DEVELOPMENT AND YIELD OF FIELD TOMATO UNDER DIFFERENT WATER SUPPLY

M. D. MÁTÉ, Ildikó SZALÓKINÉ ZIMA

Szent István University, Institute of Irrigation and Water Management
Corresponding author: zima.ildiko@gk.szie.hu

Abstract: *In this paper the effect of different water supply treatments of processing tomato planted under field conditions was examined in the growing season of 2017, 2018 and 2019, so as to see how these various treatments affect the height of tomato plant and the chlorophyll content of the leaf (SPAD value). At harvest, the amount and proportion of stems to total fruits, the amount of red (marketable), green and diseased berries within the total crop, and the weight of small, medium and large berries within the red fruits were examined. Besides this, the soluble solids content of the red fruits was also determined. The field experiment was carried out in Szarvas, Hungary on the experimental area (School Land) of Szent István University. The soil type was chernozem meadow. The plots received different water supplies. Treatments are marked with: K; I50; I75; I100. The I100 = 100% represents the same water supply as potential evapotranspiration (PET). The plots with lower water supply received a certain percentage of the irrigation water delivered at 100 % water treatment. Control (K) received only the amount of water by the precipitation besides the required irrigation (irrigation right after planting, irrigation after fertilization events). Increasing water supply results in a rising tendency at plant height and a decreasing trend at SPAD values. Regarding the ratio of stems to total fruits, it can be stated that due to the increasing water supply increases the weight of both the total fruits and the stem. The distribution of the quality categories of all the fruits points to the fact that an excessive dose of water not only increases the total fruit yield but also increases the weight of red (marketable) berries, and the number of ill fruits. Increasing water doses increase the weight of medium and large fruits within the red fruit compared to the control treatment. According to the results of the soluble solids measurement, the increasing water supply decreases the soluble solids content of the fruits. Larger tomato fruits have a slightly lower soluble solids content than medium and smaller fruits have.*

Key words: *tomato, fruit yield, water supply, soluble solids content*

INTRODUCTION

The use of tomatoes in the world is increasing. Due to steadily increasing consumption, major exporting countries have begun to increase their production areas to meet the needs of importing countries (NICOLA et al., 2009). Processing tomato fruit yields increased in Hungary thanks to modern hybrids and improved cultivation technologies (BŐCS et al., 2009). The yield of up to 90-110 t/ha can be achieved with proper agrotechnology, variety selection and irrigation (BŐCS ET AL., 2011). The amount of nutrients required for the smooth development of the plant is supplemented with organic manure and fertilizer according to its active ingredient requirement (KHAN, 2019). Water supply is one of the most critical factors in the cultivation of processing tomatoes (LE ET AL., 2016). Tomato uses a lot of water due to its high intensive evaporative foliage and long growing time (TAKÁCS et al., 2018). There are many different ways of growing tomatoes, such as growing on fields, in foils, and in greenhouses. One of the biggest challenges in field cultivation is that the conditions present here cannot be influenced, as in a greenhouse, where the climate needed for the plants can be artificially provided (SAGLAM and ONDER, 2016). The safety of tomato cultivation in the field is mainly determined by weather conditions and environmental conditions (PÉK et al., 2015). Tomato cultivation is located in a geographical area suitable for warm-demanding plants (LOVELLI et al., 2017, KATERJI et al., 2013). In addition, we also need to know the rainfall conditions at the place of cultivation, which should satisfy the water demand of the plant (SOMOS, 1971).). An important part of cultivation technology is the irrigation technique (NANGARE et al., 2016). When determining the need for irrigation, the requirement for the plant should always be considered. The water uptake rate of a plant is determined by the water content of the soil and the root system of the plant. The evapotranspiration of the plant is determined by the level of sunlight, and the humidity of the air and its temperature contribute to this. Leaf surface index and stoma activity also determine the transpiration of the plant (HELYES, 1999; PÉK et al., 2014). In the case of non-irrigated cultivation, the annual fluctuation in yield is extremely high, which has a negative effect not only on the quantity of the crop but also on its quality (HELYES et al, 2013). The crop safety of the plant can be increased by proper irrigation, which is extremely important in open field cultivation.

The focus of our study is to study the irrigated cultivation of tomato, which was conducted for 3 years between 2017 and 2019. In the first year of the study three different water supply stages were set, and in the following two years four ones. The aim of the studies was to find the most favorable water supply for tomatoes, which would produce the most marketable crops. In addition, the dry matter content that is relevant for industrial processing was measured also in different irrigation treatments.

MATERIAL AND METHOD

The field experiment was carried out in Szarvas, on the experimental area (Pilot field) of Szent István University. Processing tomato was grown under field conditions in an irrigation experiment for three years (2017, 2018, 2019). The soil type was chernozem meadow (physical texture was clay-loam) with 3% humus content and pH 6.68. The amount of nutrients: NO_3-N + NO_2-N: 9.87 mg/kg; P_2O_5> 700 mg/kg and K_2O > 600 mg/kg. The size of the experimental field was 0.5 ha each year. Parcels were created within the field. Three plots (50 × 33m) in 2017 and 4 plots (50 × 25m) in 2018 and in 2019 respectively. The examined processing tomato hybrid was UG812J. The row and stem spacing was 140 x 24 cm in 2017 and 140 x 20 cm in 2018-2019.

The plots received different water supplies. Treatments are marked with: K; I50; I75; I100. I100 = 100% represents the same water supply as potential evapotranspiration (PET). The plots with lower water supply (I50, I75) received 60% and 80% of the irrigation water delivered at 100% water treatment. Control (K) received only the amount of water by the precipitation besides the required irrigation (irrigation right after planting, irrigation after fertilization events to wash off fertilizer from leaves). In 2017 there were three water supply stages: K = 41%, I50 = 70%, I100 = 100%. In 2018 and 2019, four water supply levels have already been set. Water supply treatments in 2018 were K = 50%, I50 = 75%, I75 = 87%, I100 = 100% and in 2019 K = 72%, I50 = 86%, I75 = 93%, I100 = 100%. Water supply treatments (irrigation + rainfall) were in *2017:* K = 186.2 mm, I50 = 319.1 mm, I100 = 453 mm. In *2018*: K = 170.7 mm; I50 = 257.9 mm; I75 = 296.5 mm; I100 = 340.4 mm and in *2019:* K = 284.1 mm; I50 = 337.8 mm; I75 = 364.6 mm; I100 = 391.5 mm. Precipitation during the growing season was in 2017: 146 mm, in 2018: 127 mm, and in 2019: 257 mm.

The amount of active NPK substance applied in 2017: N: 138 kg/ha; P: 117 kg/ha; K: 183 kg/ha; in 2018: N: 137 kg/ha; P: 69 kg/ha; K: 174 kg/ha; and in2019: N: 129 kg/ha; P: 89 kg/ha; K: 317 kg/ha.

RESULTS AND DISCUSSION

Factors examined were plant height and chlorophyll content during the growing season. At harvest time, we analyzed the biomass product, the yield per plant and the total yield (tons/hectare) for the different water supply levels. In addition, we classified the total yield into quality groups (red/marketable, green, bad) and size distribution of red fruits (small, medium, large). The soluble solids content of red fruits was also investigated.

Evaluation of plant height results in case of different water supply

The plant height was measured in 2017-2018 and 2019. The results measured in 2018 are shown in *Figure 1*. As a result of the increasing water supply, the height of the plants increased.

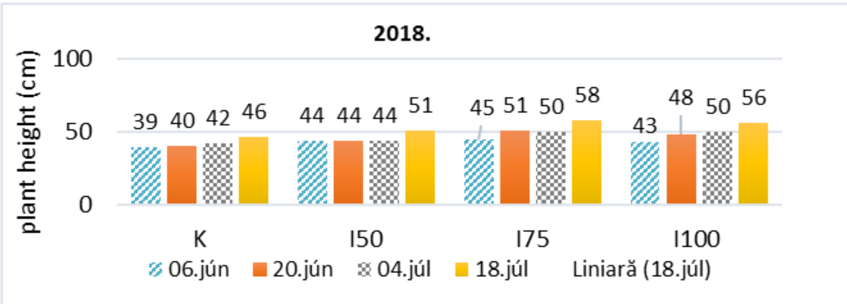


Figure 1. Plant height data for 2018. Szarvas

Evaluation of chlorophyll content results

Chlorophyll content was determined by a SPAD meter on plant leaf in 2017, 2018 and 2019. From the three years I present the results of the 2018 SPAD measurements *(Figure 2)*. Results for the 2018 experimental year show a downward trend both with growing season and increasing water supply. Based on the results of three years, it can be said that increasing doses of water resulted in decreasing chlorophyll content.

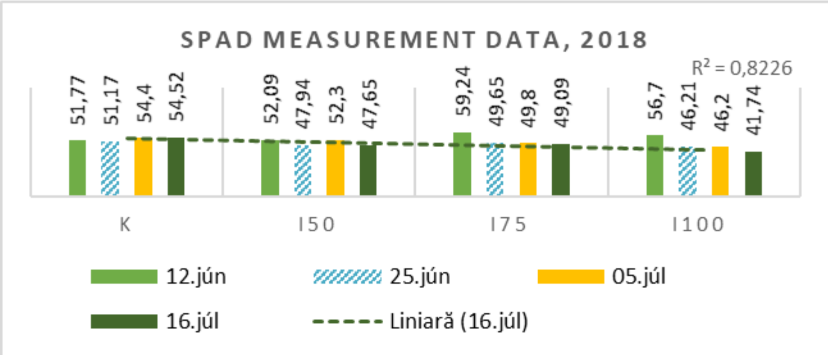


Figure 2. SPAD measurement data. 2018

Evaluation of the results of vegetative weight measurement and yield
In **2017**, the ratio of stem to total yield is shown in the diagram below *(Figure 3)*.

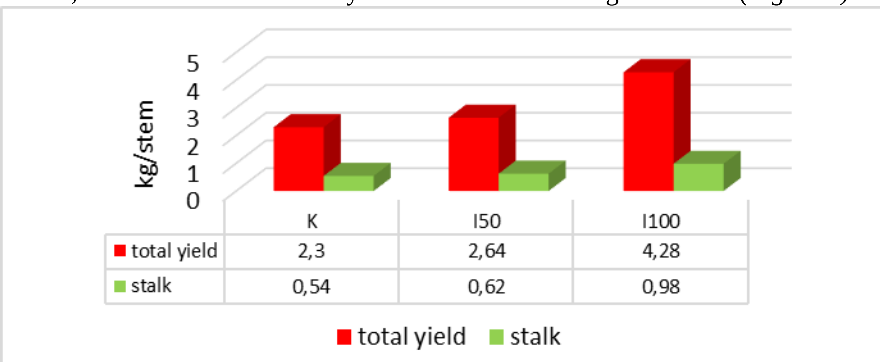


Figure 3. Distribution of total fruit yield to stalk (kg/plant), 2017. Szarvas

The figure shows the beneficial effect of increasing water on both the total yield and the stalk weight. Increasing water supply results in more biomass products.
At the harvest on August 28, 2017, the mass of the total fruits per plant can be seen in *Figure 4*.

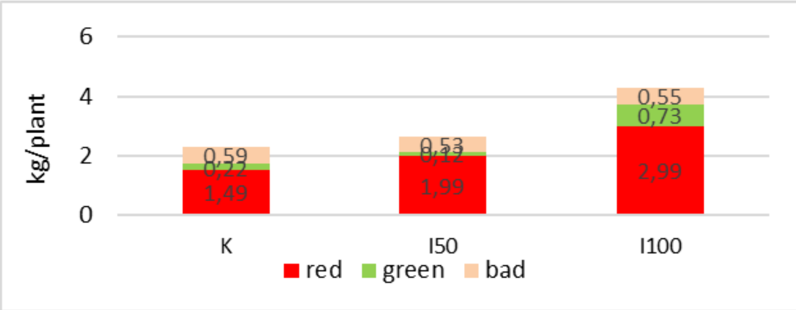


Figure 4. Distribution of total tomato fruit yield by stem (kg /plant), 2017.

All tomato fruits were classified into three separate groups, red (marketable) green (immature) and bad (ill) berries. The marketable yield per tons per hectare can be calculated from the red fruits per plant, which is as follows: K = 44.3 t/ha, I50 = 59.2 t/ha, I100 = 88.9 t/ha. The parcel with the lowest water supply (K) received 41% of PET. Plots with a higher water supply level (70% PET treatment and 100% water treatment) had higher total yields. In the 100% water treatment (I3) was the most total fruit, but also the most green berries.

The harvested red (marketable) fruits were classified into 3 other groups. The small fraction is about 2.5 cm in diameter and less, the medium is more than 3 cm in diameter and less than 4.5 cm, and the large fraction refers to berries of 4.5 cm or more in size. The size distribution of marketable (red) fruits in 2017 is shown in the figure below *(Figure 5).*

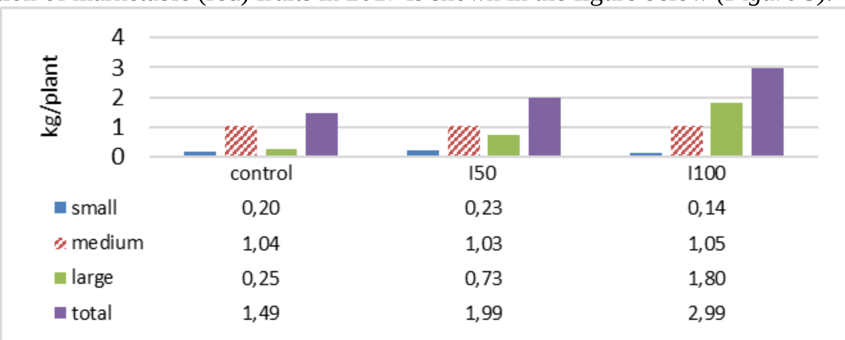


Figure 5. Size distribution of marketable yield in 2017 (kg/plant).

The amount of small fruits decreased slightly with the improvement of water supply (0.2 kg/t and 0.14 kg/t in K and I100 treatment), while medium-sized tomatoes are equally present (1.04 to 1.05 kg/t). in three treatments. The yield of large fruits per plant increases significantly as water supply improves. In the 100% water supply, the yield of the big berries is 1.83 kg/plant, which could probably produce a higher proportion of big fraction fruits due to the water. In addition, this treatment (I100) has the highest total yield of the three treatments, nearly twice the yield of the control plots (K = 1.5 kg/stem; I100 = 3.0 kg/stem).

In **2018** the change and the percentage distribution of stems and total fruits can be seen in *Table 1.*

Table 1.

Distribution of tomato biomass, stem and total fruit yield by plant, 2018. Szarvas

treatment	biomass	total fruit	stem	total fruit	stem
	kg/plant			%	
K	*1,68*	*1,31*	*0,37*	*78*	*22*
I50	*2,37*	*1,86*	*0,51*	*77*	*23*
I75	*2,78*	*2,26*	*0,52*	*81*	*19*
I100	*3,77*	*3,24*	*0,54*	*84*	*16*

Increasing doses of water resulted in increasing total fruit yields. Treatments with a lower water supply also reduce the weight of stems and fruits. The K and I50 treatments show almost the same values (78:22) for the percentage of total fruits to stems. The I75 and I100 treatments show better results in the total fruit and stem ratio (81:19; 86:14). This is important because in more favorable water supply treatments, the total yield of fruits within the total biomass product is higher than the amount of stalk compared to lower water supply treatments.
Total fruit yields per plant were classified into quality groups, separated by red, green and sick *(Figure 6).*

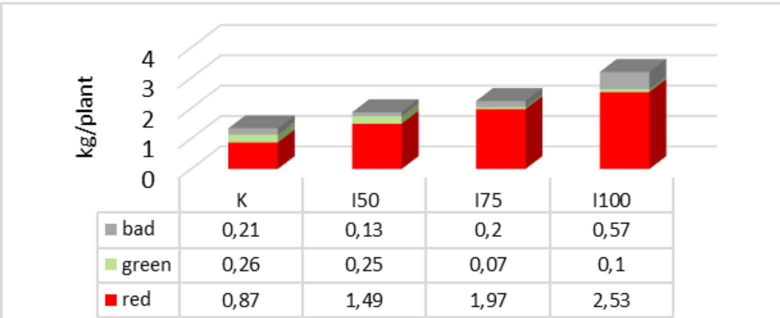
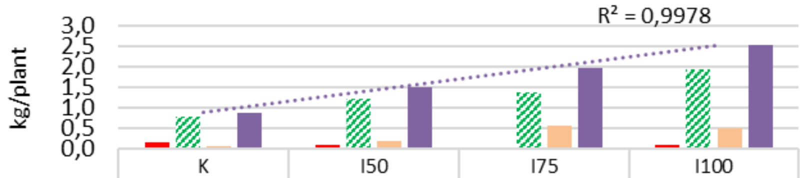


Figure 6. Distribution of total fruit yield per plant in 2018 (kg/stem)

The yield of red (marketable) fruits per hectare is K = 31.07 t/ha, I50 = 53.21 t/ha, I75 = 70.35 t/ha, I100 = 90.35 t/ha. The K and I50 treated plots had lower yields, and the marketable yields for the I75 and I100 plots were higher. The I100 treatment produced more red fruits compared to other water supply treatments, but also more bad berries, probably due to excess water.

Size classification of marketable yields after the 2018 harvest are shown in the following diagram *(Figure 7).*



	K	I50	I75	I100
small	0,15	0,08	0,04	0,08
medium	0,79	1,22	1,37	1,94
large	0,06	0,19	0,55	0,5
total	0,87	1,49	1,97	2,53

Figure 7: Size distribution of red berries in 2018 (kg/plant);

Control (K) has the lowest values for small, medium and large fruits.

From the crop/yield data of the 2018 results, we can also calculate data to ton per hectare. The total fruit yield in different water treatments is shown in the diagram below *(Figure 8).*

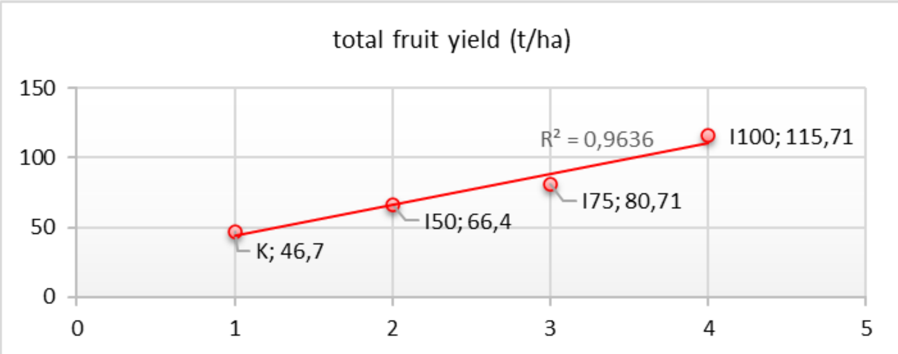


Figure 8: Total tomato fruit yield (t/ha), 2018. Szarvas

The total yield of fruits was 46.7 t/ha on the control plot and on average 66.4 t/ha on the with a one higher water supply level. In the I75 treatment the average fruit yield was 80.71 t/ha and in the I100 treatment it was 115.71 t/ha. These values increase in direct proportion to the increasing water supply, as evidenced by the Pearson correlation value (R2 = 0.9636).

In **2019** the distribution of the ratio of stems to total fruits can be seen *in Table 2.*

The K and I50 treatments have less total weight of berries and stems than the higher water treatments, but the distribution of percentages of these factors shows better results than the I75 and I100 treatments.

Table 2.

Distribution of tomato biomass, stem and total fruits by blant, 2019.

treatments	biomass	total fruits	stem	total fruits	stem
	kg/plant			%	
K	*3.10*	*2.55*	*0.55*	*82*	*18*
I50	*3.54*	*3.04*	*0.50*	*86*	*14*
I75	*3.89*	*3.03*	*0.86*	*78*	*22*
I100	*4.75*	*3.49*	*1.25*	*73*	*27*

This year, 257 mm of precipitation fell during the growing season, and the volumes of irrigation water discharged were 28 mm 81 mm 108 and 135 mm. Due to lot of rainfall during the growing season in 2019, the plants began to develop evenly. The amount of water applied in the I75 and I100 treatments did not significantly increase the total fruit yield. The results of the total tomato production in 2019 grouped into quality categories (red, green, bad) are shown in *Figure 9.*

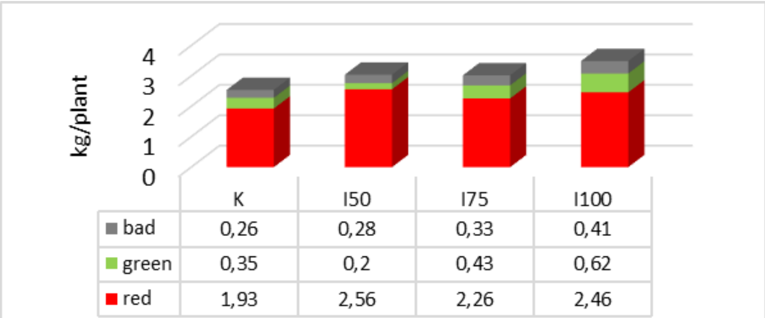


Figure 9: Distribution of total yield (kg/plant), 2019, Szarvas

Regarding the total fruit yields, the increasing levels of water supply improve total fruit yields. However, excess water has a negative effect on the quality fraction.

Of all the fruits, the red (marketable) fruit was divided into three further fractions by size, the results of which are shown in *Figure 10.*

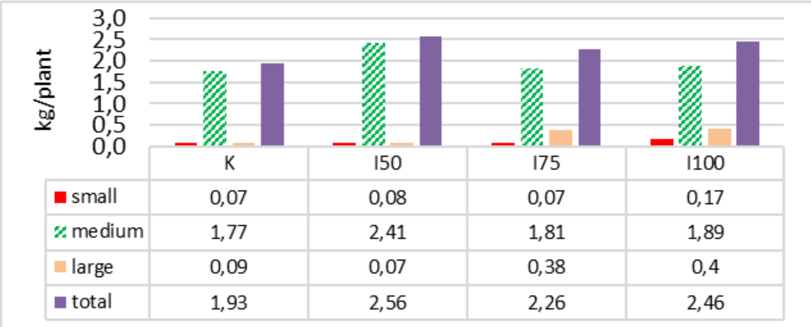


Figure 10: Size distribution of red (marketable) tomato fruits, 2019 (kg/plant);

The results of the size grouping of red (marketable) fruits after the 2019 harvest show that this year the I50 treatment gave the most medium fruit yields. By size class, medium-sized berries (3 to 4.5 cm in diameter) are present in the highest amounts in all treatments. The development of large fruits was ensured only by the I75 and I100 water supply treatments.

The effect of increasing irrigation was also reflected in all crop yields. Pearson correlation values show a close relationship between these values (R2 = 0.893) *(Figure 11).*

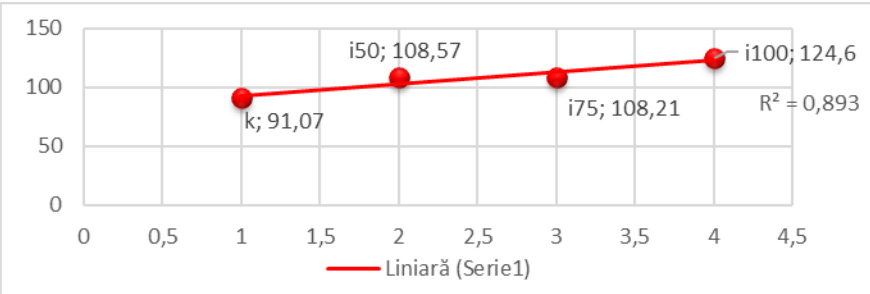


Figure 11: Results of total tomato fruit yield (t/ha), Szarvas, 2019.

Results of dry matter measurement

The results of the soluble solids content are shown in the *Table 3.* The soluble solids content of red tomato fruits was measured by a hand refractometer.

Table 3

Results of soluble solids measurement in tomatoes (°Brix)

treatment	*2018*			*2019*		
	fruit size			*fruit size*		
	small	*medium*	*large*	*small*	*medium*	*large*
K	*7,5*	*7*	*4,5*	*6,6*	*5*	*4*
I1	*6,5*	*6,5*	*6*	*6*	*5,5*	*5*
I2	*6,5*	*6*	*6*	*5*	*4,5*	*4*
I3	*6*	*5,5*	*4*	*5*	*4,5*	*3,5*

During the measurement, three size fractions were analyzed. Results are averages of 3 replicates. The results indicate that in smaller water supply treatments the fruits have a higher soluble solids content due to less water The treatments with higher water supply have a lower soluble solids content. Lower soluble solids content is in connection with more water, with higher water supply soluble solids dilutes due to higher water. This is also true for size fractions, where smaller yields have a higher, more concentrated soluble solids content due to less water, while in larger fruits this can be found more diluted.

CONCLUSIONS

Plant height increases linearly with increasing water supply, which is also reflected in the Pearson correlation values (R2 = 0.789). According to the results of the experiment, the amount of irrigation water influences the chlorophyll content so that the more water the plant receives, the more its value decreases, i.e. the ratio of green color bodies is "diluted".

With regard to the ratio of the stalk to the total fruit yield, it can be stated that the increasing water supply increases both the weight of the whole fruits and the weight of the stem. The distribution of total fruit yields by quality group points to the fact that an excessive dose of water not only increases the total yield but also increases the weight of red (marketable) berries, and increases the amount of ill, bad fruits as well. In a wetter year (2019), treatment with too much water does not show any further improvement in the marketable fruit yield compared to a lower (I75) water supply treatment. With increasing doses of water, the weight of medium and large fruits within the red berry increases relatively to the control treatment. According to the results of soluble solids measurement, the soluble solids content of the fruits in the lower water supply treatments is higher than in the higher water supply treatments. Larger tomato fruits have a slightly lower soluble solids content than medium and smaller berries.

Studies have shown that cultivation conditions, which can be improved with fertilizers, greatly influence the efficiency of production, but the most important influencing factor is irrigation and water supply.

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