HUNGARIAN UNIVERSITY OF
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EFFECT OF PLANT GROWTH PROMOTING BACTERIA AND IRRIGATION ON PROCESSING TOMATO GROWING

Theses of doctoral dissertation

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Antecedents and objectives of the work

Nowadays, the basic goal is to create products that are competitive through sustainable cultivation. Competition for water is intensifying due to climate change and population growth. Because of it, it is important to establish appropriate irrigation, increase the efficiency of water use, and regulate the water management of plants and soils. Experiences have shown that irrigation significantly affects the number of berries per plant and the average weight of the berries, and although it results in higher yields, it also reduces the water-soluble dry matter content of the berries.

Tomatoes are water-intensive plant, so they definitely need irrigation, especially in semi-arid and arid areas, which can be greatly facilitated by incomplete irrigation strategies such as deficit irrigation (DI). The critical period of its water supply is from the beginning of fruit setting to the end of crop development, i.e. from mid-June to early August. During this time water scarcity can cause significant crop losses.

To mitigate the harmful effects of water scarcity, the use of tools to promote growth and improve quality such as mycorrhiza fungi or bacteria has also become more widespread. Plant growth promoting rhizobacteria (PGPR) are free-living microorganisms in the soil that interact with the roots of the plant to produce beneficial effects in plants by improving mineral nutrition and synthesizing antibiotics involved in the suppression of plant diseases.

The aim of our three-year field experiment with processing tomatoes is to evaluate the effect of environmental stresses during plant development, especially water supply and temperature, and to monitor the effect of applied bacteria on the quality, the quantity and the content of the crop during different water supply.

MATERIAL AND METHOD

The experiments were conducted over three years. In 2018 and 2020, we examined industrial tomato hybrids called H-1015 (H. J. Heinz Company, Pittsburgh, USA), and in 2019, we studied UG812J (United Genetics Italia, Parma, Italy). The experiments were carried out in the open field, at the experimental site of the Horticultural School Workshop of MATE GAK Ltd.

Prior to planting, the seedlings were subjected to 3 bacterial treatments, which were provided by the Bay Zoltán Research Institute (BAY-BIO Szeged) with B1, B2 and B3 names. The treatments were performed in a split-plot system, in a random block layout, in four replicates.

The water requirements of the plants were determined with AquaCrop v5.0 software (Land and Water Division, Food and Agriculture Organisation of the United Nations, Rome, Italy). Using ETc = ET0 x Kc equation, two irrigation treatments were applied: the optimal water supply on the irrigated plots (I100) was 100% replaced by the calculated evapotranspiration, while for deficit irrigation (I50) the irrigation water dose was half of the optimal treatment.

Instrumental measurements were performed once a week, usually between 10 a.m. and 2 p.m. Relative chlorophyll was measured using SPAD 502 (Konica Minolta, Warrington, UK), leaf temperature was measured with Raytek MX4 infrared thermometer (Raytek Corporation, Santa Cruz, CA, USA), and chlorophyll fluorescence was measured with PAM-2500 (Heinz Waltz GmgH, Effeltrich, Germany). Soil moisture was measured with a PT-1 digital spear (Kapacitív KKT., Budapest).

In all three years, 10-10 plants were randomly harvested from each plot within the designated 4 rows, and their yields were divided into 3 groups: mature, green and non-marketable. Samples selected from ripe fruits were measured for water-soluble dry matter content and vitamin C in the Food Analysis Laboratory of the Regional University Knowledge Centre in all three years.

Data were analysed using SPSS Windows 20.0 statistical software. Regression analysis was performed to explore the relationship between the physiological properties of the bacteria-treated plants and the yield.

According to meteorological data, the years were divided into three groups: 2018 was moderately dry, 2019 was dry, and 2020 was wet.

RESULTS AND DISCUSSION

Effect of water supply and bacterial treatments on physiological properties

Good water supply reduced leaf temperature in moderately dry (2018) and dry years (2019). The relative chlorophyll content of the leaf (SPAD value) decreased significantly under deficit and regular irrigation in very dry (2019) and rainy (2020) years compared to non-irrigated plants (I0).

In a moderately dry year (2018), B2 and B3 bacterial treatments significantly reduced chlorophyll fluorescence (Fv/Fm) and increased leaf temperature. In the dry year (2019), the SPAD value increased significantly as a result of B2 and B3 treatments. In 2020, treatments B2 and B3 maintained photosynthesis (Fv/Fm and SPAD are the same as the untreated control), but bacterium B1 reduced chlorophyll fluorescence (Fv/Fm).

Effect of water supply and bacterial treatments on the number of berries

Of the three years, 2019 had the most marketable berry and the fewest in 2020. There were the most green berries in 2018 and in 2020 the fewest while the opposite was true for diseased crops.

In 2018, only irrigation had a significant effect on the number of marketable and green berries, while we could not detect an effect on diseased berries.

In 2019, water supply had the greatest impact on all berry groups, except for diseased berries, where bacterial treatments significantly reduced the number of diseased berries overall.

In 2020, there was only a small significant difference in green berries at irrigation, where most green berries per plant were formed in non-irrigated treatments and the fewest in regularly irrigated plants. As in the previous year, there is a statistical difference between irrigation and bacterial treatments for diseased crops, but neither bacterial treatment nor irrigation has a significant effect on marketable yields.

Effect of water supply and bacterial treatments on tomato berry weight

Examining the effect of irrigation, we were only able to detect a significant effect on the weight of green berries in 2018 out of the three years. So, only in this year the effects both of the irrigation and the bacterial treatments on the weight of green berries and marketable berries can be demonstrated.

In 2019, a significant difference can only be detected between the interaction of water supply and bacteria in marketable crops, while in green berries only between bacterial treatments.

In the rainy year 2020, the weight of marketable and green berries decreased as a result of bacterial treatments compared to the untreated (B0) control, but the extent of the decrease was not statistically significant.

Effect of bacteria and water supply on yield

In 2018, the positive effect of B3 on marketable crops was observed without irrigation and with deficit irrigation: 28% more without irrigation compared to untreated (B0) crops. In water deficiency (I0, I50), tomatoes treated with B2 and B3 had higher green and diseased yields than untreated (B0) plants. Treatment with B2 significantly increased the amount of diseased yield in plants with good water supply. We have observed that regular irrigation (I100) in any case increases the number of diseased and damaged berries more than deficit irrigation or control without irrigation.

In 2019, we showed a statistically significant effect of the irrigation, the bacterium treatments and their interaction on the marketable yield. The highest marketable yield was achieved with B1 treatment and deficit irrigation. Without irrigation (I0), the B2 and B3 treatments significantly reduced the average green yield and the diseased yield was lower.

In 2020, I0B1 treatment had the highest marketable yield. B3 treatment also reduced the marketable crops in all irrigation treatments this year, as in 2019. Irrigation reduced the amount of green berry yield, which was also statistically detectable, in contrast to bacterial treatments, which did not significantly affect it. Irrigation increased the amount of diseased crops, while this was mainly observed in B2 treatment.

Influence of physiological traits during generative stages

In the moderately dry 2018 year, bacterial treatments affected the physiological properties from flowering to berry setting. During this time, without irrigation (I0) and deficit irrigation (I50), there is a significant relationship between leaf temperature and yield (r=-0.5188, r=0.8178). In addition to deficient irrigation (I50), chlorophyll fluorescence (Fv/Fm) and relative chlorophyll content (SPAD) significantly affected the yield in bacterial-treated plants (r= -0.5363, r=-0.6029), but in good water supply (I100) they had no effect on yield.

In the dry year of 2019, there is no significant relationship between the physiological traits measured during the generative phase and the yield in the bacterial-treated plants.

In the rainy year 2020, a significant relationship between Fv/Fm and yield was detected only in the case of non-irrigated, bacteria-treated plants (r=0.5318).

Effect of water supply and bacteria on quality properties

The water-soluble dry matter content (°BRIX) is greatly affected by irrigation. In all three years, the non-irrigated (I0) plants had the highest dry matter content. In both 2018 and 2020, the highest soluble dry matter content was provided by the B1 treatment in the non-irrigated treatment. In 2019, without irrigation and with regular irrigation, the highest dry matter content can be achieved by applying the B3 treatment.

A good water supply increased vitamin C content in dry years. In 2018, non-irrigated treatments had the highest vitamin C content in the crop, while in rainy 2020, vitamin C content was low and no significant difference was detected between water supply treatments.

In both 2018 and 2020, it was proved that the irrigated plants did not benefit from bacterial treatments. In 2019, B3 treatment had the greatest positive effect on the vitamin C content of the crop.

CONCLUSIONS AND RECOMMENDATIONS

Based on our results, we can state that by measuring the physiological properties such as chlorophyll fluorescence, relative chlorophyll content and leaf temperature, we can successfully test the degree of stress tolerance of industrial tomato cultivars.

In our experiment, we demonstrated that a good water supply reduces leaf temperature in drier years. SPAD values also decreased significantly as a result of irrigation, even in the rainy year. In the moderately dry year, B2 and B3 bacterial treatments reduced chlorophyll fluorescence but increased leaf temperature. In the dry year, the B2 and B3 treatments significantly increased the SPAD value. In the rainy year, treatments B2 and B3 maintained photosynthesis, but bacterium B1 reduced chlorophyll fluorescence (Fv/Fm).

For the H-1015 processing tomato hybrid, marketable yields were increased by B3 treatments for non-irrigated and moderately irrigated conditions in the moderately dry year (2018). In a rainy year (2020) B1 has already increased in more under non-irrigated conditions, while B3 treatment rather reduced marketable yield (t/ha). This variety had a higher BRIX content than both non-irrigated and moderate irrigation, regardless of years, which was best increased by B1 treatment. In the dry year, good dry matter content can be achieved with the use of B3 treatment without irrigation and regular irrigation.

In the dry year, B3 treatment had the greatest positive effect on the vitamin C content of the crop, however, this treatment reduced the amount of marketable yield (t/ha). In the wetter years, the increased water supply no longer increased but rather reduced the vitamin C content. So, it was not the effect of bacteria, it was the effect of the irrigation that applied more to the vitamin C content.

In deficit deficiency in 2018, we were best able to demonstrate the significant influence of chlorophyll fluorescence and SPAD on yield using bacterial treatments.

The results showed that the effect of bacterial treatments is highly dependent on the variety and environmental factors, which requires further investigation in the future. The bacterial preparations tested contained several strains. Not all bacteria may or may not have symbiotic interactions with the plant, which may have a different effect on photosynthesis and crop production. My suggestion is that these bacterial preparations should be tested on the varieties under controlled conditions and only then selecting bacteria that are positive for most varieties should be further experimented on in the open field,

NEW SCIENTIFIC RESULTS

1. I found that the relative chlorophyll content (SPAD) value decreased significantly with unsatisfactory (deficit) and regular irrigation in dry and rainy years in processing tomatoes.
2. In moderately dry years, treatments B2 and B3 significantly reduced chlorophyll fluorescence (Fv/Fm), increased leaf surface temperature, and had a positive effect on marketable yield.
3. I showed that in the rainy year, B2 and B3 treatment was favourable for chlorophyll fluorescence (Fv/Fm), but B1 treatment reduced it.
4. I have shown that in moderately dry years there is a significant relationship between chlorophyll fluorescence (r=-0.5363), SPAD (r=-0.6029), leaf surface temperature (r=0.8187) and yield under deficit irrigation in plants treated with bacteria.
5. I have shown that in the moderately dry year, under deficit irrigation, B2 and B3 bacterial treatments significantly increased the marketable and green yield.
6. In a dry year, with deficit irrigation, B3 bacterial treatment reduced the yield of marketable and green berries better than B2 treatment, but increased the proportion of diseased yield.
7. I found that in the wet year, under deficit irrigation, the B3 bacterial treatment reduced the marketable yield but increased the yield of the green berries compared to the B2 bacterial treatment.
8. In the dry year, the B1 bacterial treatment had a positive effect on the water-soluble dry matter content (BRIX) of processing tomatoes. Bacterial treatments had no significant effect on vitamin C content regardless of year.

Publications related to the topic of the dissertation

<u>Published in an International Impact factor journal:</u>

1. Andrei B., **Horváth K. Zs**., Agyemang Duah S., Takács S., Égei M., Szuvandzsiev P., Neményi A. (2021): Use of plant growth promoting rhizobacteria (PGPRs) in the mitigation of water deficiency of tomato plants (*Solanum lycopersicum* L.). Journal of Central European Agriculture, 2021, 22 (1): 167-177 p. IF=0,60 Q4
2. **Horváth K. Zs**., Andrei B., Helyes L., Pék Z., Neményi A., Nemeskéri E. (2020): Effect of mycorrhizal inoculations on physiological traits and bioactive compounds of tomato under water scarcity in field conditions. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 48 (3): 1233-1247 p. IF=1,144 Q3

<u>Published in a foreign language, with non-Impact factor journal:</u>

1. Andrei B., **Horváth K. Zs**., Ráth Sz., Nemeskéri E., Neményi A., Pék Z., Helyes L. (2020): Effect of plant growth promoting Rhizobacteria (PGPRS) on yield and quality of processing tomato under water deficiency. Acta Agraria Debreceniensis 2020-2 19-22 p.
2. Andryei B., **Horváth K. Zs**., Nemeskéri E. (2019): The effects of water supply on the physiological traits and yield of tomato. Acta Agraria Debreceniensis 2019 (2): 25-30 p.
3. Nemeskéri E., **Horváth K. Zs**., Pék Z., Helyes L. (2019): Effect of mycorrhizal and bacterial products on the traits related to photosynthesis and fruit quality of tomato under water deficiency conditions. Acta Hortic. 1233 (1), 61-66 p. IF=0,23 Q3

Published in a non-Impact factor journal in Hungarian language:

1. **Horváth K. Zs**., Andrei B., Ráth S., Égei M. (2020): Vízellátás és a növekedést serkentő baktériumok hatása az ipari paradicsom termésére és minőségére. Kertgazdaság 52 (2) 59-67 p.
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3. **Horváth K. Zs**., Andryei B. (2021): Szárazság elleni védekezés lehetőségei a jelentősebb zöldség kultúrákban. Agrofórum, 8 (32): 114-117 p.
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1. Andrei B., **Horváth K. Zs**., Pék Z., Nemeskéri E., Helyes L. (2018): Effects of irrigation and plant growth promoting rhizobacteria on processing tomato – 7th International Scientific Conference – Sustainable Developement of Agriculture and Economy. Scientific Journal – Agricultural Economics vol.09. Published by School of Economics and Business Mongolian University of Life Science. ISSN 2519-2000. 203-206 p.
2. **Horváth K. Zs**., Helyes L., Nemeskéri E.(2019): Növekedést segítő baktériumok hatása ipari paradicsom fotoszintézisére és termésére vízhiányban. In: Növénynemesítés a 21. század elején: kihívások és válaszok szerk. Karsai Ildikó. XXV. Növénynemesítési Tudományos Nap Kiadó: MTA Agrártudományok Osztályának Növénynemesítési

Tudományos Bizottsága, Magyar Tudományos Akadémia, Budapest. 86-89 p.

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