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# IMPACT OF DIFFERENT IRRIGATION REGIMES ON CABBAGE GROWTH

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***Abstract***

*Water is essential for agricultural production and food security. At present and in the future, irrigation will be carry out in condition of water shortage.*
*The field experiments were carry out in 2022 on the Experimental Field of the University of Forestry, located in the Sofia Field, near Vrajdebna village. The soil type is alluvial - meadow with light mechanical composition. The growing crop is a late season cabbage variety Balkan which is the standard variety for Bulgaria. Six variants of irrigation regime was tested, as follow 130%, 100%, 70%, 40% of irrigation rate, without first irrigation during the development stage and without second irrigation during the head formation. Climate, soil moisture, biometric data and yield was measure. The data show the greatest yield in variants without second irrigation. Furthermore, the results show that early drought stress effects can be compensate by an appropriate water supply in later growing stages.*

***Key words:*** *irrigation regime, drought stress, drip irrigation.*

## INTRODUCTION

Bulgaria is located in the temperate continental climate zone, characterized by warm summers and cold winters. According to National Institute of Hydrology and Meteorology report, a temperature increase in Bulgaria between 2 and 5 degrees at the end of the 21st century. The available data for a long period show that the temperature sums during the growing season of the main agricultural crops are relatively stable, its mean that they are not a limiting factor for normal plant development (Stoyanova, R., 2020). However, this is not the case with precipitation. Unsustainable rainfed, predetermination the irrigation as the main factor for obtaining high and sustainable crops yields. Therefore, is need development of efficient and economical irrigation is the key for effective use of limited water resources.

With about 338 genera and more than 3,700 species, the *Brassicaceae* family is one of the major angiosperm families. Cabbage vegetable crops are grown for their valuable nutritional qualities. According to FAO data, about 2.6 million hectares of cabbage are cultivated in the world, from which about 55 million tons of fresh produce are obtained.

Irrigation of late cabbage has a much greater importance for the quantity and quality of the yield. Cultivation of late cabbage can be successfully carried out even with a deficit irrigation regime. In addition, a deficit irrigation strategy is a practice allows crops to maintain some degree of water deficit with insignificant yield loss (Abdelkhalik, A., 2019). This has the potential to increase water use efficiency and save water. It is expected that deficit irrigation would be applied to a wide variety of crops and in more regions, especially in arid and semiarid climates around the world.

In literature, there are a large number of studies aimed at establishing the net irrigation requirement of cabbage crops (Zavadil, J., 2006; Ayas, S., 2019). Yordanova, M., 2013 made an experiment with cabbage, testing three different rate of drip irrigation. The author found that the cultivation of cabbage for late field production, with a reduction in the irrigation rate (60% m), leads to a decrease in yields of 4-16%, depending on the weather conditions. Increasing the irrigation rate above the optimum (120% m) does not lead to a directly proportional increase in yields but has a depressing effect and lowers yields by 9 to 18%.

Leskovar D.I. (2014) based on the field experiment made conclusion that deficit irrigation at 75% ETc had little influence on plant size, leaf pigment content, leaf characteristics, head weight and size, except for a moderate reduction in marketable yield.

The aim of study is to establish the influence of different irrigation regimes on influence of deficit irrigation on cabbage growth, head weight, size and yield for the conditions of the Sofia region.

## MATERIALS AND METHODS

The experiment was carried out during the 2022 in the area of the Vrajdebna-Sofia. The soil type is alluvial-meadow. The standard for the Bulgaria variety of cabbage "Kyose" is used. The experiment was carried out using the method of long plots in four replications, with the size of the harvest plots - 12 $m^2$ and the sowing scheme being a two-row strip with an inter-row distance of 70 x 50 cm.

To evaluate the influence of the irrigation regime on growth, development, and yield the vegetation period of cabbage is divided into two sub-periods, namely: "vegetative" and "reproductive".

Different variants of the irrigation regime were tested as follows:

Var. 1. Irrigation with 40% of the irrigation rate determined in the optimal variant.

Var. 2. Irrigation with 70% of the irrigation rate determined in the optimal variant.

Var. 3. Irrigation with full irrigation rate (100% m) - optimal irrigation (control).

Var. 4. Irrigation with an increased irrigation rate (130% m) - determined in the optimal variant.

Var. 5. Without irrigation during the "planting-vegetative growth" period.

Var. 6. Without irrigation during the "head formatting" period.

Irrigation in the optimal variant (var. 3) will be applied when the soil moisture drops to 80% of the field capacity (FC) in the 0-40 cm layer, and the size of the irrigation rate will be determined to moisten the entire active soil layer (0-60 cm). For this purpose, the dynamics of soil moisture will be monitored during 5-7 days using the Gravimetric Soil Moisture Detection (S.G. Reynolds, 1970).

GWC (%) = [(mass of moist soil (g) − mass of dry soil (g)) / mass of dry soil (g)] × 100

The irrigation rate in the optimal variant will be calculated according to a formula (G. Krafti et al., 1969; Z. Stoyanov et al., 1981; G. Georgiev et al., 1991), based on the water balance equation.

The experimental plots will be irrigated with drip hoses, in order to precisely dose the irrigation water. The amount of water delivered to each of the irrigated plots will be measured on an hourly flow rate basis.

Biometric measurements were performed on 10 plants from each plot in four replicates. The diameter and height of the head, average weight per head and yield.

Water content in cabbage head was measuring using the formula (Jin X. et al., 2017):

Water content (%) = (Wf−Wd)/Wf∗100

Where: Wf - fresh weight and

Wd - dry weight.

The amount of precipitation is recorded with a rain gauge in the morning. No fertilization during the cabbage growth was applied.

## RESULTS AND DISCUSSIONS

During the growing season, average daily air temperatures and the amount of precipitation were recorded (Figure 1). The annual amount of precipitation is 613.8 mm, which defines the year as average in terms of precipitation. However, the precipitation during the growing season of cabbage is 269.6 mm, which leads to a good supply of soil moisture, which is around 80-90% of the maximum field moisture capacity for this soil type (21.1 FC).

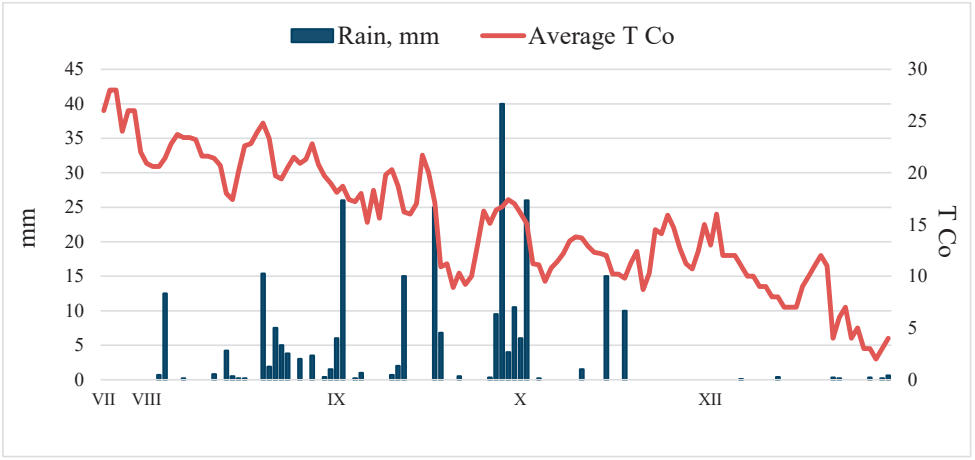


Figure 1. The precipitation and average air temperatures for 2022, filed experiment Vrajdebna

An even distribution of precipitation is observed during the vegetative phase of cabbage development. This is the reason for realizing a smaller number of irrigations. In the month of September, two large rainfalls of 26 and 40 mm were recorded. On 28.09. 2022 y. along with the 40 mm of rain, there was hail the size of a walnut, making it impossible to measure the diameter of the rosette. The large amount of precipitation leads to a reduction in the effect of the applied irrigation regimes. This is also the main reason for obtaining the highest yields in variant 6 (without irrigation during the "head formatting" period).

The average daily temperature ranges between 28ºC at the end of June and 2ºC in November. In mid-September, a sharp drop in temperature was observed, dropping from 21.7ºC to 8.9ºC.

Cabbage was harvested at the beginning of November. The same trend is observed for all reported indicators for the quality of the harvest, the lowest indicators are reported for variant 3 which is optimal, and variant 4 with the increased irrigation rate. This is due to waterlogging of the soil profile, which leads to stress and difficult work for the root system. Yordanova M. (2013) reported a reduction in yield by 9-10% at an irrigation rate of 120% of the optimal rate.

The smallest head height of 17 cm was recorded for variants 3 (100% of the irrigation rate) and var. 4 (130%) of the irrigation rate. In the variant with a reduced irrigation rate, var. 1 (40%) has a height of 19.2 cm, while the highest result is for variant 6 with 19.7 cm. Values in a column are significantly different at $P \leq 0.05$. The statistical analysis of the data showed very good evidence of differences between variants (P=1.08170542218746E-06). The diameter of the head follows the same tendency. Again, the smallest width was reported for variants 3 and 4 (19.4 cm and 18.99 cm), the removal of the irrigation during the second phase of development also had a favourable effect on the width of the head (21.22 cm) (Figure 2).

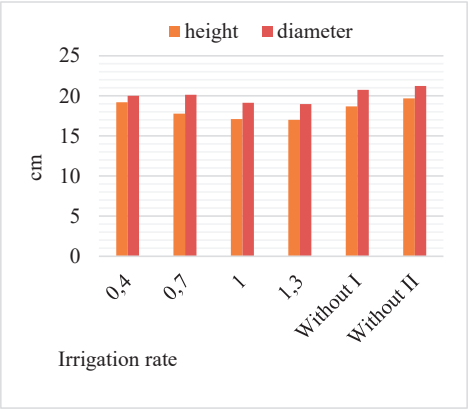


Figure 2. Effect of irrigation rate on the head size of cabbage sp. Kyose 2022

The reported fresh weight of the heads keeps the same trend. The values for variants 3 and 4 are very close and are the lowest for the variants (1.55 kg). The weight of the cabbage heads in variant 6 is 15% greater than that reported in the flooded variant (2.33 kg). The

difference between the variants with 1 (40%) and 2 (70%) is minimal, the values are very close for the parameters of the product part. The results of the Anova statistical program show (P= 7.98331E-06) (Figure 3).

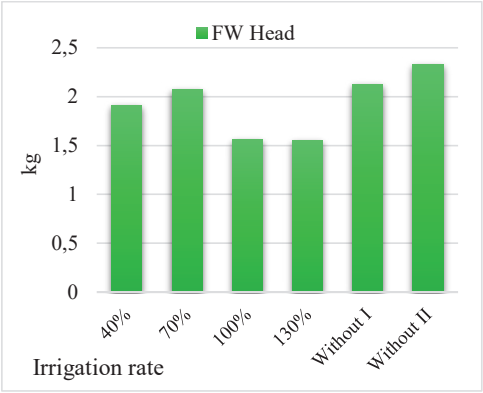


Figure 3. Effect of irrigation rate on the head weight of cabbage sp. Kyose 2022

The best results in the development of the product part of the cabbage variety Kyose are reported in the variant with cancellation of irrigation during the "head formation" period (var.6).

The obtained results for the parameters of quality and quantity of production clearly show the negative impact of waterlogging on white cabbage. In confirmation of this, there are also data obtained from other authors. In studies done on the response of white cabbage to waterlogging, Huđ A, at al 2023, reported that in short-term waterlogging of cabbage, the plants showed signs of stress. The reported data show that plants exposed to a single waterlogging event in the early growth stage were not stressed. While repeated waterlogging in the later stages of development induced a metabolic response in the plants. Casierra-Posada and Cutler 2017 demonstrated that prolonged waterlogging significantly reduced leaf area, total dry weight, chlorophyll content, leaf area ratio, absolute growth rate, and relative plant growth rate.

To determine the absolute dry mass of the productive part of the cabbage, an average sample of 3 heads weighing 300g was taken. The absolute dry mass varies from 24.57 g to 29.6 g. The driest mass is accumulated in var.4 followed by var. 6 (Figure 4).

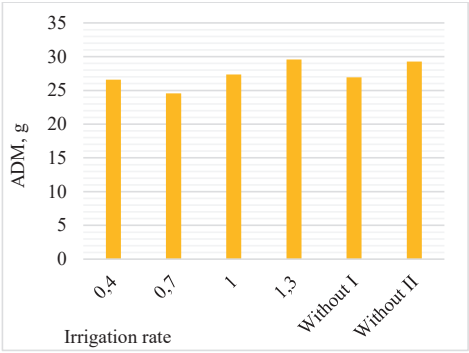


Figure 4. Effect of irrigation rate on the absolute dry mater of cabbage sp. Kyose 2022

The moisture contents of the cabbage samples were opposite those obtained for the dry mass. The highest moisture content is option 2 (70% of the irrigation rate) followed by var.1. The lowest values are for var. 4 followed by var. 6 (Figure 5).

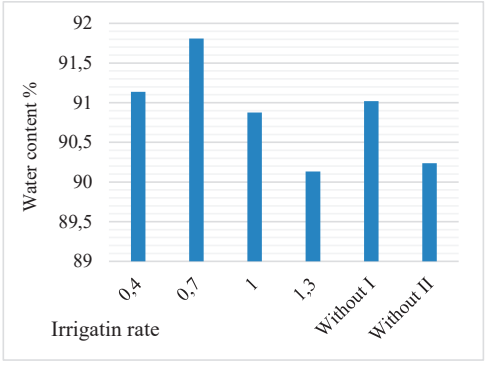


Figure 5. Effect of irrigation rate on the water contend in marketable part of cabbage sp. Kyose 2022

The yield was calculated based on a planting density of 2,857 plants per $ha^{-1}$. The lowest yields were reported for var. 3 (44.5 t/ha) and var. 4 (44.41 t/ha). The yield obtained in the variants with skipped irrigation is 66.4 t/h (Figure 6).

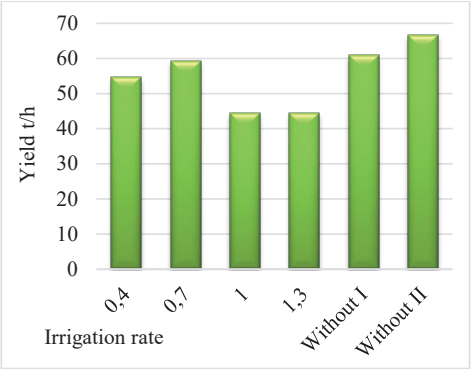


Figure 6. Effect of irrigation rate on the yield in marketable part of cabbage sp. Kyose 2022

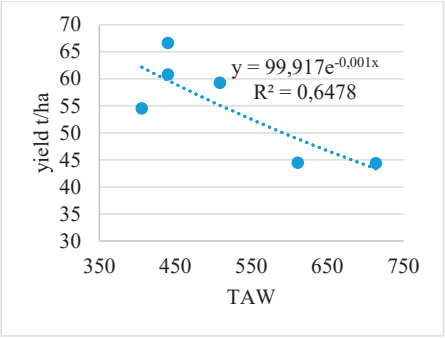


Figure 7. Dependence yield amount of available water

The Figure 7 clearly shows the dependence of the increase in yield on the increase for water. After soil moisture exceeded the level by 500 mm, a decrease in yield was observed. At a humidity level of 713 mm, the yield drops sharply. The negative influence of soil waterlogging on yield is clearly outlined. The applied irrigation rates and subsequent rainfall far exceed the net irrigation requirement for cabbage. According to data from the regulation on water consumption of the Republic of Bulgaria from December 22, 2016, the net irrigation requirement varies from 310 to 520 mm, depending on the year's climate characteristics.

## CONCLUSIONS

Based on the data obtained from the conducted experiment, the negative influence of waterlogging on the size, weight, and yield of late cabbage is clearly outlined. The cancellation of irrigation in the phase of head thickening, combined with the fallen precipitation, leads to obtaining the highest yields of 66.4 t/h.

Cultivation of cabbage with a disturbed irrigation regime is a promising way to reduce the irrigation rate and increase water use efficiency.

Based on the obtained results, we can recommend reducing the irrigation rate by 70%, in yields of 59.25 t/ha. Applying a disturbed irrigation regime leads to water savings with a slight decrease in yield.

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