IRRIGATION LEVELS AND SOIL COVERS IN CARROT CROP

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Abstract

To increase the sustainability of irrigated cultivation, the use of soil coverings can favor the reduction of water consumption. Thus, the aim of this research was to characterize the carrot collection (cultivar Brasília) grown under different irrigation water depths and different soil cover conditions. The experiment was conducted at the Federal University of Viçosa, MG. The experimental design was a randomized block in a factorial scheme. Five percentages of the water capacity of the soil (20, 40. 60, 80 and 100%) were applied using tensiometry, and three cultivation environments without cover (control), white colored polyethylene, and biodegradable semi kraft paper. Soil and leaf temperature, number of plants, root length, Normalized Difference Vegetation Index (NDVI) and fresh root mass were evaluated. Then, the analysis of variance was performed using the F test. For comparison of means, the Tukey test ($P \leq 0.05$) was used. For the regression analysis, the equation with the largest significant fit was chosen. According to the results, the use of semi kraft paper is an option in the cultivation of carrots. The use of semi-kraft paper is an option for growing carrots better than white polyethylene. Levels up to 60% of the actual water capacity in the soil showed positive results in the carrot production.

Introduction

A carrot (*Daucus carota* L.) is one of the most important vegetables on the world stage, due to its large area of planted and for enabling the socioeconomic development of farmers (1) since the return on invested capital is relatively quick. In addition, this root vegetable has high nutritional value, as it contains vitamins, fibers, minerals and other phytochemicals, which can be beneficial for cancer prevention (2)(3)(4).

Brazil is the fifth largest world producer of carrots (5) and the crop is considered one of the four most important vegetable crops in the country. In 2017, the world production of carrot was 42,831,598 tons (6) in Brazil alone, the 2018 harvest reached about 14,077 kg ha, with emphasis on the state of Minas Gerais (7).

The irrigation of carrots, like most vegetables, increases and improves the quality of the product, moreover, it is an important factor in determining the production (5).With an adequate application of the amount of water, the water needs of the harvest are supplied, reducing the proliferation of pests, diseases and leaching of nutrientes (8). Hence, irrigation planning and management must be adopted to obtain maximum efficiency and preserve the carrot's high economic value in the market (9).

In order to favor the reduction of evapotranspiration and, thus, reduce the irrigation necessary for agricultural crops, some soil coverings can be used. The technique of covering the soil with organic or inorganic materials forms a physical barrier to limit evaporation of water from the soil, it also maintains a good soil structure and protect crops from contamination in contact with the soil (10).

According to (11) soil cover with polyethylene film is still the most used in vegetables by producers and this is due to the relatively low price of polymer materials and durability. Despite this, there are several types of paper with potential for use as soil cover, among which stand out the alternative papers, such as semi-kraft, recycled, paper for printing newspapers and paper produced from cane straw sugar (12). In this context, studies related to this technique can make it possible to increase production in a sustainable way. The objective of this research was to evaluate the biophysical parameters of carrots grown under different levels of irrigation and different conditions in the soil cover.

Materials and methods

Experimental site

The experiment was conducted in the Experimental Area of Irrigation and Drainage, belonging to the Department of Agricultural Engineering of the Federal University of Viçosa (DEA / UFV), in Viçosa-MG. Located at 20° 45 ’S latitude, 42° 52’ W longitude and 648 m altitude. The experiment was conducted between the months of August and November 2019.

The climate of the region, according to Köppen, is of the “Cwa” type, tropical altitude, with rainy summer and dry winter. The experiment was developed between the months of August and November 2019. The soil in the experimental area is classified as Red-Yellow Argisol, with a granulometric distribution of 46% clay, 39% sand and 15% silt. The density of the soil in the layers of 0-0.20, 0.20-0.40m is 1.3 g / cm3. Field capacity is 36.8%, and the wilt point is 19.5% according to the soil water retention curve made in the area.

Plant material and experimental design

The experimental design was in randomized blocks with four replications, in a 5 x 3 factorial scheme, totaling 60 experimental plots. Five percentages of the water capacity of the soil (20, 40. 60, 80 and 100%) and three cultivation environments without cover (control), white colored polyethylene, and biodegradable semi kraft paper.

In the experimental area, 5 seedbed were made with dimensions of 12.0 m x 1.0 m x 0.3 m in length, width and height, respectively. Fertilization, based on soil analysis, was carried out following a fifth approach to the use of correctives and fertilizers from the State of Minas Gerais described by (13)

The cultivar used was Brasília, which has high field resistance to leaf burning. At the seedbed, the spacing between rows was 0.30 m and sowing was carried out with 3 seeds per hole at 0.10 m deep in the soil, with a spacing of 0.10 m between plants. Thinning was carried out after the culture was established at 0.10 m in height.

Irrigation management and Water consumption

The irrigation levels (20; 40; 60; 80 and 100%) based on the actual water capacity in the soil, were equivalent to 4.54; 9.04; 13.56; 18.08 and 22.6 mm, respectively. The drip system used was the irrigation system. The uniformity of water distribution by the emitters under field conditions was evaluated. Irrigation management was carried out by tensiometers that was installed at a depth of 0-0.10 and 0.10-0.30 m. The tensimeter reading was converted to soil moisture through the soil water retention curve, obtained by the Richards chamber method. The Van Genuchten model (14) was adopted. The irrigation age calculated for each treatment according to Equação 1.

$$I = \frac{(\theta cc - \theta a) \times Z}{Ie} \quad (1)$$

Where, I - irrigation level, mm ; θcc -soil volumetric density with field capacity, $m^3\ m^{-3}$; θa - current volumetric soil moisture before irrigation, $m^3\ m^{-3}$; Z - irrigated soil layer, mm; Ie - Field irrigation system efficiency, 0.99.

The actual water consumption during the carrot cycle was calculated based on equation 2 of the soil water balance of (15).

$$WU = (P + I) - (R_0 - Dep + Dr) \quad (2)$$

Where, WC is water consumption (mm), P is precipitation (mm), I is the amount of irrigation water applied (mm), R0 is capillary increase (mm), Dep is the depletion of soil moisture (mm); Dp is superficial runoff (mm).

In this method, the depletion of soil moisture (Dep) between the sampling intervals was calculated keeping in mind the amount of irrigation (I) and precipitation (P), if there is between the intervals and then the integration during the period of cultivation. The R0 was considered null because the water table was more than 15 meters below the surface, Dp was also assumed to be insignificant because an experimental area is flat.

Soil temperature

After thinning the carrots, data on maximum and minimum temperature and thermal amplitude were collected daily. Every 30 minutes, digital sensors, model DS18B20 with an accuracy of ± 273.5K in the range of 272.9K to + 358K, previously installed in the center of 15 experimental plots, collected the temperature data and stored in dataloggers.

Agronomic variables

The evaluations were carried out in five plants on the central line of each experimental unit. The number of sheets (units) was counted manually. The leaf temperature (K) was estimated by a digital infrared thermometer with laser sight, model ST600, from the INCOTERM® manufacturer (± 275.0 K precision and 273.1 K resolution). During the readings the device was positioned 0,15m away from the leaves.

At harvest, the root length was measured using a millimeter ruler. To measure the root diameter, a caliper (mm) was used. The fresh mass was determined with the aid of an analytical balance with a resolution of 0.01 g.

Data analysis

The data obtained were subjected to analysis of variance through the F test, using the R software, with the Experimental Designer package. The Tukey test ($P \leq 0.05$) was applied to compare the means. For the regression analysis, the most significant adjustment equation was chosen.

Results and discussion

The water consumption during the carrot cycle in five irrigation depths and three types of cover can be seen in Fig 1. For all irrigation depths, the carrot showed higher water consumption when grown in soil without cover (control).

Fig 1. Carrot water consumption (mm) in situations of percentage of the actual water capacity in the soil (CRA) and soil cover.

The situation of 20% of the CRA (L1) had a higher consumption (33 mm) in an environment with no cover (control).In soil with white polyethylene and semi-paper coverage kraft, there was a saving of 0.45 and 0.68 in water consumption when compared to the control situation. This condition have occurred because the cover provided a decrease in the rate of evaporation in the soil and greater water retention in the soil (16).

As the treatments of polyethylene and semi-kraft paper required less water volume during the whole harvest cycle, when compared to the soil without cover (control), this resulted in a reduction in the water resource applied to the crop. (17) and (12) claim that the use of toppings can save water when growing vegetables.

The coverage with polyethylene had the water consumption of the crop superior to the situation of covering with semi kraft paper. This may be related to the fact that the white plastic covering provides greater conversion of energy from solar radiation, increasing the heat flow in the soil (18), therefore, it increases the temperature of the soil and the transpiration of the plant, which will need more water for the photosynthetic processes (19). (20) claim that paper coverage is efficient in saving water and is it comparable to polyethylene film, hence, it can be a suitable alternative to replace it.

The values of the maximum and minimum temperatures, in the depths of 0.05m, were lower in the conditions of covering of the ground with recyclable semi Kraft paper in comparison to the other treatments (Table 2).

Table 2. Soil temperature at 0.05m depth, grown with carrots at different percentages of the actual water capacity in the soil and ground cover

Cover	Temperature (°K)	Irrigation levels in percentage of CRA				
		20	40	60	80	100
Control test	Average	296,17	296,01	296,28	296,24	295,86
	Maximum	298,54	298,60	298,20	298,93	298,58
	Minimum	293,60	293,68	293,73	293,86	291,63
	Range	4,94	4,93	4,47	5,07	6,95
White polyethylene	Average	295,46	273,00	295,53	295,44	296,08
	Maximum	299,81	299,42	298,15	298,19	298,65
	Minimum	294,05	292,50	294,13	294,13	294,46
	Range	5,75	6,92	4,02	4,06	4,19
Semi kraft paper	Average	296,04	294,87	295,22	295,31	294,77
	Maximum	298,58	297,00	296,91	297,94	296,97
	Minimum	293,60	292,04	292,36	294,11	293,59
	Range	4,97	4,95	4,55	3,83	3,38

Table 2 shows that the highest temperature averages were observed for the control treatment, in all applied irrigation depths. However, for maximum and minimum temperatures, it was observed that there was variation according to the blade used in each treatment. The highest temperatures were obtained in the irrigation depths for 20 and 40% of the CRA combined with soil cover with white polyethylene. Meanwhile, the lowest temperatures were observed in the cultivation with irrigation depths of 40 and 60% of the CRA combined with semi-kraft paper. According to (21) this occurs because the coverage with white polyethylene increases considerably the heat flow in the soil, therefore, it increases the temperature of the soil, meanwhile, the paper is not developed in the same way.

According to (19), this is because the coverage with white polyethylene considerably increases the heat flow in the soil, therefore, it increases the temperature of the soil, while the paper is not developed in the same way. Similar results were found in the lettuce culture by (22). (23) who found that the soil temperature was lower when they

used brown Kraft paper, compared to the soil covered with black polyethylene film and without coverage. (24) found that the polyethylene film increased the average soil temperature between 2 and 3º C compared to the soil without cover. (25) working with the pepper culture, found that the soil cover with polyethylene film increased the soil temperature around 2 ºC in relation to the conventional weeding system.

(26)in Japan, (27) in the United States, (28) in Vietnam, and (29) in Mexico, observed that the coverage with black colored polyethylene film provided the highest soil temperatures. Indeed, when covering the soil, there are interferences in variables such as soil temperature, humidity, wind, radiation, energy and, consequently, the evaporation process (30). It is observed that the soil cover does not allow wind and radiation, which are mainly responsible for the evaporation of water, to reach the soil directly, thus having an interception of these parameters by the cover used (31).

The use of soil cover allows to reduce the temperature fluctuation and the evaporative rate of the soils. This can accelerate the development of the crop during the initial growth stage and promoting the control of weeds (18), (32) and (33)

The soil without cover had an average temperature of 296 ° K, with minimums around 293 ° C, this is because the soil had a greater conversion of energy from solar radiation into latent heat, as there is no barrier for water evaporation from the soil. Thus, the temperature of the soil does not decrease as much as the other environments found in this study and remain high during the cycle, with little variation in thermal amplitude. (32) found the greatest variations in thermal amplitude of treatments with plastic soil cover in relation to organic materials.

The agronomic variables of root length, fresh weight the vegetation index by Normalized difference (NDVI) and diameter were influenced ($P < 0.05$) by the soil cover factor (Table 3).

Table 3. Agronomic variables of the carrot (*Daucus carota* L.) submitted to different soil coverings.

Cover	Root length (cm)	Fresh weight (t ha $^{-1}$)	NDVI	Diameter (cm)
Control test	21,95 a	21,501 b	0,68 a	4,79 c
White polyethylene	19,43 b	26,265 ab	0,51 b	5,81b
Semi kraft paper	20,83 a	28,353 a	0,62 a	6,25a
Significance level	**	**	**	**
CV (%)	8,74	26,06	15,95	7,3

The means followed by the same letters in the column do not differ by the Tukey test. Significance level: * (P≤0.05), ** (P≤0.01), ns (not significant)

It was observed that the length of the roots is longer in a situation of soil without cover. However, there is no significant difference between it and the cover with semi kraft paper. The white polyethylene cover provided the lowest root length values, this may be related to the fact that the soil cover reduces the harmful effect of spontaneous plants(34) (35) thereby, probably the carrot grown without cover (control) needs to compete for water and nutrients.

The fresh weight obtained a lower average when subjected to cultivation without soil cover, reaching only 21,501 tons per hectare, and a better average for the cultivation with paper, nevertheless, there was no difference between the three treatments. There are many reports informing the increase in plant growth and the consequent gains in plant yield through the use of plastic coverings (26). (36) studying with water deficit and soil coverings on onion, found that polyethylene improves the recovery of water from the onion harvest.

The diameter is one of the characteristics of the carrot most appreciated by the consumer. In this study, the factores both coverages (Table 3) and irrigation levels (Fig 1) influenced the results of this variable in isolation (p<0,01). The coverage using semi kraft paper obtained the best averages, reaching an average of 6 cm, corroborating with (37).

The irrigation depths factor shows a quadratic behavior, with a tendency to increase the root when submitted to larger depths (Fig 1). The highlight in this variable is the 100% of the CRA (22.6 mm), as the water in the field capacity provided a balanced environment in the soil-plant-water-atmosphere relationship.

Fig 2. Carrot (*Daucus carota* L.) diameter in percentages of soil water capacity

The Normalized Difference Vegetation Index (NDVI) indicates the nutritional status of the plant in relation to nitrogen (38) . The effects found in this work indicate superior results for the treatment with soil without cover and semi kraft paper (table 3), because the higher the value of NDVI, the greater the growth force of the culture (39). This result indicates that there was a difference in reflectance values between the plastic cover and the other treatments. In addition, the vegetation index by Normalized difference (NDVI) was influenced by the irrigation depths (Fig 2), with a decrease in the index as the percentage of water in the soil increases, with a critical point in 76% of the CRA, allowing a maximum point of 0.67.

Fig 3. Vegetation Index of Normalized Differences (NDVI) in carrots (Daucus carota L.) submitted to percentages of soil water capacity

The number of leaves and the leaf temperature (Figs 3 and 4) were influenced ($P < 0.05$) by the irrigation depths. In the commercial market, there is a niche for the sale of carrot leaves and, considering the response of this experiment, it is observed that the maximum point can be reached in the cultivation of carrots irrigation at 83% of the CRA, the result of which will be approximately 7 leaves per plant. These results are different from the one found by (40), where the number of leaves per plant did not differ significantly in irrigation treatments.

Fig 4. Number of leaves in carrots (Daucus carota L.) submitted to percentages of soil water capacity

The leaf temperature had little variation, being around 291.5 to 293 °K, being lower when submitted to the smaller irrigation depth (Fig 4). This result may have occurred because, when water is limited for the crop, the photosynthesis and transpiration processes become less active, so the maximum rate of carbon assimilation can be inhibited by decreasing stomatal conductance and the leaf temperature becomes lower (41).

Fig 5. Leaf temperature in carrots (Daucus carota L.) submitted to percentages of soil water capacity

The temperature of the leaf determines the concentration or pressure of water vapor within the leaf and therefore determines the driving force of transpiration (42). The difference in leaf temperature in plants with and without stress is based on their water status, stomatal behavior and the loss of latent heat through perspiration. Nevertheless, this whole process varies for each species, depending on the intensity and duration of water stress (43).

Conclusions

The irrigation depth of 60% of the real water capacity of the soil can be used in the production of carrots in order to promote water saving and good crop development.

It is recommended to use soil cover with semi-kraf paper in the cultivation of carrots, as it provides thermal comfort even in situations of water stress and helps in the sustainability of the environment.

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Fig 1. Carrot water consumption (mm) in situations of percentage of the actual water capacity in the soil (CRA) and soil cover.

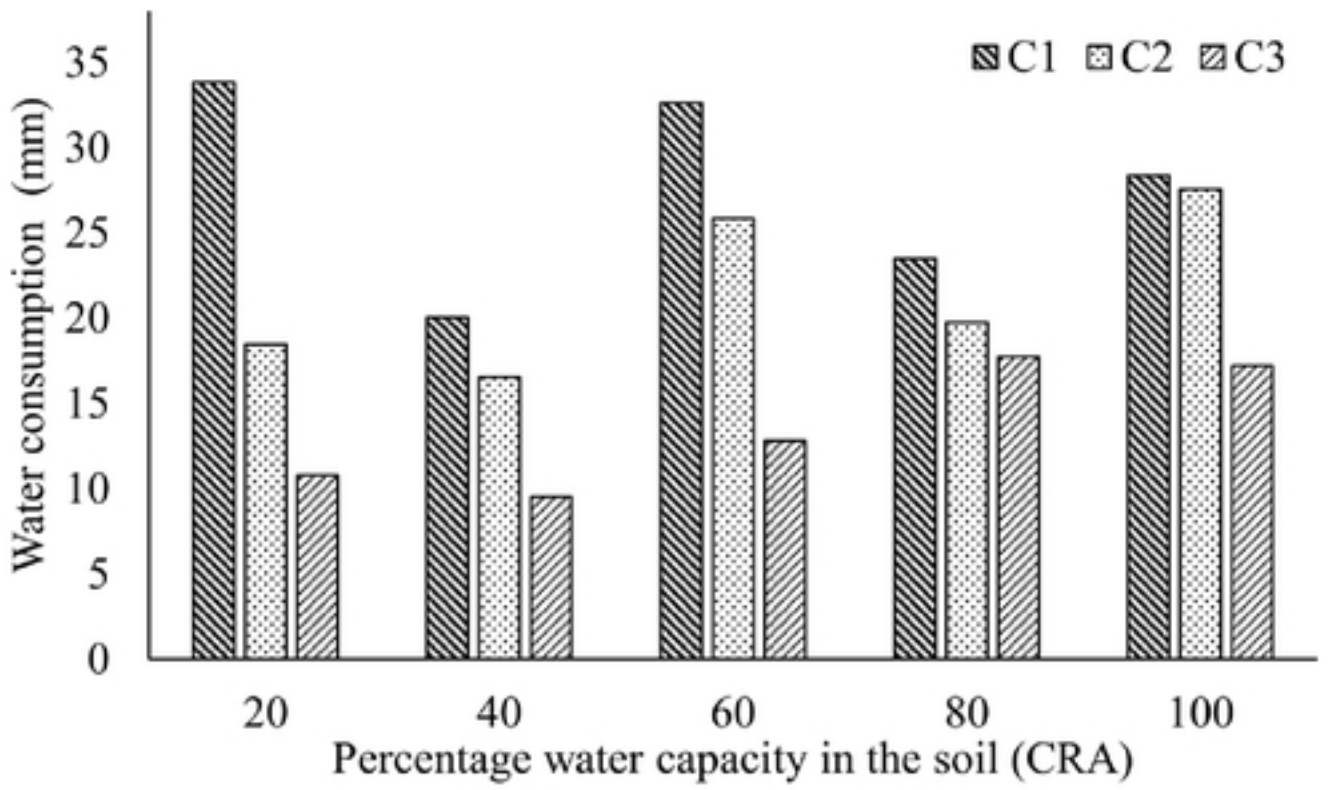

Fig 2. Carrot (*Daucus carota* L.) diameter in percentages of soil water capacity

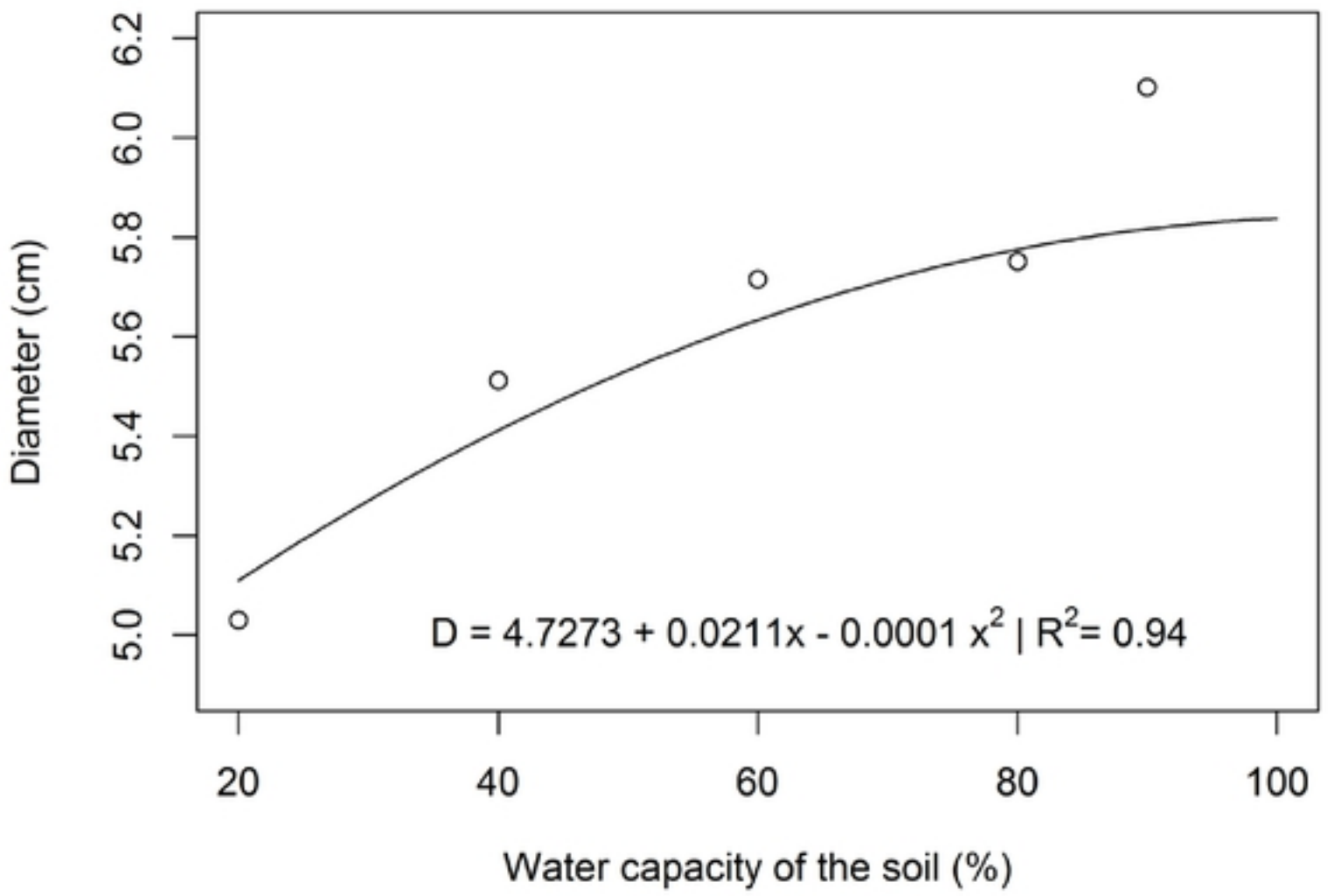

Fig 3. Vegetation Index of Normalized Differences (NDVI) in carrots (Daucus carota L.) submitted to percentages of soil water capacity

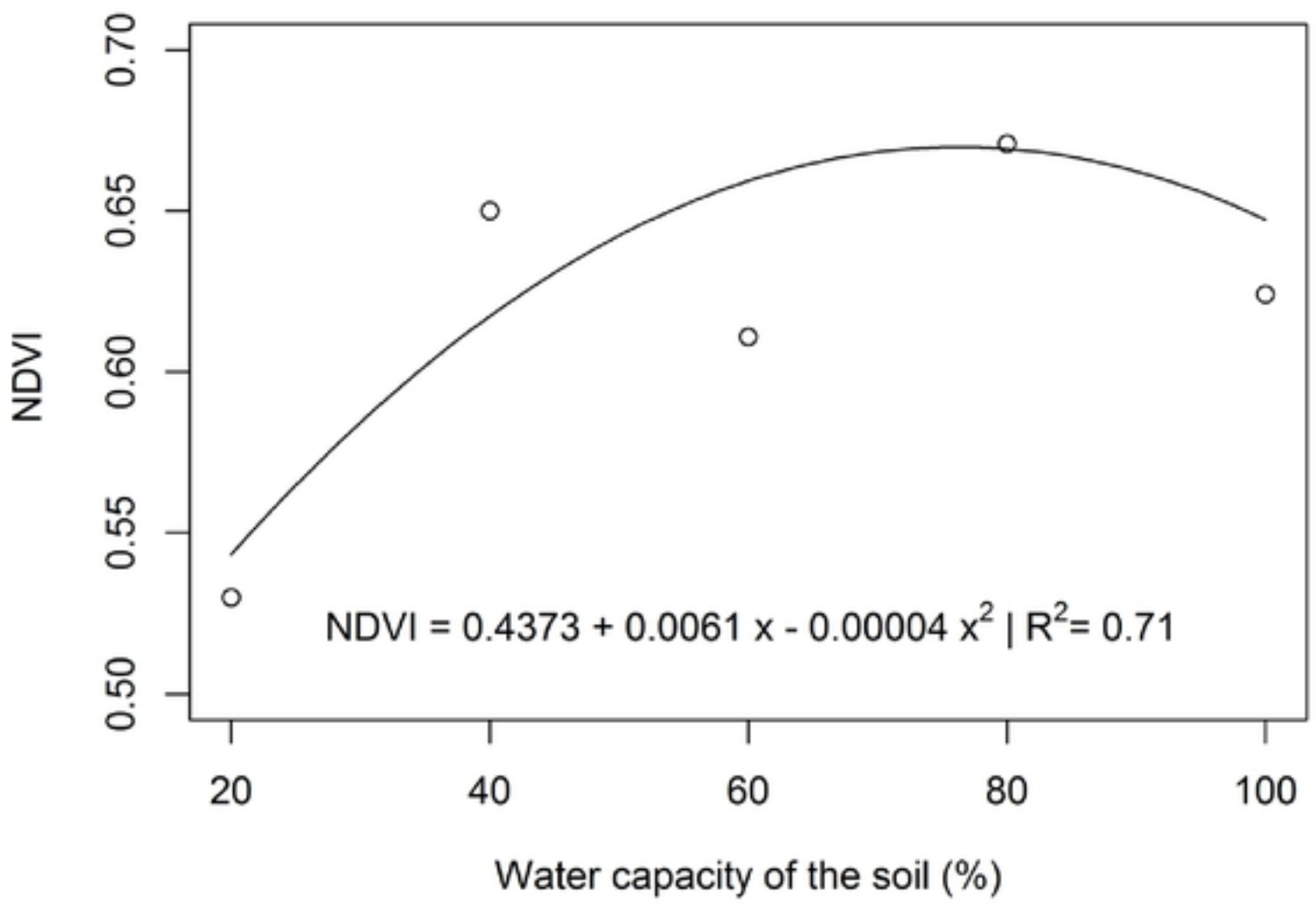

Fig 4. Number of leaves in carrots (Daucus carota L.) submitted to percentages of soil water capacity

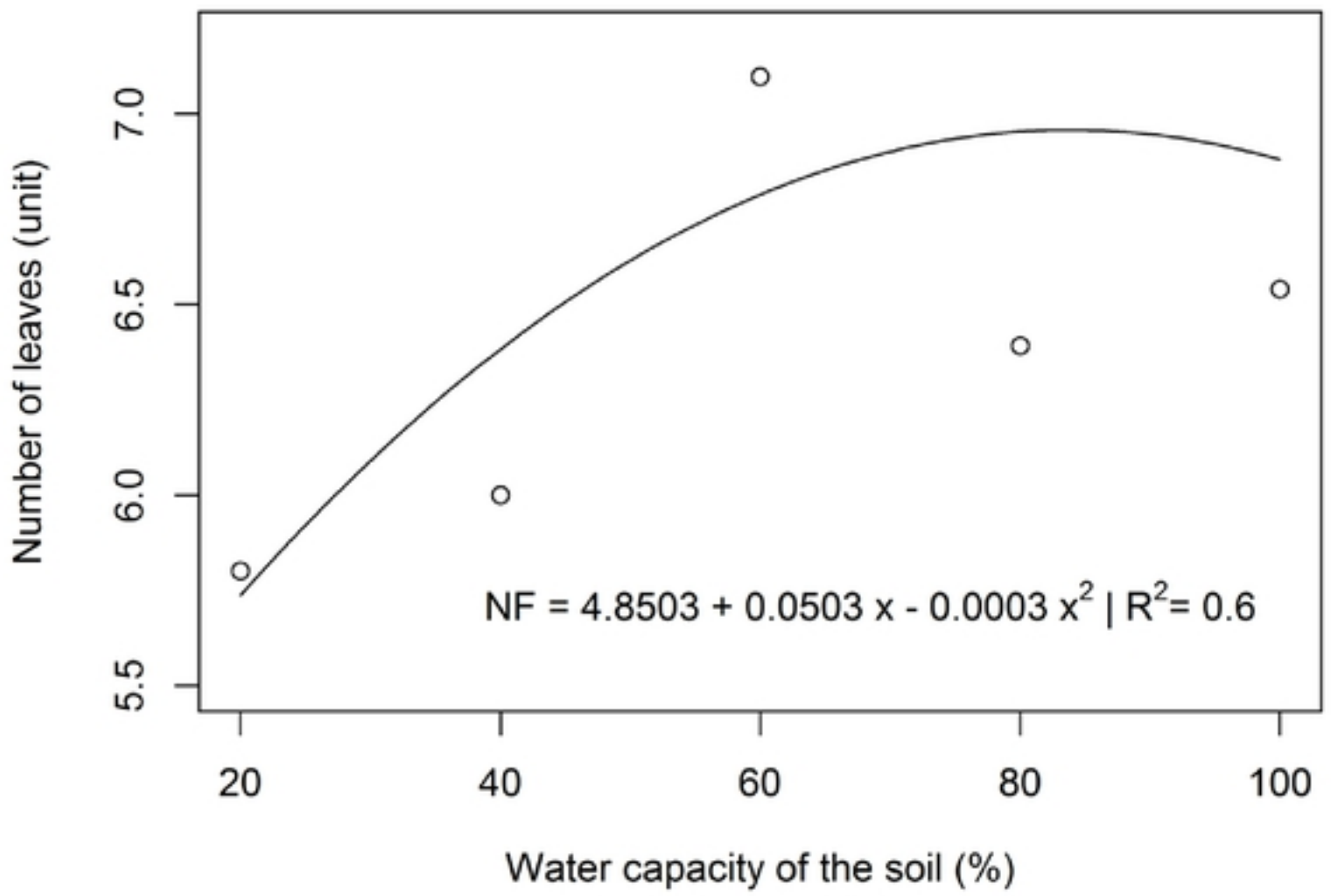
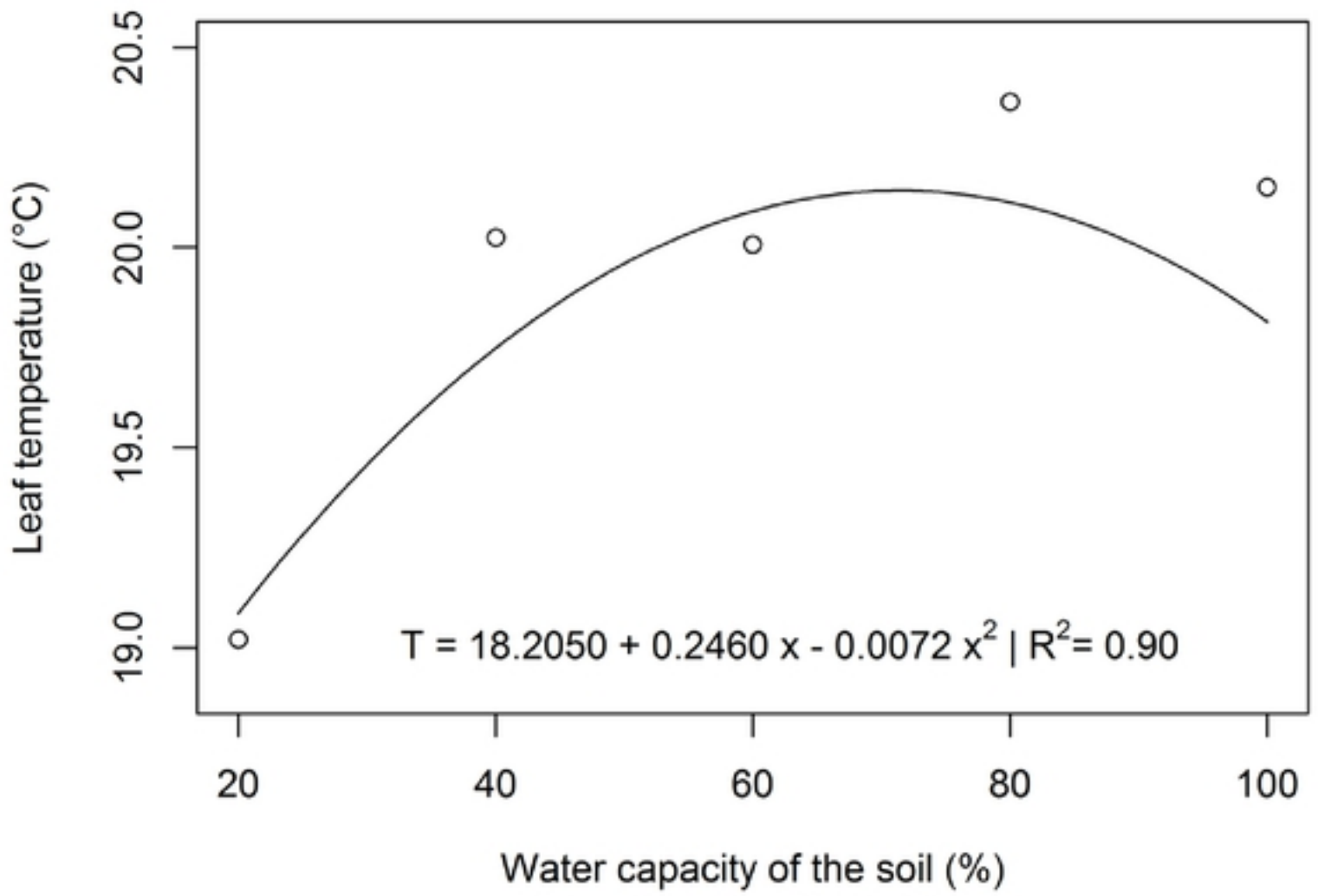
Fig 5. Leaf temperature in carrots (Daucus carota L.) submitted to percentages of soil water capacity