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Determination of irrigation rate for peanuts (*Aracis hypogaea* L.) related to climate changes

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Abstract

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A study was conducted to determine the influence of the change in the irrigation rate on the yield of peanuts for the conditions of Haskovo, Bulgaria. It was established that the mass of fruits and seeds in a plant increases with an increase in the irrigation rate from 280 L/m^2 to 420 L/m^2. For fruits, this increase is 20% for every 70 L/m^2, and for seeds 15% to 21%. The increase in seed yield is insignificant and is within 0.6%. The main influence on the change in the amount of yield, formed by the mass of fruits and seeds in a plant, is the irrigation rate and, to a lesser extent, the conditions of the year expressed by the following day's temperature and precipitation during the vegetation of the crop. The yield of seeds is strongly influenced by the annual conditions and less by the combination of the factors year and irrigation rate. The growth of the masses of fruits and seeds of a plant with increasing irrigation rate, has an exponential character at a sufficiently high value of the determinant.

Keywords: peanuts; yield; irrigation rate; regression models; climate change

Introduction

Climate change is expected to adversely affect crop production worldwide (Lobell et al., 2011; Rosenzweig et al., 2013). Model simulations of agricultural crop production are critical to understanding the impacts of climate change and planning strategies to mitigate yield reductions and food security. Irrigation is critical to food security, economic livelihoods and ecosystem health (Chaves et al., 2003; Flexas et al., 2006). Agricultural production is also the largest consumer of water in the world. Irrigation causes 70% of fresh water consumption and 90% of water consumption. 43% of irrigation water use is from groundwater, the share of which is growing the fastest in absolute and relative terms (Siebert et al., 2010). A number of authors consider the role of irrigation as an adaptive response to climate change (Hansen et al., 2011) and reducing the negative impact of extreme temperatures on production (Schauberger et al., 2017; Siebert et al., 2017; Carter et al., 2016).

Peanut (*Arachis hypogea* L.) is an annual legume crop, that is widely grown in tropical and subtropical regions of Asia, Africa, and North America, which are characterized by high temperature and erratic rainfall (Qin et al., 2012). A significant increase in seasonal temperatures and rainfall anomalies may be detrimental to groundnut growth in the future (Vara Prasad et al., 2003; Eck et al., 2020). Most of the groundnuts in this region are grown under irrigated conditions on sandy or loamy sandy soil, which has a lower water holding capacity. Even peanuts grown under irrigation can experience varying duration and intensity of heat and water stress due to insufficient water supply (Kambiranda et al., 2011; Zhen et al., 2022). Therefore, it is important to understand how peanut yields and irrigation requirements may change under climate change scenarios to allow farmers and policy makers, to determine how to maximize gains and minimize losses (Jin et al., 2018). The level of damage caused to peanuts by water deficit is determined by the intensity, duration of the stress and the phenological stage (Duarte et al., 2013). According to Azevedo et al. (2014), in irrigated agriculture, it is necessary to determine the limiting factors in irrigation management, which directly determine the greater or lesser water consumption, and to determine the water needs of crops according to the different phenological stages. The development cycle of Bulgarian peanut varieties varies from 125 to 135 days, and depending on the climate, their water needs vary from 280 to 320 mm.

The purpose of the experiment is to determine how a change in the irrigation rate during the growing season of peanuts will affect their productive capabilities, and to assess the potential effects of future climate change on peanut production, and a change in irrigation rates in Bulgaria.

Material and Method

Experience design

The experiment was conducted in the period 2021–2023, with the newest variety of peanuts of IRGR – Sadovo, variety Adata, in the city of Haskovo. Plants were sown in 28 m^2 experimental plots. Each trial variant was harvested in four replicates. The irrigation rate for the individual variants was realized with waterings during the active vegetation of the peanuts in the period 15.06–15.08. Each irrigation was carried out with 70 L/m^2, thus to achieve an irrigation rate of 280 L/m^2 4 irrigations were carried out, for 350 L/m^2 five and for 420 L/m^2 six irrigations. Data were collected from the weather station in the area on average daily temperatures and precipitation for the months of May-September, which are elements of the climate in the conditions of the peanut growing season.

Data collection

From each variant, 10 plants were harvested and biometric measurements were carried out on them, to determine the mass of pods per plant, the mass of seeds per plant, and with their help the seed randomness was calculated.

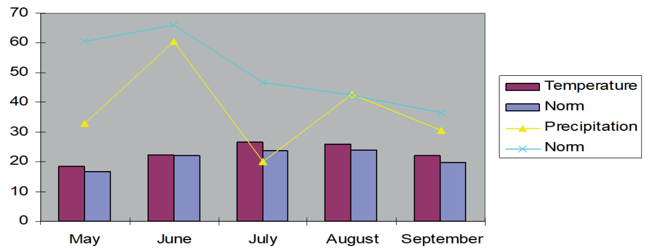
Statistical analyses

Two-factor analysis of variance was used to establish the reliability of differences between individual survey items. Modeling of the obtained occurrence was carried out using regression models.

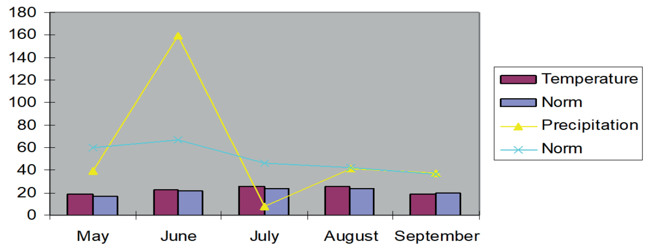
Results and Discussion

The results in Figure 1 shows two of the characteristics of the climatic setting, in which the experiment was performed. It is evident from it that the vegetation of the peanuts takes place with an increase in the average daily temperature, compared to the norm for a period of 127 years by 0.5°C to 1.7°C in the individual months. As a result, the temperature sum increased from 3201.17°C to 3484.2°C over the period of the experiment. Furthermore, the threshold stress level of 27°C according to Mahan et al. (2005) is many times exceeded. The precipitation situation also shows a significant change compared to the norm for the area. It is evident from the graph. that periods of drought followed by large amounts of rain are observed.

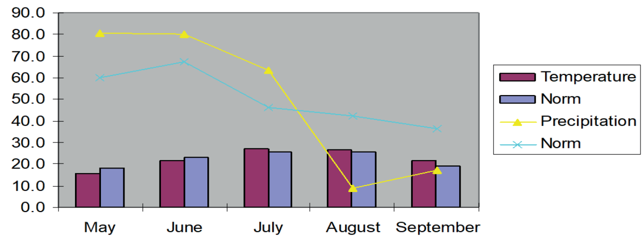
Mass of pods per plant increased with increasing irrigation rate from 280 L/m^2 to 420 L/m^2 with statistically significant differences between them (Table 1). The increase was significant and averaged 20% for each 70 L/m^2 increase in irrigation rate. The obtained results correspond with the re-



Daily average temperature and precipitation 2021



Daily average temperature and precipitation 2022



Daily average temperature and precipitation 2023

Fig. 1. Characteristics of temperature and precipitation for the period of the experiment

sults obtained by (Kheira, 2009; Costa et al., 2007; Geerts and Raes, 2009; Stewart et al., 2011). The highest mass of fruits in a plant within the experiment was realized in 2021. The year with the most extreme and high temperatures, and with sharply expressed drought in the spring and summer season. In this year, the irrigation rate has the highest impact on this indicator. This fact has also been established by the research of Rao et al. (1985), Stansell and Pallas (1985) and Wright et al. (1991).

Table 1. Mass of pods per plant

Irrigation rate, L/m²	Mass of pods, g			
	2021	2022	2023	Average
420	125.6*	109.5*	101.2*	112.1*
350	101.6*	91.9*	86.2*	93.2*
280	85.6*	76.1*	71.8*	77.8*

LSD 0.05%

The differences in the individual variants are a reflection of the influences of the year and the irrigation rate (Table 2). The influence of the irrigation rate factor is stronger, with a higher dispersion, a fact also established by Zhao et al. (2019). The annual influence is weaker and with lower dispersion, and the combination of factors is insignificant and unproven. This is due to the general trend of increasing the mass of fruits per plant in individual years with increasing irrigation rate.

Table 2. Influence of the factors in the experiment on the mass of the pods per plant for the period 2021–2023

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	22961.089	8	2870.136	21.820	0.000
Intercept	801833.611	1	801833.611	6095.992	0.000
Year*	4948.822	2	2474.411	18.812	0.000
IR*	17673.156	2	8836.578	67.181	0.000
Year*IR	339.111	4	84.778	0.645	0.632
Error	10654.300	81	131.535		
Total	835449.000	90			
Corrected Total	33614.389	89			

IR – irrigation rate

The exponential increase in pods mass per plant with increasing irrigation rate is shown in Figure 2. The equation has the following form (1) and the pods mass per plant increases with increasing irrigation rate at high coefficient of determination.

$$Y = 131.6e^{-0.18x}, \quad (1)$$

where: Y – mass of pods per plant;
x – quantity of the irrigation rate.

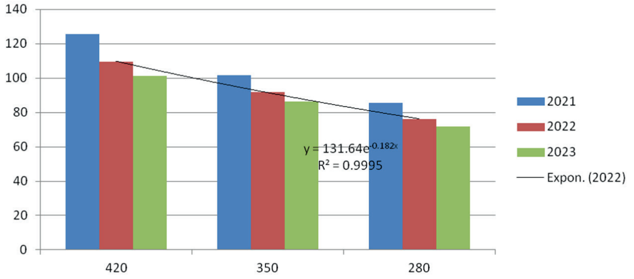


Fig. 2. Mass of pods per plant at different irrigation rates

Seed mass per plant has a linear character with fruit mass and also increases with increasing irrigation rate from 280 L/m² to 420 L/m² with statistically significant differences between them, Table 3. The increase is significant and is between 15% and 21% with each increase in the irrigation rate by 70 L/m². The highest mass of seeds in a plant within the experiment was realized in the same year 2021.

The differences in the individual variants are due to the independent influence of the year and the irrigation rate (Table 4). The influence of the irrigation rate factor is stronger, with a higher dispersion. The annual influence is weaker and with lower dispersion, and the combination of factors is insignificant and unproven. This is due to the general trend of increasing the seed mass of a plant in individual years with an increase in the irrigation rate.

Table 3. Mass of seeds per plant

Irrigation rate, L/m²	Mass of seeds, g			
	2021	2022	2023	Average
420	80.5*	79.4*	67.5*	73.5*
350	63.8*	62.7*	58.3*	60.5*
280	55.4*	54.3*	47.5*	52.4*

LSD 0.05%

The exponential growth of seed mass per plant is identical to that of the exponential growth of pods per plant with increasing irrigation rate, and is shown in Figure 3. Equation (2) also does not change and seed mass per plant increases with increasing the irrigation rate at a high coefficient of determination.

$$Y = 94.54e^{-0.19x}, \quad (2)$$

where: Y – mass of seeds per plant;
x – quantity of the irrigation rate.

Table 4. Influence of factors in the experience on the mass of seeds per plant for the period 2021–2023

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9166.822	8	1145.853	20.562	0.000
Intercept	349939.378	1	349939.378	6279.651	0.000
Year*	987.622	2	493.811	8.861	0.000
IR*	8022.156	2	4011.078	71.979	0.000
Year*IR	157.044	4	39.261	0.705	0.591
Error	4513.800	81	55.726		
Total	363620.000	90			
Corrected Total	13680.622	89			

IR – irrigation rate

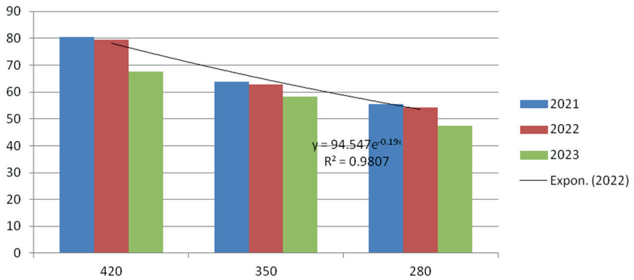


Fig. 3. Mass of seed per plant at different irrigation rates

Seed yield also increased with increasing irrigation rate with statistically significant differences (Table 5). The increase was not significant and was 0.6% in favor of the highest irrigation rate. The highest yield of seeds per plant within the experiment was realized in 2022. This year is characterized by a peak of precipitation in June compared to the 127 annual norm and relatively equal to the norm precipitation in the remaining months of the peanut vegetation. This is the year with the least increase in temperatures during the growing months of the crop.

Table 5. Seed yield per plant

Irrigation rate, L/m^2	Seed yield, %			
	2021	2022	2023	Average
420	63.2*	69.6*	66.7	73.5*
350	61.8*	68.8*	67.7	60.5*
280	63.5*	68.5	66.3*	52.4*

LSD 0.05%

The differences in the individual variants are due to the independent influence of the year and the combination of the irrigation rate and year (Table 6). The influence of the year is stronger, with a higher dispersion. The combined influence between the two factors is weaker and with lower dispersion, and the irrigation rate is insignificant and unproven.

Table 6. Influence of the factors in the experience on the seed yield per plant for the period 2021–2023

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	611.758	8	76.470	34.371	0.000
Intercept	394459.321	1	394459.321	177298.861	0.000
Year*	578.165	2	289.082	129.935	0.000
IR	3.789	2	1.894	0.851	0.413
Year*IR*	29.805	4	7.451	3.349	0.014
Error	180.211	81	2.225		
Total	395251.290	90			
Corrected Total	791.969	89			

IR – irrigation rate

Conclusion

During the period of the experiment, climatic changes are shown related to the average daily temperature and the amount of precipitation during the peanut vegetation. Increasing the irrigation rate for peanuts leads to a proven increase in fruit and seed yield by 15–21%. Within the experiment, such an increase was found with the increase of every 70 l/m^2 of water. The increase in yield is influenced by the size of the irrigation rate and the meteorological conditions of the year related to the average daily temperature and the amount of precipitation during the year. The increase has an exponential pattern, and can be used to calculate the irrigation rate in each specific case.

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