0 m x 2.0 m = 18.0 m width). Each block had four subplots per treatment, with an area of 216.0 m² (18.0 m x 12.0 m). The total area of the experiment was 864.0 m² (18.0 m x 48.0 m). There were approximately 864 plants throughout the experimental area (864 m²).

The sowing of the 1st cycle was carried out on August 15 and 2nd cycle on November 12. They were carried out in styrofoam trays with 128 cells with the commercial substrate. Transplanting occurred on August 22 (1st cycle) and November 19 (2nd cycle).

The amounts of the chemical fertilizers used to supply the crop requirements were recommended according to the soil analysis results. However, for the determination of the frequency of fertirrigation application, the research carried out by [7] was used as the basis, which in his search verified better results with daily applications, throughout the watermelon cycle. Fertilizers were applied via fertirrigation, starting on the day of transplanting and ending at 50 DAT (days after transplanting). The commercial chemicals used were urea (N), white potassium chloride (K₂O), phosphoric acid (P₂O₅), sulfur sulfate (S) and boric acid (B).

The control of weeds was carried out during the crop cycle, with weeds, using hoes, in the inter - rows and manual thinning near the plants.

White fly, cochineal and fungus attack were observed, and they were controlled with the rational use of insecticides and fungicides. Nim seed oil was used for the control of white fly and cochineal. Applications were performed at 15, 22, 40 and 47 days after transplanting. Amistar fungicide was applied for the control of powdery mildew. The applications were performed at 30 and 40 days after transplanting.

The first and second cycles were started when the fruits reached the point of physiological maturation, with a minimum °Brix around 8°, determined with a portable refractometer.

The periodic harvests were carried out at intervals of five days, beginning at 67 days after transplanting. Two harvests were made, with commercial fruits weighing more than 0.80 kg, normal and non-spoiled.

The daily irrigations were performed with self-compensating drippers, average flow of 2.3 L h⁻¹, service pressure of 300 kPa.

The crop evapotranspiration (ET_c) data were obtained through local experiments, by soil water balance methodology; and reference evapotranspiration (ET_o) was estimated by Penman - Monteith / FAO, described by Allen et al. [8], with data from local climatic variables. The crop coefficient (K_c) was obtained by the ratio between ET_c and ET_o.

The irrigation time was calculated from the irrigation depth proposed for each treatment, according to equation 1.

$$Ti = \frac{L_i * E_L * E_g * F_C}{E_i * q_g}$$

Where: Ti is the irrigation time, in hours; Li is the irrigation depth proposed by each treatment on the ISAREG model; EL is the spacing between irrigation lines, 2.0 m; Eg is the drip spacing, 0.5 m; FC is the soil cover factor, dimensionless; Ei, is the irrigation efficiency, dimensionless (0.95); qg, is the flow of the dripper (2.3 L h⁻¹).

The application of the coverage factor (Fc) of the watermelon cycle, which represents the relationship between the wet area and the area occupied by the crop, was followed by the recommendation of Bernardo [9], when he stated that Fc should be of at least 33% (0.33) for arid and semi-arid regions. The Fc used varied from 0.33 to 1.00 (phase of maximum water demand of the crop).

Tensiometers were installed at 20 cm depth to verify soil moisture at the effective depth of the watermelon root system.

The variables analyzed were average fruit weight, average productivity and number of fruits per plant.

The qualitative results were submitted to analysis of variance. The results were submitted to the Tukey averages test at 1% and to 5% of probability when significant by the F test. The quantitative variables were submitted to regression analysis.

3. RESULTS AND DISCUSSION

Number of fruits per plant, average fruit weight and average productivity in First (1st) cycle

From the analysis of variance (Table 1), a significant effect was observed for the interaction between irrigation depth versus soil cover, for the following analyzed variables: number of fruits per plant (P <0.05), average fruit weight (P <0.01) and average productivity (P <0.01).

Table 1. Summary of analysis of variance and significance levels for the variables: number of fruits per plant (NFP), average fruit weight (AFW) and average productivity (AP) - 1st cycle

VS	DF	Medium Square		
		NFP	AFW	AP
Irrigation depth (I)	3	0.09563*	5.08333**	511.02042**
Residue (a)	12	0.02187	0.10083	0.94094
Covers (C)	3	0.57229**	10.27000**	2171.01042**
Interaction I x C	9	0.05451*	1.79667**	118.92333**
Residue (b)	36	0.02299	0.04417	0.61455
Total	63	-	-	-
CV % (I)	-	10.31	6.43	1.58
CV % (C)	-	10.57	4.26	1.28

VS= Variation source; DF = Degree of freedom; CV= coefficient of variation; * and ** = Significant at 5% and 1% respectively

The regression analysis (Figures 1A and 1B), clearly shows that the different irrigation depths, in the absence and presence of soil cover, exhibited a polynomial effect, for the number of fruits per plant and average fruit weight.

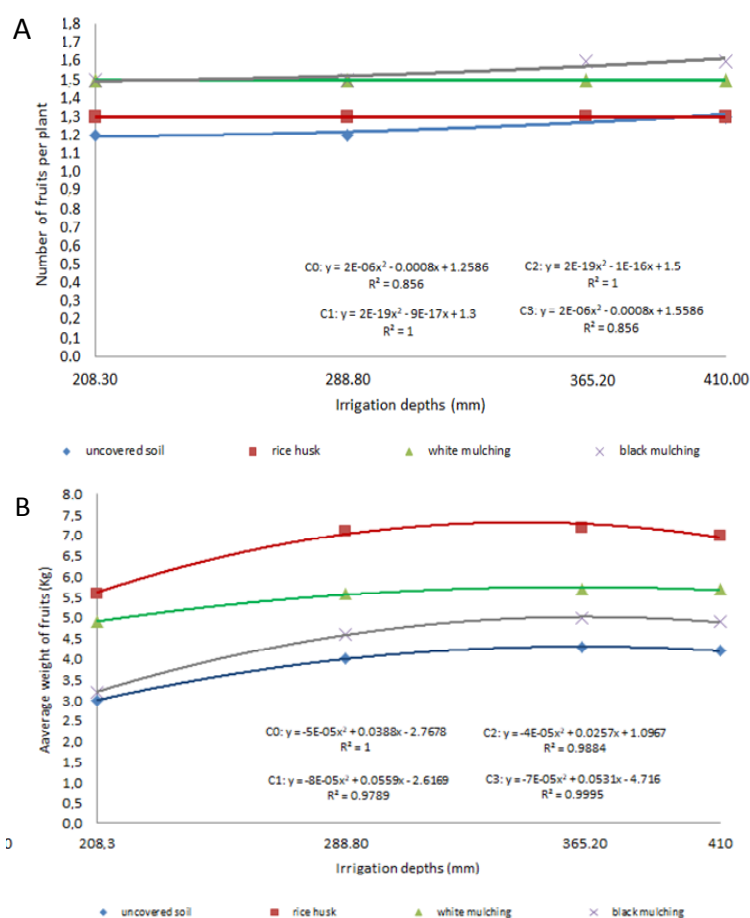


Figure 1. Influence of irrigation depths and soil cover conditions on the number of fruits per plant (A) and average fruit weight (B) of watermelon, during the first cycle.

In Figure 1A, when analyzing the interactions of irrigation depths with soil covering, indicates that there is a trend of increase in the number of fruits per plant, in relation to the amount of water applied, until the irrigation depth M1 (365.2 mm), which is evidenced in uncovered soil conditions and black mulching. Likewise, [10], evaluating irrigation methods in watermelon production, verified that the applied blade influences, to a certain extent, the number of fruits per plant.

The irrigation depth M1 (365.2 mm) and M4 (410 mm), with a black mulching cover resulted in the highest numbers of fruits per plant (1.6). However, the uncovered soil, mainly with the lowest irrigation depth (208.3 mm), resulted in the lowest number of fruits per watermelon plant (minimum of 1.2 and maximum of 1.3). This was probably due to the lower humidity in the soil. This is in accordance with Azevedo et al. [11], where the water deficiency caused a marked decrease in the physiological activities, mainly in the division and growth of cells and, consequently, in the growth and production of watermelon. According to Marouelli et al. [12] and Sousa et al. [13], the water deficit during flowering and fruit development decrease the number of fruits per watermelon.

The regression analysis of Figure 1B, reveals that the different irrigation depths, in the absence and presence of soil cover, induced a polynomial effect on the average weight of the fruits per watermelon. This is in line with Sousa et al. [14] who also observed a similar response in average weight of watermelon fruits in response to increasing irrigation depths.

An analysis of the interactions between the irrigation depths and soil coverings revealed a positive influence on, the average weight of the fruits. So with an increase in irrigation depths, up to the limit of M1, the fruit weight was higher, regardless of the type of coverage. This can be explained by the ISAREG model simulations, which predicted the presence of excess water excess in the soil, when the irrigation depth was beyond 365.2 mm (M1).

Regarding soil cover, the heavier fruits were obtained in rice husk mulching and the less heavy ones in the soils without any cover. Among the soils covered by plastic, better results were obtained when the soils were covered by white mulch. It can be affirmed that the use of soil coverages assists in the retention of moisture in the soil besides favoring other positive aspects to the development of the watermelon.

Lopes et al. [15] while studying the influence of different types of soil coverings on tomato, found that the use of soil cover contributed to the increase of fruit mass.

As in the other types of coverings, in the condition of uncovered soil the effect increased until the M1 blade, reaching a maximum weight of 4.3 kg. However, it was possible to observe the primary influence of the amount of water applied, on the average weight of the watermelon fruits. Ramos et al. [16] in a similar experiment showed that the average weight of watermelon fruits was 3.6 kg. Fernandes [7], in an experiment with irrigated watermelon, but under different conditions of applied irrigation showed that the average maximum and minimum fruit weight of 10.2 kg and 7.1 kg, respectively.

The combination of the M1 irrigation depth with a soil covered by rice husk resulted in the highest average fruit weight (7.2 kg). The lowest average weight fruit (3.0 kg) was obtained in the M3 irrigation depth (208.3 mm) in the soil without any cover. As observed for the number of fruits per crop, the lowest average fruit weights were observed in the soil without cover, independent of the irrigation depth. With lower soil moisture in the absence of cover, critically affected the fruits would development resulting in lighter fruits. According to Andrade Júnior et al. [17], water stress tends to reduce the average weight of the watermelon fruits, making them unacceptable in the consumer market.

According to a regression analysis of the mean values of total productivity (Figure 2), the irrigation depths and coverings in the soil produced a polynomial effect.

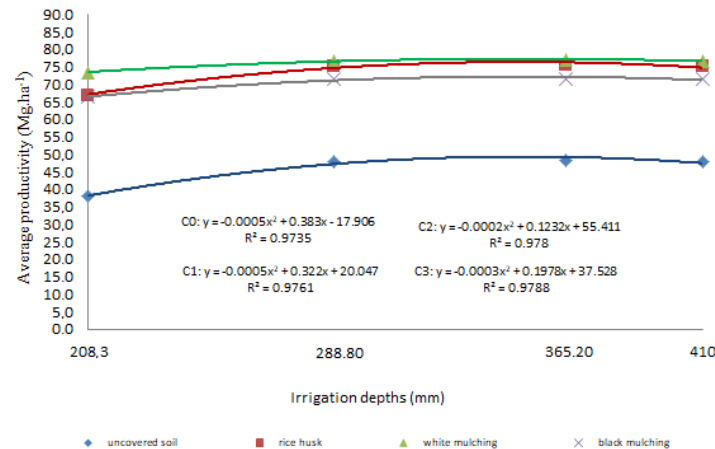


Figure 2. Influence of irrigation depths and soil cover conditions on the average productivity of the watermelon during the first cycle.

An analysis of the interactions between irrigation depths and soil coverings revealed a positive influence on the average productivity of the watermelon, in relation to the amount of water applied, independent of the type of cover in the soil. Batista et al. [18] when analyzing the effect of water deficit on watermelon, found higher productivity under adequate water availability. Oliveira et al. [19] found similar results for watermelon and suggested that maintenance of adequate soil moisture for the crop allows greater absorption of water and nutrients, which results in greater translocation of photoassimilates from the leaves to the reproductive organs, translating into increased production.

M1 irrigation depth (365.2 mm) showed higher productivity (77.0 Mg ha⁻¹) in combination with the soil covered by white mulching, showing the importance of using this cover for irrigated watermelon cultivation. Analyzing the watermelon productivity for the soil covered with white mulching, maximum

productivity (74.38 Mg ha⁻¹) was observed with a 308 mm applied irrigation depth. Ramos et al. [16] analyzing the productive characteristics of irrigated watermelon, obtained average total productivity values of 76.1 Mg ha⁻¹. Dantas et al. [20], in their study carried out in Mossoró city with irrigated watermelon cultivation with different soil coverages, found maximum and minimum yields of 93.1 Mg ha⁻¹ and 72.2 Mg ha⁻¹, respectively.

The lower watermelon productivity was observed in the soil without cover for the M1 irrigation depth. Negreiros et al. [21] while analyzing the yield and quality of the melon under irrigation depths and soil cover, found that there was a 51.5% increase in fruit yield with the use of ground cover when compared to uncovered soil. Medeiros et al. [22] evaluated the yield aspects of melon as a function of irrigation depths and soil cover in the city of Baraúna and they found a 14% higher productivity when the soil is covered by black mulch compared to the uncovered soil.

The highest watermelon yields were obtained in the soil covered by white mulching for the M4, M2 and M3 irrigation depths. It is possible to suggest that the positive relation of the use of white mulching in the soil cover in the increase of the productivity of the watermelon crop, mainly due to the retention of humidity. Carvalho et al. [23] found that the water reduction can contribute substantially to the decrease of watermelon productivity in certain phenological stages of the crop.

A lower watermelon productivity of 38 Mg ha⁻¹ was observed with the application of the lowest irrigation depth in the soil without any cover. This yield reduction has a physiological explanation, because according to Azevedo et al. [11], the water deficit can cause a marked decrease in physiological activities, mainly in the division and growth of the cells and, consequently, in the growth of the crops. This deficiency can also cause the stomata to close, decreasing the intracellular concentration of CO₂, generating a decrease in its assimilation, damaging the crop yield.

In the productivity analysis, with white mulching, rice husks and black mulching, in descending order, gave the best results. This demonstrates the technical advantage of using these mulches as soil cover in watermelon cultivation.

Soil coverages with polyethylene films have led to an increase in growth and productivity in several crops [24]. In addition to the efficiency of the coverages, deficit irrigation calculations using ISAREG proved to be effective in irrigation management.

Number of fruits per plant, average fruit weight and average productivity in Second (2nd) cycle

From the Analysis of Variance (Table 2), a significant effect (P <0.01) was observed for the interaction between irrigation depths versus soil cover, for the following analyzed variables: number of fruits per plant, average fruit weight and average productivity.

Table 2. Summary of Analysis of Variance and significance levels for the variables: number of fruits per plant (NFP), average fruit weight (AFW) and average productivity (AP) – 2nd cycle

VS	DF	Medium Square		
		NFP	AFW	AP
Irrigation depths (I)	3	0.13667**	2.20917**	302.64229**
Residue (a)	12	0.00917	0.06667	0.46146
Covers (C)	3	0.63000**	14.78250**	2119.70562**
Interaction I x C	9	0.09000**	2.52694**	446.77840**
Residue (b)	36	0.01139	0.08444	0.33521
Total	63	-	-	-
CV % (I)	-	6.90	4.23	1.09
CV % (C)	-	7.69	4.76	0.93

VS= Variation source; DF = Degree of freedom; CV= coefficient of variation; ** = Significant at 1%

The regression analysis (Figures 3A and 3B) showed the polynomial effect on the number of fruits per plant and the average weight of the fruits of the watermelon.

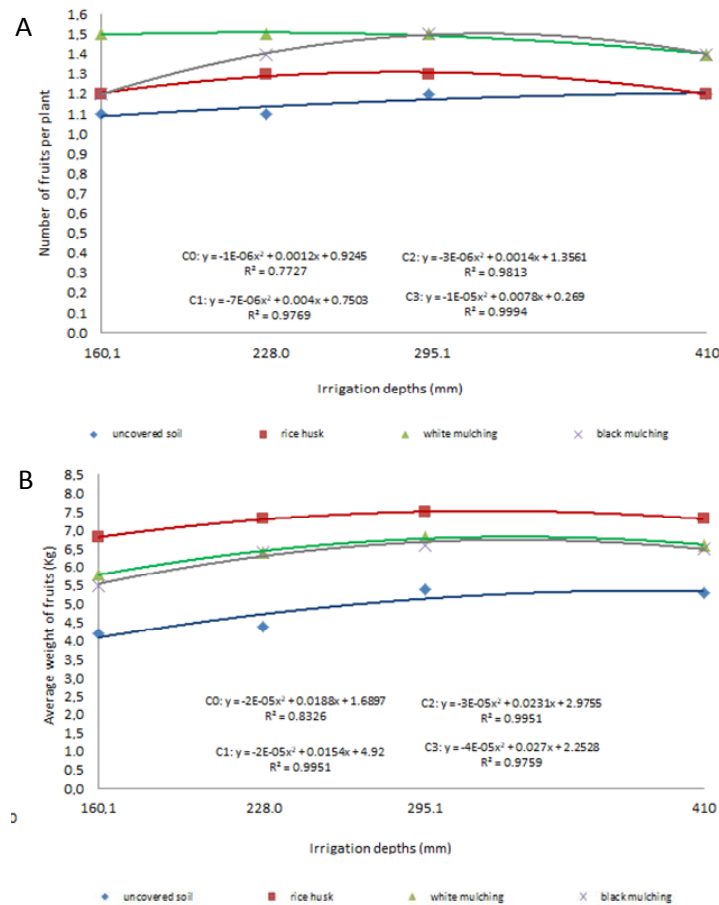


Figure 3. Influence of irrigation depths and soil cover conditions on the number of fruits per plant (A) and average fruit weight (B) of watermelon, during the second cycle.

The same tendency of the first cycle of watermelon was verified for the interactions between irrigation depths and soil cover (Figure 3A).

As in the analysis of the first cycle of watermelon, the combinations of soils covered by "mulching" (white and black) generated better results, that is, a greater number of fruits per crop. However, in the uncovered soil condition, regardless of the applied irrigation depth, the number of fruits per watermelon plant was lower (1.1), with the lowest amount of fruits per crop being observed. Similar results were observed by Lima Junior and Lopes [10].

The combination of the irrigation depth M1 in a soil covered by white mulching resulted in the highest number of fruits per crop (1.5). Dantas et al. [20], in their study carried out in Mossoró city, with irrigated watermelon cultivation and in different soil coverages, showed that the maximum number of fruits per watermelon equal 2.0. This increase can be explained by the higher plant spacing used. The lowest numbers of fruits per watermelon plant (1.1) were obtained with the lowest irrigation depth (160.1 mm) in the soil without cover. A similar result to that obtained in this study was also observed by Medeiros et al. [22], who, when analyzing the influence of irrigation slides on the production of Cantaloupe melon, observed that the reduction of the irrigation depth determined the reduction of the number of total fruits and the number of fruits for the domestic market.

The regression analysis of Figure 3B shows that the different irrigation depths, in the absence and presence of soil cover, promoted a polynomial effect on the average weight of the watermelon fruits. Lopes et al. [15] analyzing the influence of black and white mulchings on the productive characteristics of vegetables, verified an interactive effect among the variables analyzed by them. Research has shown higher yields with mulching, especially with increasing soil water in arid and semi-arid conditions [25, 26].

Regarding the soil cover used in the second cycle for watermelon cultivation, as well as in the first cycle, the heavier fruits were obtained in the combinations with rice husk and the lighter ones in the soils without cover. Among the soils covered by plastic, better results were verified with the use of white mulching. This result also demonstrates the effectiveness of plastic coverings in watermelon cultivation. Silvernail et al. [27] while investigating the effect of mulching on the watermelon production characteristics in the state of Kentucky concluded that the plastic cover provided higher average fruit weights when compared to other non-plastic coverings.

The combination of the M1 irrigation depth (295.1 mm) in a rice husk soil resulted in the highest average fruit weight (7.5 kg). Andrade Júnior et al. [28], in a similar research carried out in Piauí, found that the average weight of the watermelon fruit to be around 8.0 kg for the largest applied irrigation depth. Conclusion shared by Santos et al [29], on the influence of irrigation on the watermelon production, suggests heavier fruits with the increase of the applied water blade. Dantas et al. [20], investigating the yield and quality of the watermelon cultivated under agrotexile plastic coverings, showed that the lowest mean fruit weight in watermelon happened in the control, whose soil was not covered.

In general, the fruits harvested in the second cycle showed higher average weights than those of the first cycle, since even though it is known that water is not the only limiting factor for fruit growth, this behavior may have its cause in the climate (less evapotranspiration) of the second cycle, resulting, among other factors, in higher moisture retained in the soil. Andrade Júnior et al. [27] in their nutritive composition of watermelon showed that the fruits contained 92.6% water. Therefore the mass of the fruits is quite related to the water content, which makes the production of this crop quite dependent on water.

Through the regression analysis of Figure 4 the polynomial effect was verified under the average productivity of the watermelon.

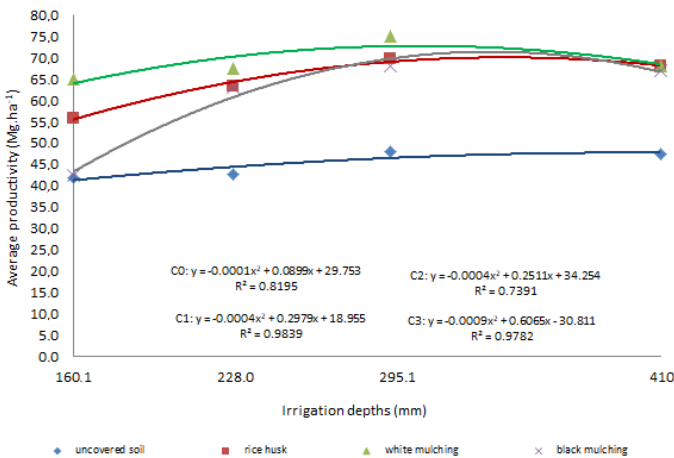


Figure 4. Influence of irrigation depths and soil cover conditions under the average yield of watermelon crop during the second cycle.

The highest watermelon yield was observed in the soil with white mulching cover (75.0 Mg ha⁻¹) with the M1 irrigation depth and the maximum productivity (73.66 Mg ha⁻¹) was obtained with an applied irrigation depth of 314 mm. Andrade Júnior et al. [28], in a similar research carried out in Piauí, observed maximum and minimum productivity of watermelon to be 95.28 Mg ha⁻¹ and 74.57 Mg ha⁻¹, respectively. The lowest watermelon productivity was observed in the soil without cover (47.9 Mg ha⁻¹) for the same irrigation depth. Andrade et al. [30] conducted an experiment with Cantaloupe melon with soil cover, and identified that, with the exception of brown plastic, all other plastics provided superior yields to the uncovered soil.

The M3C0 combination showed the lowest productivity with a value of 41.9 Mg ha⁻¹. This may have occurred due to the water deficit provided by the lower irrigation depth and the uncovered soil. Fernandes and Prado [31] observed that watermelon is not very resistant to soil water deficit, since

frequent irrigation along the crop cycle significantly increased fruit yield. Several factors may influence fruit development, however, the cell cycle process is a function of cell division and cell expansion, and the presence of water is of great importance for this occurrence [32]. In comparison, Azevedo et al. [33], investigating the watermelon, obtained a maximum and minimum yields of 67.5 Mg ha⁻¹ and 46.6 Mg ha⁻¹, respectively.

By analyzing the obtained values, in comparison with the results of the first cycle, it could be concluded that, independently of the coverings, that the larger the applied irrigation depth, the greater the productivities. Inclusively, Santos et al. [28], investigating the influence of irrigation depths on watermelon production, found that there is a direct and positive relationship between the applied irrigation depth and the watermelon productivity, because in the comparison between the plants irrigated under 100 mm and 500 mm irrigation depths, the authors observed an increase of about 13.1 Mg ha⁻¹ in average productivity. However, the soil of this experiment has less drainability than the experiment of the aforementioned authors.

As occurred in the first cycle, watermelons cultivated in soils with coverings reached higher yields, the reverse occurring in the condition of the uncovered soil. Silvernail et al. [26] researched the effect of "mulching" on the watermelon production characteristics. They concluded that plastic cover provided higher yields when compared to other non-plastic coverages or uncovered soil.

The ISAREG model proved to be effective as a strategy in irrigation simulations with deficit. It was verified that the management of irrigation practiced by the farmers, mainly regarding the waste of water, is not the ideal, because, throughout the cycle of the watermelon, the farmer applied more water than the need of the crop. Saraiva et al. [5] obtained similar results when simulating the ISAREG model to analyze the irrigation management of the watermelon crop in Acaraú - CE.

4. CONCLUSION

The farmers don't practice the correct irrigation management, because they apply more water than the indication of the highest irrigation depth (100% of the available water capacity) by ISAREG model throughout the watermelon cycle. In general, plants irrigated by the M1 irrigation depth and on soils covered by rice husk and white mulching showed better productive characteristics.

REFERENCES

1. Barbosa, FC. Estimate of the irrigation necessities and evaluation of the impact of the collection for the use of water resources in the Low Jaguaribe Basin - CE. (Masters dissertation). 148p. Fortaleza, CE. Federal University of Ceara, 2005. Portuguese. Available: <http://www.repositorio.ufc.br/handle/riufc/17986>
2. Pereira, LS. Water requirements and irrigation methods. Published in Europe and America. 300p. Lisboa-Portugal. 2004. Portuguese.
3. Léo, LFR; Hernandez, FBT. Irrigation in irrigated agriculture. São Paulo-SP. 2007. Portuguese.
4. Jobim, C. I.; Louzada, J. A. Avaliação de desempenho do modelo ISAREG de simulação de balanço hídrico. Porto Alegre, RS. Pesquisa Agropecuária Gaúcha. V. 15, n. 2, p.91-98, 2009.
5. Saraiva, KR; Bezerra, FML; Souza, F; Camboim Neto, LF. Using "ISAREG" on irrigation management in watermelon cultivation in the Baixo Acaraú, Ceará. Revista Ciência Agronômica, v.44, n.1, p.53-60, 2013. Portuguese. Available: <http://ccarevista.ufc.br/seer/index.php/ccarevista/article/view/1901/772>
6. Pereira, J.; Peres, JRR. Management of organic matter. In: Cerrado Soils - technologies and management strategies. São Paulo: Nobel/Brasília: Embrapa- CPAC, 1986. p. 270-278. Portuguese.
7. Fernandes, CNV. Frequency of irrigation and fertigation with nitrogen and phosphorus in the culture of watermelon. (Masters dissertation). 79p. Fortaleza, CE. Federal University of Ceará, 2012. Portuguese. Available: <http://www.repositorio.ufc.br/handle/riufc/17736>
8. Allen, RG; Pereira, LS; Raes, D; Smith, M. Crop evapotranspiration: guidelines for computing crop water requirements. Rome: FAO, 279p. (FAO, Irrigation and Drainage Paper, 56). 1998. English. Available: <http://www.fao.org/docrep/x0490e/x0490e00.htm>

9. Bernardo, S. Irrigation Manual. 6th ed. Viçosa: Ed. UFV, 1995. 656p. Portuguese.
10. Lima Junior, JA; Lopes, PRA. Soil covers and irrigation in the production of watermelon. Semina: Ciências Agrárias, v.30, n.2, p.315-322, 2009. Portuguese. Available: <http://www.uel.br/revistas/uel/index.php/semagrarias/article/view/2585/2244>
11. Azevedo, BM; Bastos, FGC; Viana, TVA; Rêgo, JL; D'ávila, JHT. Effects of irrigation levels in the crop of the watermelon. Revista Ciência Agronômica, v.36, n.1, p.9-15, 2005. Portuguese. Available: <http://ccarevista.ufc.br/seer/index.php/ccarevista/article/view/4061/1057>
12. Marouelli, WA; Braga, MB; Andrade Junior, AS. Irrigation in watermelon culture. Technical Circular (Embrapa), n.108, 22p. Brasília, 2012. Portuguese. Available: <http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/942564>
13. Sousa, VF; Marouelli, WA; Coelho, EF; Pinto, JM; Coelho Filho, MAC. Irrigation and fertigation in fruit trees and vegetables. Embrapa Information Technology, 771p., Brasília, DF, 2011. Portuguese.
14. Sousa, JRM; Alvino, FCG; Brito, MEB; Wanderley, JAC; Sá, FVS; AraújoFilho, GD. Growth and production of melancholy submitted to water stress in the semi - arid Paraíba. In: INOVAGRI International Meeting. Annals... INOVAGRI International Meeting e IV WINOTEC. Fortaleza, CE. 2012. Portuguese.
15. Lopes, FB; Souza, F; Andrade, EM; Meireles, ACM; Caitano, RF. Determination of the pattern of irrigation management practices in the irrigated perimeter of Baixo Acaraú, Ceará, by multivariate analysis. Irriga, v.16, n.3, p.301-316, 2011. Portuguese. Available: <http://dx.doi.org/10.15809/irriga.2011v16n3p301>
16. Ramos, ARP; Dias, RCS; Aragão, CA. Quality of watermelon fruits under different planting densities. Horticultura Brasileira, v.27, n.2, p.2182-2188. 2009. Portuguese. Available: http://www.cpatsa.embrapa.br:8080/public_eletronica/downloads/OPB2597.pdf
17. Andrade Júnior, AS; Frizzone, JA; Bastos, EA; Cardoso, MJ; Rodrigues, BHN. Optimal irrigation strategies for watermelon crop. Pesquisa Agropecuária Brasileira, v.36, n.2, p.301-305, 2001. Portuguese. Available: <http://www.scielo.br/pdf/pab/v36n2/a13v36n2.pdf>
18. Batista, PF; Karasawa, M; Silva, MC; Pires, MML; Pimenta, RMB; Aragão, CA. Productivity of watermelon drip irrigated submitted to different plant spacing and irrigation depth. Horticultura Brasileira, v.26, n.2, Supplement - CD Rom, 2008. Portuguese. Available: http://www.abhorticultura.com.br/eventosx/trabalhos/ev_2/a999_t2167_comp.pdf
19. Oliveira, PGF; Moreira, OC; Branco, LMC; Costa, RNT; Dias, CN. Efficiency of use of production factors water and potassium in the watermelon crop irrigated with water of reuse. Revista Brasileira de Engenharia Agrícola Ambiental, v.16, n.2, p.153-158, 2012. Portuguese. Available: <http://www.scielo.br/pdf/rbeaa/v16n2/v16n02a04.pdf>
20. Dantas, MSM; Grangeiro, LG; Medeiros, JF; Cruz, CA; Cunha, APA. Yield and quality of watermelon grown under non woven textile protection combined with plastic mulching. Revista Brasileira Engenharia Agrícola e Ambiental, v.17, n.8, p.824-829, 2013. Portuguese. Available: <http://www.scielo.br/pdf/rbeaa/v17n8/04.pdf>
21. Negreiros, MZ; Costa, FA; Medeiros, JF; Leitão, VBRMM; Bezerra Neto, F; Espínola Sobrinho, J. Yield and fruit quality of melon cultivated under irrigation depths and coverage with polyethylene film of different colors. Horticultura Brasileira, v.23, n.3, p.773-779, 2005. Portuguese. Available: <http://www.scielo.br/pdf/hb/v23n3/a17v23n3.pdf>
22. Medeiros, JF; Santos, SCL; Câmara, MJT; Negreiros, MZ. Melon yield and fruit quality as influenced by soil coverages, agrotexile and irrigation depth in dry season. Horticultura Brasileira, v.25, n.4, p.538-547, 2007. Portuguese. Available: <http://www.scielo.br/pdf/hb/v25n4/a09v25n4.pdf>
23. Carvalho, LCC; Bezerra, FML; Carvalho, MAR. Evapotranspiration and crop coefficients of seedless watermelon. Revista Ciência Agronômica, v.39, n.01, p.53-59, 2008. Portuguese. Available: <http://ccarevista.ufc.br/seer/index.php/ccarevista/article/view/24>
24. Moraes, NB; Bezerra, FML; Medeiros, JF; Chaves, SWP. Response of watermelon cultivated under different levels of water and nitrogen. Revista Ciência Agronômica, v.39, n.3, p.369-377, 2008. Portuguese. Available: <http://ccarevista.ufc.br/seer/index.php/ccarevista/article/view/74/69>
25. Huang, YL; Chen, LD; Fu, BJ; Huang, ZL; Gong, J. The wheat yields and water-use efficiency in the Loess Plateau: straw mulch and irrigation effects. Agricultural Water Management, v.72, n.3, p.209-222, 2005. English. Available: <https://doi.org/10.1016/j.agwat.2004.09.012>
26. Zhang, SL; Lo`Vdahl, L; Grip, H; Tong, YA; Yang, XY; Wang, QJ. Effects of mulching and catch cropping on soil temperature, soil moisture and wheat yield on the Loess Plateau of

- China. Soil and Tillage Research, 102, p.78-86, 2009. English. Available:
<https://doi.org/10.1016/j.still.2008.07.019>
27. Silvernail, A; Bomford, M; Harvey, B. Alternatives to plastic mulch for organic watermelon production. Kentucky Academy of Science Meeting, Agricultural Sciences Section. Morehead, KY. 2006. English.
28. Andrade Júnior, AS; Dias, NS; Lira, RB; Figueredo Junior, LGM; Daniel, R. Frequency of nitrogen and potassium application through irrigation water by drip in the watermelon culture in Parnaíba, PI. Agropecuária Científica no Semi Árido, v.03, p.01-07, 2007. Portuguese. Available: <http://dx.doi.org/10.30969/acsa.v3i1.1>
29. Santos, GR; Leão, EU; Gonçalves, CG; Cardon, CH. Potassium fertilizer and irrigation management in the progress of fungal diseases and yield of watermelon. Horticultura Brasileira, v.31, p.36-44, 2013. Portuguese. Available:
<http://www.scielo.br/pdf/hb/v31n1/v31n1a06.pdf>
30. Andrade, PCSG; Negreiros, MZ; Medeiros, JF; Lima Júnior, OJ; Santos, SCL; Bezerra Neto, F; Lisboa, RCC. Production of Cantaloupe melon cultivated with different soil cover and irrigation depths. Horticultura Brasileira, 22, Supplement - CD ROM. 2004. Portuguese.
31. Fernandes, FM; Prado, RM. Fertigation of watermelon culture. In: Baretto, AE; Villas Boas, RL; Souza, WF; Parra, LRV. Fertigation: theory and practice. Piracicaba, v.1, p.632-653, 2004. Portuguese.
32. Taiz, L; Zeiger, E. Plant physiology. Porto Alegre, RS, Artmed. 918p. 2013. Portuguese.
33. Azevedo, BM; Fernandes, CNV; Nascimento Neto, JR; Viana, TVA; Vasconcelos, DV; Fernandes, CND. Frequency of fertirrigation with phosphate in watermelon culture productivity. Irriga, v.21, n.2, p.257-268, 2016. Portuguese. Available:
<http://dx.doi.org/10.15809/irriga.2016v21n2p257-268>