Thesis of doctoral (PhD) dissertation

THE EFFECT OF MICROALGAE TREATMENT ON WINTER WHEAT (*TRITICUN AESTIVUM* L.) YIELD AND TOLERANCE TO WATER DEFICIT STRESS

Author:
Georgina Takács
PhD candidate

MOSONMAGYARÓVÁR
2024

PhD DISSERTATION THESIS

SZÉCHENYI ISTVÁN UNIVERSITY
ALBERT KÁZMÉR FACULTY
MOSONMAGYARÓVÁR

ANTAL WITTMANN MULTIDISCIPLINARY DOCTORAL SCHOOL
PLANT, ANIMAL AND FOOD SCIENCES
GOTTLIEB HABERLANDT
PLANT SCIENCES DOCTORAL PROGRAMME

Doctoral School Leader:
Prof. Dr. László Varga DSc

Programme Leader:
Prof. Dr. Gyula Pinke DSc

Consultant:
Prof. Dr. Vince Ördög DSc
professor emeritus
Dr. István Gergely PhD
university associate professor

THE EFFECT OF MICROALGAE TREATMENT ON WINTER WHEAT (*TRITICUN AESTIVUM* L.) YIELD AND TOLERANCE TO WATER DEFICIT STRESS

Author:
Georgina Takács
Phd candidate

Mosonmagyaróvár
2024

1. INTRODUCTION AND OBJECTIVES

Drought stress worldwide is one of the most significant challenges in sustainable agriculture. From the point of view of agricultural production, it is important to learn about the physiological processes and defense mechanisms that take place in economic plants under stress conditions, and to develop procedures to increase the plants' stress tolerance. The response of plants to drought stress depends on the species, genotype, duration and extent of water loss, as well as the plant growth stage. Wheat requires 480-550 mm of precipitation, from which it absorbs most of the water during the period of flowering and fertilization (May - June). In addition to the amount of annual precipitation, the yield is determined mainly by its distribution and other factors, in summary the effect of the vintage and the variety used.

Plants give different morphological, physiological, biochemical and molecular responses to drought stress, for example larger root system, smaller leaf area, stomatal closure, reduced photosynthesis and water potential, as well as increasing proline production and abscisic acid accumulation. The degree of water stress can be characterized by water potential. There are several methods for measuring it, the most commonly used is the Scholander pressure chamber, but use of the ZIM probe is becoming more and more common, which allows the water potential to be measured without removing the leaves. The drought tolerance of winter wheat can be increased with traditional breeding methods, which requires time-consuming and years-long research. Its effectiveness is limited by the fact that drought tolerance is a complex trait which is regulated by many genes and influenced by the environment. Recently, the use of biostimulants to increase yield and drought tolerance of plants has become widespread. These include, among others, seaweed extracts and, more recently, microalgae preparations.

Nowadays it is well known that cyanobacteria, microalgae and seaweeds produce plant hormones, which is why they are suitable for special plant treatments. Auxins and cytokinins have been found in many seaweed, which contribute to increasing the yield of many plants treated with their extract. Algae also have the effect of reducing transpiration, increasing root and shoot development and protein content of crops. Among other things, they promote rooting, root formation and growth of the cut plant.

Biostimulant products help nutrients uptake of plants, increase tolerance against abiotic and biotic stress and improve crop quality. The seaweed extract Kelpak is widely used in agriculture for this purpose. It improves root and shoot growth, provides higher yields and better resistance to biotic and abiotic stress. Microalgae are used in plant cultivation as biofertilizers, biostimulants and soil conditioners, but they are also suitable for reducing climatic stress effects.

During my research work, I investigated the effect of a cyanobacterium (*Nostoc piscinale*, MACC-612) and three green algae (*Tetracystis sp*., MACC-430, *Chlorella vulgaris*, MACC-755 and MACC-1) on the winter wheat varieties "Bőség" and "GK Csillag".

1.1. Research objectives

During my experiments, in small-plot experimental conditions, the winter wheat varieties "Bőség" and "GK Csillag" (*Triticum aestivum* L.) were treated with foliar spraying with a fast growing cyanobacterium MACC-612 *Nostoc piscinale* and three green algae strains MACC-430 *Tetracystis sp.*, MACC-755 and MACC-1 *Chlorella vulgaris*, all obtained from the Mosonmagyaróvár Algae Culture Collection (MACC) and showing auxin-like activity detected in bioassays.

The main objective of my work was to determine if and how microalgae treatments show biostimulating effects with special regards to answering the following questions:

1. in which phenophase of the plant and at what concentration, the best biostimulant effect and the highest yield can be achieved,
2. how does the algal treatment affect the crop yield, which treatment, applied in what concentration and in which phenophase, results in the greatest additional income,
3. which crop elements can explain the change in yield,
4. as a result of the treatments, what physiological and water deficit stress-specific changes take place in the plant (leaf relative water, chlorophyll, proline, malondialdehyde content, water potential measurement, root dry weight determination).

2. MATERIAL AND METHOD

2.1. Experimental plant

During the experiment, I used two varieties of winter wheat (*Triticum aestivum* L.), "Bőség" in 2015/16, 2016/17, 2017/18, 2018/19, and "GK Csillag" in 2019/20 and 2020/21. The selection of the new variety was justified by the fact that it was included in the variety list between 2000 and 2018, after which its distribution was discontinued.

2.2. Microalgae

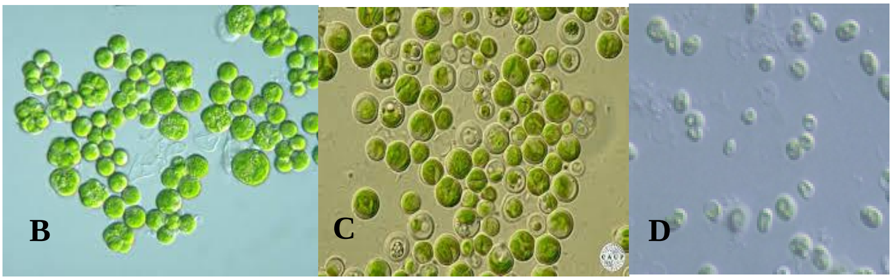
For my experiments, I chose one cyanobacterium and three green algae from the Mosonmagyaróvár Algae Culture Collection.

Cyanobacterium:

- MACC-612 *Nostoc piscinale* (A)

Green algae:

- MACC-430 *Tetracystis sp.* (B)
- MACC-755 *Chlorella vulgaris* (C)
- MACC-1 *Chlorella vulgaris* (D)



A: MACC-612 *Nostoc piscinale*, B: MACC-430 *Tetracystis sp*.,
C: MACC-755 *Chlorella vulgaris*, D: MACC-1 *Chlorella vulgaris*.

2.3. Biomass production and bioactivity detection

After a 7-day incubation, the cultures were harvested between 2 and 3 p.m. The microalgae suspension was centrifuged at 2150 g for 15 minutes (Sigma 6K15, Germany), then the supernatant was poured out and the settled biomass was placed in a Petri dish and lyophilized (Christ Gamma 1-20, Germany) for 22 hours at 25±2 °C, at a pressure of 0.035 mbar. The freeze-dried samples were stored in a closed plastic container at -20 °C. Before testing the hormone effect, I prepared a suspension with a concentration of 10 g L^{-1} from the samples with distilled water, which was treated for 3 minutes with an ultrasonic cell disruptor (VirTis, VirSonic 600 Ultrasonic Cell Disruptor, USA) with 40% pulse energy. I always prepared the microalgae suspension freshly before use and diluted it with distilled water according to the tests.

The cucumber cotyledon growth test was used to detect the cytokinin-like activity of green algae and cyanobacteria, while the auxin-like activity was evaluated with the cucumber cotyledon rooting test.

2.4. Experimental design

I set up the experiment in the Faculty of Economics of Albert Kázmér Mosonmagyaróvár Faculty of István Széchenyi University in 2015/16, 2016/17, 2017/18. The experimental results obtained in 2018/19, 2019/20, 2020/21 are included into the thesis to show the difference in the bioactivity of algal biomass produced in the laboratory and in wastewater on yield. The experimental plants were sown on a small plot (10 m^2). The experiment was set up in a random block arrangement in four repetitions, with a row spacing of 12 cm, 4.5 million sprouts ha^{-1} and a depth of 4-6 cm. I treated the plants at tillering and ear emergence in concentrations of 0.1, 0.3, 1.0 and 2.0 g L^{-1}. In order to improve the adhesion of the microalgae to the leaves, I used Trend 90 wetting agent. I treated the control plots only with tap water containing the wetting agent. I used 400 L ha^{-1} algae suspension in the treated plots. The application was carried out with a hand sprayer at a temperature below 25 ^{o}C.

Nutrient replenishment was done in autumn with 60 kg ha^{-1} nitrogen, 60 kg ha^{-1} phosphorus and 60 kg ha^{-1} potassium.

2.5. Laboratory measurements

2.5.1. Root dry weight

The samples were collected from the three middle rows of the plots two days before and ten days after the first treatment. From each plot, I collected ten plants from an area of 30 x 30 cm. I cleaned the roots from the soil particles and dried them at 106 °C to a constant weight for 24 hours, allowed them to cool, and then measured their biomass on an analytical balance. The dry weight of the root was given in grams.

2.5.2. Leaf relative water content

The relative water content (RWC, %) was measured on the flag leaf weekly (3 plants/plot) using the method of Cabrera-Bosquet et al. (2009), calculated using the following formula:

$$\text{Relative water content (\%)} = (FW - DW) / (TW - DW) * 100$$

FW - fresh weight
TW - turgescent weight
DW - dry weight

2.5.3. Leaf chlorophyll content

I measured the chlorophyll content on the flag leaf with a portable SPAD 502 Plus chlorophyll meter. The device provides the relative chlorophyll content in SPAD unit, calculated from the ratio of the red (650 nm) and infrared (940 nm) light intensity penetrating the leaf. I performed the measurement on 5 plants/plot one week after the first treatment, 5 times a week. The chlorophyll content was given in SPAD units.

2.5.4. Leaf proline content

The proline content of the flag leaf was determined based on the method of Bates et al. (1973). Before spectrophotometry, I removed the upper 2.0 mL toluene layer into Wassermann test tubes with a micropipette, and then poured it into the cuvette. I read the absorbance at 520 nm, toluene was the reference solution.

I started the measurement one week after the microalgae treatment once a week (4 plants/plot). The proline content of the samples (µg mL^{-1}) was determined based on a calibration curve. I determined the proline content based on fresh weight as follows:

$$[(\mu g \text{ proline } mL^{-1} * 3{,}0 \text{ mL toluene}) / 115{,}5 \text{ } \mu g \text{ } \mu mol^{-1}] / [0{,}3 \text{ g sample}/5] = \mu mol \text{ proline } g^{-1} \text{ fresh weight}$$

2.5.5. Leaf malondialdehyde content

There are diagnostic tests for the quantitative determination of the end products of lipid peroxidation, such as the determination of malondialdehyde (MDA). The most commonly used test is TBARS (thiobarbituric acid reactive substances test). Oxidative damage can be measured by analyzing 2-thiobarbituric acid reactive substance (TBARS) content, which is equivalent to MDA.

The supernatant was absorbed at 532 nm. Based on fresh weight, I determined the TBARS content as follows (Okem et al., 2016):

$$(A_{532} - A_{600}) * V * 1000 / E * W = \text{TBARS content } \mu mol \text{ } g^{-1} \text{ fresh weight}$$

A_{532} - malondialdehyd absorbance
A_{600} - turbidity absorbance
V - volume of grinding media (5,0 mL)
E - extinction coefficient (155 mM^{-1} cm^{-1})
W - fresh sample weight (0,5 g)

2.5.6. Leaf water potential

I measured the water potential of the flag leaves with a ZIM (Zimmermann Irrigation Monitoring) probe without removing the leaves continuously for 3 weeks during the period of the first treatment (5 days before and 16 days after the treatment). The ZIM probe measures the difference between the pressure of the magnets and the turgor pressure of the leaf. The value measured with the ZIM probe is inversely proportional to the turgor pressure of the leaf, when the leaf loses water with open stomata, the P_p (patch pressure) value characteristic of the water potential increases and vice versa, it decreases when the leaf takes in water. The device records P_p values every 5 minutes. Its unit is kPa.

2.6. Parameters measured at harvest

Before harvesting, I selected 1 meter from the middle row of the plot and collected the sample and determined:

- the ear number (m^2),
- the ear length (30 pc ear/plot),
- the number of grain/ear (30 pc ear number/plot),
- the thousand grain weight (1000 pc grain weight)
- I calculated the yield per hectare (kg ha^{-1}) from the yield per plot (kg/plot).

I examined quality parameters with a FOSS Infratec 1241 type grain analyzer. The machine determines the moisture, protein, fat content (%), Zeleny number and W alveographic values.

2.7. Statistical analysis

The statistical evaluation of the experimental data was carried out using the Dell Statistica 13.2 program. During the evaluation of the data, I used one-factor analysis of variance, LSD and Duncan tests, as well as linear regression analysis. I created the graphs with Ms Excel 2019.

3. RESULTS AND ASSESSMENT

3.1. Yield

The treatments with cyanobacteria in the phenophase of tillering and ear emergance had the highest yield in a three-year average (14.8 %). Similar yields were achieved with the treatment at tillering with the two green algae in a three-year average (15.3 and 18.9 %). The three-year average yields of the cyanobacterium and the two green microalgae were different. The highest yield were measured in green algae treated plots, MACC-755 being the most bioactive at a single application of 0.1 g L^{-1} with an 18,9 % yield increase (Figure 1). In the case of cyanobacteria double treatment was necessary because of the lower hormone production by cyanobacteria than by the green algae. Cyanobacteria produce polysaccharides, a gelatinous substance which may have reduced the effectiveness of cell disruption and thus the bioactivity of treatments. The yield increase achieved by single treatment with 1.0 g L^{-1} MACC-1 produced under laboratory condition in two-year average was 14.5 %. In the 2020/21 in the wheat experiment carried out with the MACC-1 produced in BG-11 nutrient medium in race-way pond (RWP) the yield increase was 13.5 %.

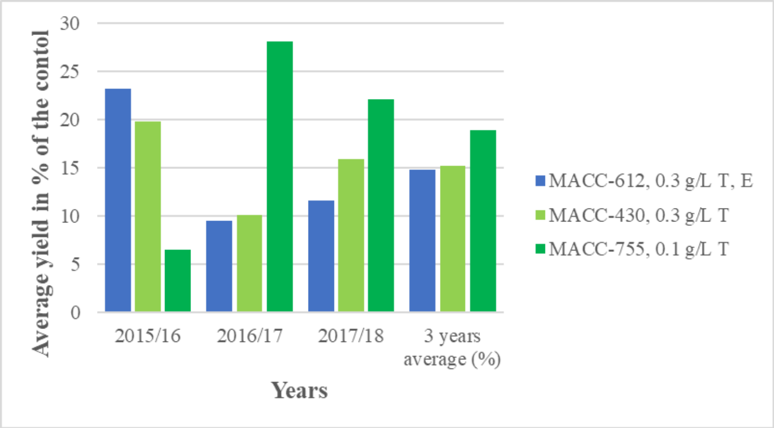


Fig 1. Average yield in % of control for the best yielding treatments.

3.2 Surplus income

In the experiments, single and double cyanobacteria or green algae treatments were the most effective at concentrations of up to 0.3 g L^{-1} and 1.0 g L^{-1}. If we suppose that algal biomass can be purchased at a price of 50 Euro kg^{-1}, and the price of winter wheat is HUF 73,478 t^{-1} (average of the three experimental years), then the single treatment of 0.1 g L^{-1} resulted in the highest surplus income (HUF 138,186), but a double treatment with 0.3 g L^{-1} also resulted in a significant surplus income (HUF 103,842). The additional income depends on the current wheat price. The cost can be reduced by combining microalgae application with herbicides used for weed control. The use of a non-auxin-containing herbicide is recommended. A separate plant treatment only with microalgae the cost of the treatment is between HUF 5-15,000, which is only informative.

3.3. Crop elements

Three components determine the amount of the crop the number of ears, the number of grains per ear and the weight of thousand grains. The germ count of the control is 4.5 million ha^{-1}. During my experiments, the number of ears on the plot treated with cyanobacteria at 0.3 g L^{-1} T, E was 5.1 thousand ha on average over three years, compared to the control (4.2 thousand ha on average over three years). *Tetracystis* sp. on the plot treated with green algae, the number of ears in the 0.3 g L^{-1} (T) treatment was 5.2 thousand ha, while in the treatment with the green algae *C. vulgaris* 0.1 g L^{-1} (T), the number of ears was 4.2 thousand ha, three years on average. In the case of the green algae *C. vulgaris* (C) in the average of two years and in 2020/21 (C1) in the case of the green algae propagated in the RWP in BG-11 medium in the 1.0 g L^{-1} (T) treatment, 4.4 and 4.1 thousand if there was the largest number of ears compared to the control (4.0 thousand ha). The cyanobacterium *N. piscinale* and *Tetracystis sp.* green algae treatments resulted in a similar number of ear, while the number of ear was much lower with *C. vulgaris* green algae (C, C1).

During my measurements, the ear length was 6.7 cm in the cyanobacterium 0.3 g L^{-1} (T, E) treatment, and 6.9 cm in the green algae 0.1 and 0.3 g L^{-1} (T) treatments, that is, longer than the control (6.3 cm) in an average of three years. In the case of the laboratory grown green algae *C. vulgaris* (C) in the average of two years and in 2020/21 (C1) in the case of the green algae produced in the RWP in BG-11 medium, used for plant treatment at 1.0 g L^{-1} (T), the ear length were 10.2 and 9.3 cm, respectively. The ear length of the control plots was 8.4 cm.

The number of grain/ear was 43 in the cyanobacterial 0.3 g L^{-1} (T, E) treatment compared to the control (35) in the average of three years. In the case of green algae, the number of grain/ear in the 0.1 and 0.3 g L^{-1} (T) treatments was 38-41 on average over three years. In the case of the green algae *C. vulgaris* (C) in the average of two years and in 2020/21 (C1) in the case of the green algae propagated in the RWP in BG-11 medium, the number of grains was 49 and 52 in the treatment of 1.0 g L^{-1} (T) number of ears (control 39 pieces).

Thousand grain weight at 0.3 g L^{-1} (T, E) was 40.8 g in the cyanobacterial treatment, which is significantly higher than the control (36.4 g) in the three-year average. The weight of the green algae treatments (0.1 and 0.3 g L^{-1} T) was 37.1-41.3 g. For the green algae *C. vulgaris* (C) in the average of two years and in 2020/21 (C1) in the case of the green algae propagated in the RWP in BG-11 medium, 40.9 and 47.0 g for the 1.0 g L^{-1} (T) treatment was the thousand grain weight compared to the control (36.6 g) (Figure 2).

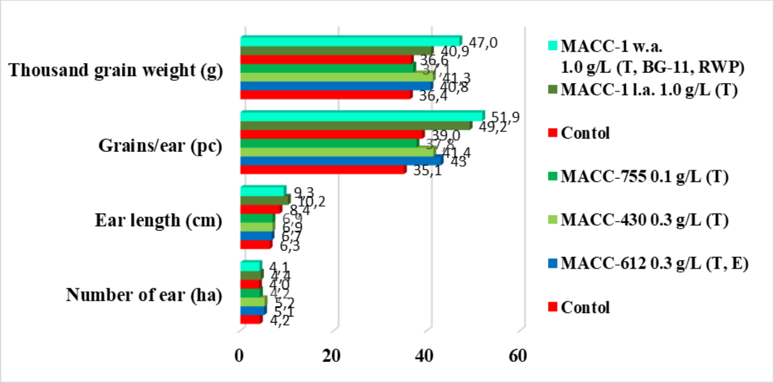


Fig 2. The effect of crop elements in algae treatments with the highest yield compared to the control over a three-year average.

l.a.: laboratory-grown algae, w.a.: wastwater grown algae, T: tillering, T, E: tillering and ear emergence, BG-11: nutrient solution, RWP (Race-Way Pond): open system algae grower.

3.4. Plant physiological parameters affected by microalgae treatment

The root dry weight of the cyanobacterium in the 0.3 g L^{-1} (T, E) treatment was 1.08 g, i.e. it was significantly higher than the control (0.62 g) in the average of three years. The *T. sp*. and when treated with green algae *C. vulgaris* at 0.3 and 0.1 g L^{-1} (T), the dry weight of the root was 0.94 and 0.89 g, significantly higher than the control in the average of three years.

The highest average RWC content of the plants treated with cyanobacteria at 0.3 g L^{-1} (T, E) treatment was 73.7 %. The *T. sp*. for green algae, the highest average RWC content in the 0.3 g L^{-1} (T) treatment was 71.9%, the control was 68.9%. For the green alga *C. vulgaris*, the highest average RWC content in the 0.1 g L^{-1} (T) treatment was 73.6 % in the average of three years.

The chlorophyll content of the plants treated with cyanobacteria is 44.8 SPAD units at 0.3 g L^{-1} (T, E), while the green algae *T. sp*. 0.3 g L^{-1} (T) treatment had 43.7 SPAD units, *C.vulgaris* 0.1 g L^{-1} (T) treatment had 43.7 SPAD units compared to the control (39.6 SPAD units) in the three-year average.

The proline content in the 0.3 g L^{-1} (T, E) treatment with the cyanobacterium is 6.8 µmol g^{-1}, while the green algae in the 0.3 g L^{-1} (T) treatment with *T. sp*. is 6.6 µmol g^{-1}, in *C. vulgaris* the proline content in the 0.1 g L^{-1} (T) treatments was 6.4 µmol g^{-1}, well above the control value (3.9 µmol g^{-1}) average of three years (Figure 3).

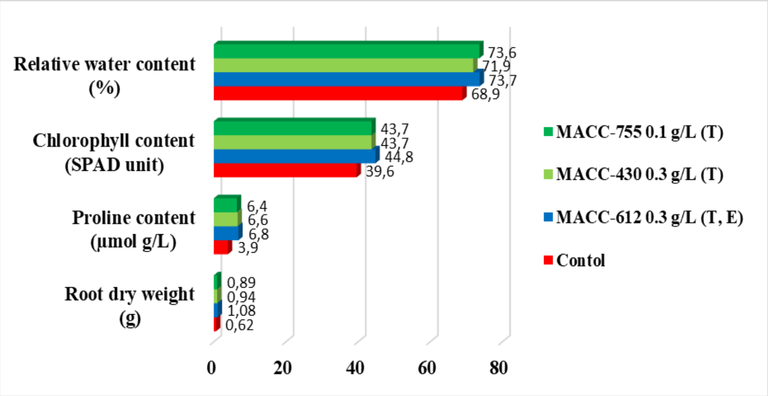


Fig 3. The development of the root mass of the plants treated with algae, as well as the parameters characteristic of photosynthesis and water balance, compared to the control over a three-year average.

T: tillering; E: ear emergence.

The MDA content in plants treated with cyanobacteria 0.3 g L^{-1} (T, E) was 0.85 µmol g^{-1}, compared to the control (0.40 µmol g^{-1}). The MDA content of green algae was 0.90-0.80 µmol g^{-1} at 0.3 and 0.1 g L^{-1}

(T) treatments. MDA content is the result of a year. The MDA content in plant samples treated with microalgae increased significantly compared to the control on each sampling day, indicating significant oxidative stress and membrane damage.

The water potential for the cyanobacterium was 80.3 kPa during the day and 73.9 kPa at night on plots treated with 1.0 g L^{-1} (T) in the average of three years. The highest water potential value for green algae resulted from the treatment of MACC-430 1.0 g L^{-1} (T) and MACC-755 0.1 g L^{-1} (T), both during the day (71.4-69.8 kPa), both in the case of nighttime values (63.7-65.4 kPa) compared to the control in the average of three years (daytime value 63.9 kPa, nighttime value 54.9 kPa).

4. CONCLUSIONS AND RECOMMENDATIONS

In three years field experiments, I determined beneficial effects on the winter wheat varieties “Bőség” and “Csillag” treated with the cyanobacterium *Nostoc piscinale*, MACC-612 and three green algae *Tetracystis sp*., MACC-430, *Chlorella vulgaris*, MACC-755 and MACC-1. I approved that biomass of the microalgae (MACC-1) grown in open raceway pond (RWP) using wastewater could show similar biostimulating effects that biomass produced in synthetic nutrient medium under controlled laboratory conditions. Compared to the control, the highest yield was achieved by the *N. piscinale* cyanobacterium treatment with 0.3 g L^{-1} at tillering and ear emergence (T, E) (8362 kg ha^{-1}). The green algae *Tetracystis sp*. treatment with 0.3 g L^{-1} (T) (6500 kg ha^{-1}) and the green algae *C. vulgaris* 0.1 g L^{-1} (T) treatment (7125 kg ha^{-1}) resulted in the highest yield. The biomass of the MACC-1 in a concentration of 1.0 g L^{-1} (T) grown in BG-11 nutrient medium and in wastewater provided a yield of 10994 kg ha^{-1} and 9332 kg ha^{-1}, respectively. From an economic point of view, a single treatment with MACC-612 and MACC-430 in 0.3 g L^{-1} (T), and with MACC-1 in 0.1 g L^{-1} can ensure the highest yield compared to the untreated plants. Favourable changes in plant physiological parameters, including higher chlorophyll content and its slower decomposition extended the vegetation period of treated plants. The yield increase was explained by the higher values of crop elements compared to the control.

5. NEW SCIENTIFIC RESULTS

1. It was the first study about the effects of foliar spraying on winter wheat (*Triticum aestivum* L.) with a cyanobacterium (MACC-612 *Nostoc piscinale*) and three green algae (MACC-430 *Tetracystis sp*., MACC-755 and MACC-1 *Chlorella vulgaris*) suspension. I found that the treatment of the winter wheat variety "Bőség" with three strains of microalgae at tillering (T) and/or ear emergence (E) with 0.1, 0.3 and 1.0 g L^{-1} resulted in a yield increase of 10.4-47.4 %.

2. I proposed profitable treatments with the investigated microalgae. I considered the average market price of wheat per ton during the three experimental years (2015-2018) based on the data of the KSH (73478 HUF) and supposed that the market price of the microalgae could be no more than 50 Euro kg^{-1}. For cyanobacteria, the 0.3 g L^{-1} (T, E) treatment resulted in the highest surplus income (103 842 HUF). In the case of treatments with green algae, this value was at 0.1, 0.3 and 1.0 g L^{-1} (T) treatment (minimum 65 019 HUF and maximum 138 186 HUF). The cost can be reduced by combining the application with weed control. The use of a non-auxin-containing herbicide is recommended.

3. Among the crop elements, the number of ears, the number of grain/ear and the thousand grain weight contributed to the higher yield in the treatments with MACC-612 and MACC-430 at 0.3 g L^{-1} (T, E), while in case of MACC-1 at 0.1 g L^{-1} (T) only the number of grain/ear contributed to the achievement of a higher yield. In wastewater grown

MACC-1 in a concentration of 1.0 g L^{-1} (T) the ear length, number of grain/ear and the thousand grain weight impacted the crop yield.

4. In plants treated with microalgae I measured higher root biomass, increased values of parameters influencing the photosynthesis (chlorophyll) and the water balance (relative water content, proline and malondialdehyde content) compared to the untreated control plants.

6. LIST OF PUBICATIONS

List of publications related to the subject of the dissertation:

Scientific papers in foreign-language published in peer-reviewed journals:

- Ördög V. - Stirk, W. A. - **Takács G**. - Pőthe P. - Illés Á. – Bojtor Cs. - Széles A. - Tóth B. - van Staden, J. - Nagy J. (2021): Plant biostimulating effects of the cyanobacterium *Nostoc piscinale* on maize (*Zea mays* L.) in field experiments. South African Journal of Botany, 140: 153-160.

- **Takács G.** – Stirk, W. A. - Gergely I. - Molnár Z. - van Staden, J. - Ördög V. (2019): Biostimulating effects of the cyanobacterium *Nostoc piscinale* on winter wheat in field experiments. South African Journal of Botany, 126: 99-106.

Scientific papers published in peer-reviewed journals in Hungarian:

- **Takács G.** - Pőthe P. - Gergely I. - Molnár Z. - Nagy J. - Ördög V. (2020): A *Nostoc piscinale* cianobaktérium biostimuláns hatása a Zephir kukorica hibridre - Mosonmagyaróvár. Növénytermelés, 69: 95-113.

- **Takács G.** - Gergely I. - Ördög V. (2021): A búza (*Triticum aestivum* L.) vízigénye és a vízhiány hatása a növényre. Acta Agronomica Óváriensis, 62 (2): 116-140.

Conference publication in foreign language:

- **Takács G.** - Gergely I. - Molnár Z. - Ördög V. (2019): Plant biostimulating effects of the green alga *Chlamydopodium fusiforme* on winter wheat in field experiments In: Ördög V.; Molnár Z. (szerk.): 9th Symposium on Microalgae and Seaweed Products in Plant/Soil-Systems: Book of Abstracts, p. 34.

- **Takács G.** - Gergely I. - Ördög V. (2017): Effects microalgae leaf treatments on proline concentration, relative water content and patch-pressure values of "Bőség" winter wheat variety leaves. In: 8th Symposium on Microalgae and Seaweed Products in Plant/Soil-Systems, p. 81.

- **Takács G.** - Gergely I. - Ördög V. (2015): ZIM-probe for measurement of winter wheat hydration status. In: Ördög V.; Molnár Z. (szerk.): 7th Symposium on Microalgae and Seaweed Products in Plant/Soil-Systems "Contribution to Sustainable Agriculture, p. 69-70.

Conference publication in Hungarian:

- **Takács G.** - Gergely I. - Ördög V. (2018): Mikroalga kezelések hatása a "Bőség" őszi búzafajta levelének prolin- és víztartalmára. In: Szalka É. (szerk.): XXXVII. Óvári Tudományos Napok, 2018. november 9-10.: Fenntartható agrárium és környezet, az Óvári Akadémia 200 éve - múlt, jelen, jövő Mosonmagyaróvár, Magyarország: VEAB Agrártudományi Szakbizottság, Széchenyi István Egyetem Mezőgazdaság- és Élelmiszertudományi Kar, p. 231-237.

- **Takács G.** - Gergely I. - Ördög V. (2016): A *Nostoc entophytum* cyanobaktérium hatása a "Bőség" őszi búzafajta növekedésére és termésére. In: Szalka É.; Bali Papp Á. (szerk.): XXXVI. Óvári Tudományos Nap: Hagyomány és innováció az agrár- és élelmiszergazdaságban I-II Mosonmagyaróvár, Magyarország: Széchenyi István Egyetem Mezőgazdaság- és Élelmiszertudományi Kar, p. 224-231.