

**Thesis of a doctoral (PhD) dissertation**

**OPTIMIZATION OF MAIZE PRODUCTIVITY THROUGH PRECISION  
DRIP IRRIGATION AND FOLIAR BIOSTIMULANT COMPLEX AND  
MICRONUTRIENTS APPLICATION**

**Ocwa Akasairi**  
Ph.D. candidate

**Supervisor: Professor Dr. Harsányi Endre**



**UNIVERSITY OF DEBRECEN**  
**Kálmán Kerpely Doctoral School of Crop Production and Horticultural  
Sciences**

**Debrecen, 2025**



## 1. Introduction

Global population increase raises food insecurity concerns (Du *et al.*, 2024) with over 1 billion people lacking adequate dietary energy and suffering from micronutrient deficiencies (Barrett, 2010). This calls for an increase in production and biofortification of major food crops including maize (*Zea mays* L.) (Tejada *et al.*, 2016). Meeting the rising food demand necessitates circa 40% maize yield improvement in the next four decades (Sui *et al.*, 2018), though, this is affected by declining soil fertility (Wu *et al.*, 2019) and climate change (Xiang *et al.*, 2024). Because climate change has precipitated water shortage (Li *et al.*, 2017), utilizing water efficient irrigation methods is inevitable since water allocation for irrigation is affected by other economic sectors (Zhang *et al.*, 2021). Besides affecting the sustainability of water resources and the functionality of irrigation systems in relation to crop production (Pool *et al.*, 2021), climate change has both direct and indirect effects on soil fertility (Biswa, 2022) hence fertilizer application commonly used as amelioration technique (Tian *et al.*, 2024). In crop production, maize and wheat account for circa 30% of the global chemical nitrogen fertilizer consumption (Ladha *et al.*, 2016). The excessive use of chemical fertilizers in an attempt to sustain soil fertility and crop production causes water pollution due to leaching and deposition of nutrients into water bodies (Li *et al.*, 2016); necessitating improvement in water application, and nutrient supply techniques (Sun *et al.*, 2023). Besides, Ram *et al.* (2017) noted that the efficacy of nutrients applied to the soil is lower for both micro and macro nutrients with 5% for micronutrients, and 50%, 40% and <15% for nitrogen, potassium, and phosphorus, respectively due to limited synchrony between nutrient release by fertilizers versus crop demand at critical growth stages. In this case, foliar nutrient supply considered as supplementary approach (Patil *et al.*, 2018) becomes handy.

Specifically, the water and nutrient requirement of maize depends on the growth stage (Illés *et al.*, 2022); hence, supply of moisture and nutrients at critical stages is of paramount importance. Therefore, the use of precision technologies that can detect water and nutrient deficiencies becomes handy. Currently, in Hungary, diverse biostimulant formulations, and chemicals fertilizers have been developed with limited robust field efficacy tests, which are necessary for farmer recommendation and/or re-constitution if field efficacy is null. Besides, conventional agronomic traits and yield assessments, this study included chlorophyll fluorescence and photochemical measurements, which are useful indicators of physiological water stress during the active vegetative and reproductive stages of maize

plant growth. Besides, photochemical efficiency of PSII is recommended for studies involving drought stress (*Faraloni et al., 2011*) and nutrition stress (*Simkó et al., 2020*). With this in mind, this study hypothesized that utilizing precision drip irrigation and biostimulant, and micronutrients foliar application does not affect the phenological, chlorophyll fluorescence and photochemical parameters, and grain yield and quality of maize. To test this hypothesis, this study was conducted with following objectives:

- a) Assess the effect of precision drip irrigation and biostimulant, and micronutrients foliar application on growth characteristics of maize.
- b) Determine the response of chlorophyll fluorescence and photochemical yield of maize to precision drip irrigation and biostimulant, and micronutrients foliar application.
- c) Evaluate the response of yield and yield components of maize to precision drip irrigation and biostimulant, and micronutrients foliar application.
- d) Evaluate the effect of precision drip irrigation and biostimulant, and micronutrients foliar application on grain quality maize.

## **2. Materials and methods**

### **2.1. Experimental site**

The experiments were conducted at the University of Debrecen, Institutes of Agricultural Researches and Educational Farm Bemutatókert experimental area (47°83, 030"N, 21°82, 060"E, 111 m asl). The preliminary experiment was conducted in 2021 while other confirmation experiments were conducted in 2022 and 2023 growing seasons. In 2021 season, the highest temperature (24.3°C) was recorded in July and lowest (8.9 °C) in April. Accordingly, 2022 season had lowest temperature of 8.8 °C in April and the highest temperatures in the months of July (23.6 °C) and August 23.8 °C). A similar trend was followed in the 2023 growing season. In terms of precipitation, generally, the growing season 2022 recorded the lowest precipitation of 22.4 mm and 17.0 mm in the months of July and August compared to 68.6 mm and 38.2 mm in the 2021 growing season, and 45.8 mm and 85.9 mm 2023 growing season, respectively. Analysis of soil and subsequent interpretation was done according to the Hungarian New Fertilization Guidelines (*Antal et al.*, 1987). The soil type in the experimental site was leached chernozem with pH of 7.6. The concentration of plant nutrients in the soil was: nitrogen (5.3%), phosphorus (320.9 mg/kg), potassium (256.2 mg kg<sup>-1</sup>), magnesium (451.6 mg kg<sup>-1</sup>), sulphur (8.8 mg kg<sup>-1</sup>), sodium (55.7 mg kg<sup>-1</sup>), copper (2.0 mg kg<sup>-1</sup>), manganese (60.1 mg kg<sup>-1</sup>), and zinc (2.7 mg kg<sup>-1</sup>).

### **2.2 Experimental design and treatments**

The experiments were laid in a randomized complete block design (RCBD) with two water management options i.e non-irrigated conditions (NI) and precision drip irrigation (IR) except in the 2021 preliminary study that only had precision drip irrigation. Precision drip irrigation system was installed on 14<sup>th</sup> June 2021, 27<sup>th</sup> May 2022 and 12<sup>th</sup> June 2023 prior to onset of drought and removed when maize plants attained physiological maturity. Each row of maize had one drip irrigation line/strip. Soil moisture content was measured using a Campbell wet sensor at different depths (-0.1m and -0.3m). Total amount of irrigation water applied during the experimental period was 283.8mm in the 2021 preliminary study, and 413.6mm and 358.0 mm in 2022 and 2023 growing seasons, respectively. The drip irrigation system was precision-managed by remote control via a mobile phone application (Hydrawise application (Hunter)), where the amount of water applied and intensity was continuously monitored. Biostimulant complex and chemical fertilizer treatments were

designated as T1 (biostimulant from plant origin), T2 (zinc based foliar fertilizer) T3 (Molybdenum and boron based foliar fertilizer) and T4 (negative control). In terms of composition, T1 had organic matter (60 m/m%), amino acids; asparagine, arginine, glutamine, alanine, leucine, histidine, glycine, proline, methionine, isoleucine, phenylalanine, lysine, and cystine (21.67 m/m%), Saccharides; fructose, glucose, raffinose, sucrose, trehalose and cellulose (6.2 m/m%), fulvic acid (23.1 m/m%), nitrogen (8 m/m%), phosphorus (0.5 m/m%), potassium (0.2 m/m%), T2 had zinc, water soluble (10.2%), T3 had P<sub>2</sub>O<sub>5</sub> (16.8%), K<sub>2</sub>O (11%), boron (8.35%), and molybdenum (11%) and T4 (control). The treatments were applied once according to the manufacturer's recommended rates: (T1 (4 l ha<sup>-1</sup>), T2 (1.5 l ha<sup>-1</sup>) and T3(1.4 kg ha<sup>-1</sup>). A motorized pump was used to apply the treatments at V8 growth stage when leaves of maize plants attained large leaf surface area necessary for absorption of nutrients.

### **2.3 Data collection and statistical analyses**

The agronomic characteristics measured were plant height, stem diameter, The Soil Plant Analysis Development (*SPAD*), Normalised Difference Vegetation Index (NDVI), and Leaf Area Index (LAI). The measurements were taken at 12 leaf stage (V12), tasseling stage (VT) and kernel blister stage (R2) on ten randomly selected maize plants. Plant height was measured using a meter rule calibrated in centimetres (cm) while stem diameter was determined using a digital Vanier calliper calibrated in millimetres (mm). Chlorophyll assessments as *SPAD* and NDVI were determined using the Greenseeker and chlorophyll meter, respectively on the third last expanded leaf at vegetative stage and a leaf opposite the ear at reproductive stage. LAI was measured using a Sunscan. In each plot, ten measurements were taken and average calculated.

Chlorophyll fluorescence and photochemical parameters including steady-state fluorescence ( $F'$ ), maximal fluorescence ( $F_m'$ ), quantum photosynthetic yield (efficiency) of PSII ( $\Phi_{PSII}$  or  $Y_{II}$ ) and electron transport rate (ETR) measurements were taken at V2, VT and R2 growth stages using Pulse Modulated Chlorophyll Fluorometer on four randomly maize plants selected in each treatment per replication (Yin *et al.*, 2011). Measurements were done on fully expanded new leaves of each randomly selected maize plants at vegetative stage and leaves opposite the ear at the reproductive stage (Simkó *et al.*, 2020). Before measurement, the leaves were dark adapted for 30minutes (Hu *et al.*,

2023) and after, measurements taken for  $F'$ ,  $F_M'$ ,  $\Phi_{PSII}$  and ETR.  $F'$  was the steady-state fluorescence signal under actinic light prior to saturation pulse,  $F_M'$  was maximal fluorescence under actinic light at steady state photosynthesis when all the reaction centers are closed. The difference in fluorescence between  $F_M'$  and  $F'$  ( $F_M' - F'$ ) was the  $F_q'$  (Baker, 2008; Janka *et al.*, 2015). The  $\Phi_{PSII}$  was the quantum photosynthetic yield (efficiency) of PSII calculated as  $(F_M' - F')/F_M'$  (Baker, 2008; Janka *et al.*, 2015). The ETR was an estimate of the number of electrons transported through photosystem II under steady-state photosynthetic conditions, calculated using the formula indicated in the manufacturer's protocol as well as in published literature (Flexas *et al.* 2002; Hu *et al.*, 2023) as:

$$\text{ETR} = \text{Quantum photosynthetic yield} \times 0.84 \times 0.5 \times \text{PAR}$$

Where 0.84 is average leaf absorptance value of PSII, and 0.5 means two photons used to excite one electron (Flexas *et al.* 2002), and PAR is photosynthetically active radiation.

Yield and yield component data collected included cob length (cm), cob weight (g), cob diameter (mm), number of seeds/cob, weight of seeds per cob (total seed weight), 1000 seed weight and yield per hectare. Ten cobs per treatment in each replication were randomly collected and processed using HALDRUP LT-35 laboratory thresher (HALDRUP GmbH, Ilshofen, Germany). Cob length was measured using a ruler calibrated in cm. Cob diameter (mm) as determined using a digital Vanier calliper. Cob weight was determined using an electronic weighing balance. Seeds/cob, weight of seeds per cob (total seed weight), and 1000 seed weight were determined using VSC-201 Vibrating Seed Counter (PLC Tuning Ltd - Hungary) and grain yield ( $\text{t ha}^{-1}$ ) calculated at moisture content of 14.5%.

The quality of grain in terms of protein content, oil content, starch content and moisture content were determined using Perten DA7250 NIR infrared grain analyser. The Perten DA7250 NIR infrared grain analyzer has the capacity to obtain 30 spectra at 5nm interval. The samples were analysed in the range of 570-1100nm (Szabó *et al.*, 2022).

The data was analysed using two-way ANOVA and Biostimulant and micronutrients means were separated using Tukey test at 5% probability level. The water regimes was compared using the t-test. The relationship between growth traits, chlorophyll fluorescence parameters, photochemical efficiency/yield, and yield and yield components was established using Pearson correlation. These analyses were done using OriginPro Graphing and Analysis Software (version 2024) and R software (version 4.3.2).

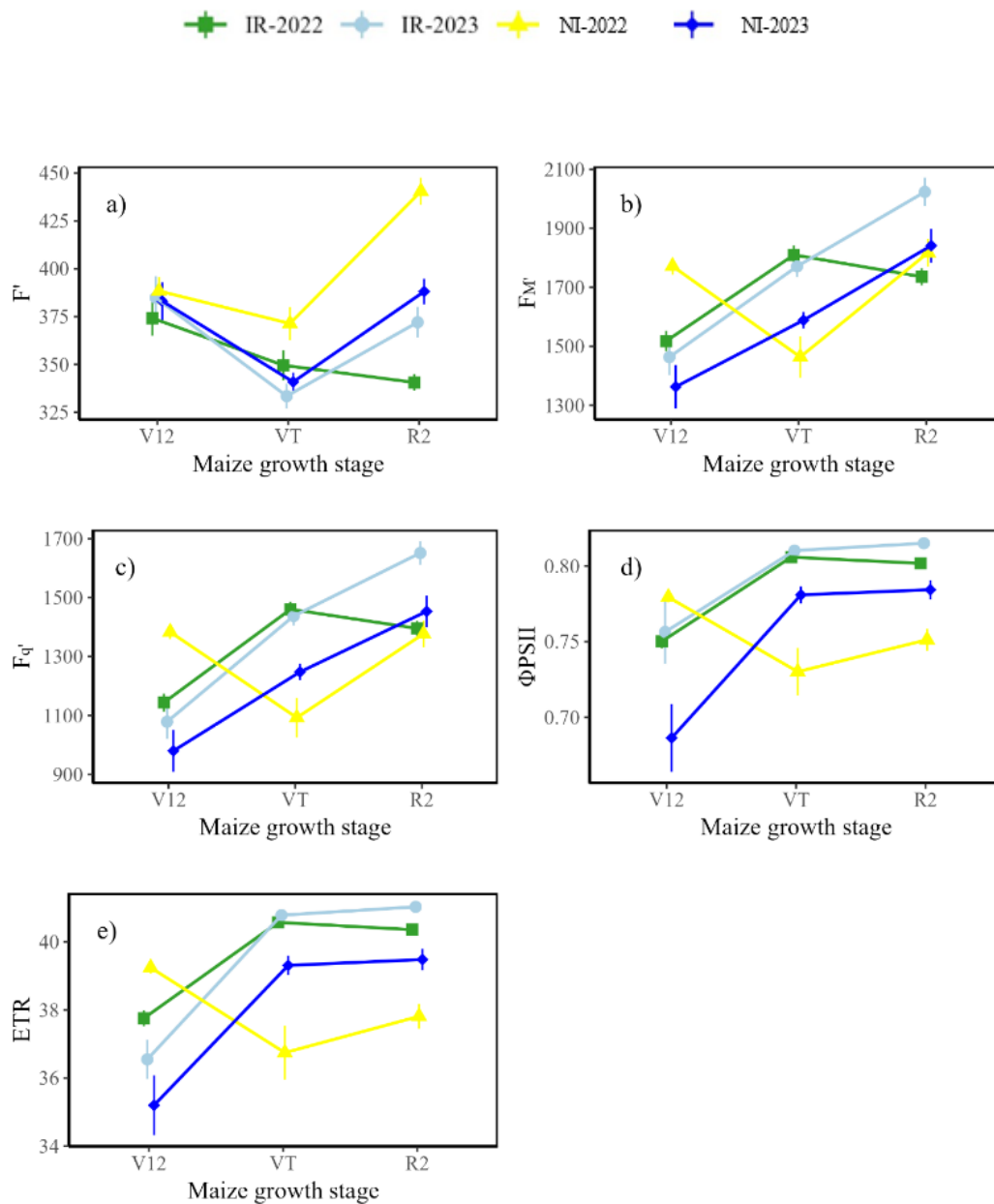
### 3. Results

Precision drip irrigation exhibited optimal effects on growth parameters. Plant height was optimized by an average of 165% and 5.7% in the two seasons. Stem diameter was only optimized by 9.4% at R2 growth stage in 2022, and by average of 7.4% in the 2023 growing season. The LAI was only improved at the VT and R2 growth stages by 134.2% and 121.0% in 2022 season. Therefore, optimal precision effects of drip irrigation on plant height and LAI were high with increased drought stress.

For the nitrogen content of the plant as evidenced by the SPAD values, precision drip irrigation reduced SPAD by -7.7% at the V12 growth stage and increased it by 43.1% at the R2 stage in 2022 season that was characterized by severe water stress and high temperature. In 2023 season with limited water stress and average temperature, precision drip irrigation optimized SPAD by 3.2% and 2.9% at the V12 and R2 growth stages, respectively. The comparative biostimulant and micronutrient effect also revealed a significant reduction in the SPAD values in T1, T2 and T3 treatments by -5.9%, -8.0%, and -8.1% under precision drip irrigation at the V12 growth stage. However, at the R2 growth stage, all the three treatments improved SPAD by 39.9%, 48.9%, and 41.8%. In 2023 growing season, the significant improvements were only evident at the V12 stage where T1 and T2 optimized SPAD by 4.3% and 4.2%. Overall, these results indicates that overlapping effect of excess moisture shortly after application reduces SPAD values since all the reductions occurred at V12 growth stage that preceded the stage of irrigation installation.

Precision drip irrigation optimised chlorophyll fluorescence parameters and quantum photochemical yield. The values of  $F_m'$ ,  $F_q'$ ,  $\Phi PSII$ , and ETR under precision drip irrigation at the V12 were lower compared to the non-irrigated conditions in 2022 growing season. However, a remarkable optimization effect at the VT stage was recorded by precision drip irrigation with 23.4%, 33.5%, 10.4%, and 10.4% improvement of  $F_m'$ ,  $F_q'$ ,  $\Phi PSII$ , and ETR, respectively. Later, conspicuous significant improvement of  $\Phi PSII$  and ETR by 6.7% and 6.9%, respectively by precision drip irrigation was recorded at the R2 stage. In 2023 growing season, the significant effects were evident at the VT and R2 growth stages. As such, the improvement by 11.5%, 15.2%, 2.9% and 3.8%, of  $F_m'$ ,  $F_q'$ ,  $\Phi PSII$  and ETR were observed at the VT growth stage, and similar trend of effects were recorded at the R2 growth stage. In terms of overall progression of  $F$ ,  $F_m'$ ,  $F_q'$ ,  $\Phi PSII$ , and ETR across the

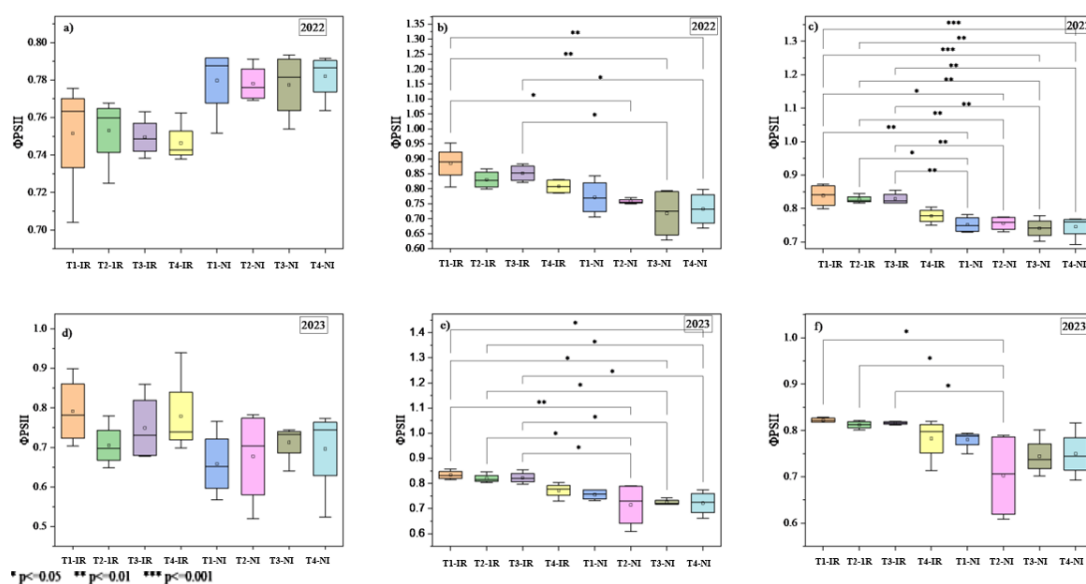
three stages,  $F_M'$ ,  $F_q'$ ,  $\Phi_{PSII}$ , and ETR exhibited gradually increasing response while  $F'$  showed notable reduction at the VT stage and increased by R2 growth stage (Figure 1).



**Figure 1** Chlorophyll fluorescence parameters and photochemical yield dynamics under precision irrigation (IR) and non-irrigated (NI) conditions at different maize growth stages in 2022 and 2023 growing seasons. a)  $F'$  (steady-state fluorescence signal under actinic light prior to saturation pulse), b)  $F_M'$  (maximal fluorescence under actinic light at steady state photosynthesis when all the reaction centers are closed), c)  $F_q'$  (fluorescence difference between  $F_M'$  and  $F'$ ), d)  $\Phi_{PSII}$  (quantum photosynthetic yield (efficiency) of photosystem II), e) ETR (electron transport rate). Vertical bars indicate the standard error.

For  $\Phi_{PSII}$  and ETR, the biostimulant, and micronutrients individual effects in each water management regime were not significantly different, albeit existence of significant interactive differences between water management  $\times$  foliar biostimulant and micronutrients

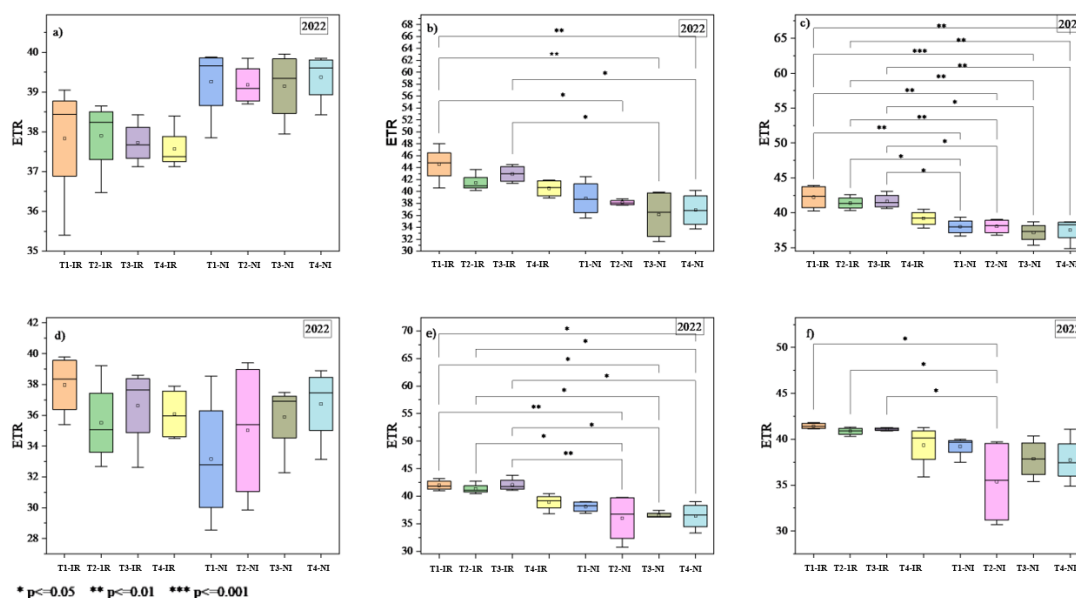
application at VT as well as R2 growth stages, respectively (Figure 2 and 3). In the season 2022 at the VT growth stage under drip precision irrigation, T1 had significantly higher  $\Phi$ PSII as compared to T2 and T3 under non-irrigated conditions. Also, T3 improved  $\Phi$ PSII under precision irrigation when compared with the value recorded under non-irrigated conditions. Correspondingly, at R2 growth stage, higher values of  $\Phi$ PSII were recorded in all treatments T1, T2 and T3 as compared to the values under non-irrigated conditions.. The same trend was observed in season 2023. The direction of response of ETR was similar to  $\Phi$ PSII, where interactive effects showed significantly higher ETR in T1, T1 and T3 treatments under precision drip irrigation as compared to non-irrigated conditions. Most importantly, T1 maintained a higher photochemical parameters at the VT and R2 growth stages in both seasons.



**Figure 2** Quantum photosynthetic yield (efficiency) of photosystem II ( $\Phi$ PSII), under biostimulant and micronutrient treatments for precision drip irrigation (IR) and non-irrigated (NI) conditions at different stages of maize growth. a) V12 (season 2022), b) VT (season 2022) c) R2 (season 2022), d) V12 (season 2023), e) VT (season 2023), f) R2 (season 2023). T1 – biostimulant, T2 and T3 – chemical fertilizers containing different micronutrients, T4 – control. Significance levels: ns (not significant), \*( p<0.05), \*( p<0.01), \*( p<0.001). Uncompared treatments did not differ significantly. (Debrecen, 2022-2023).

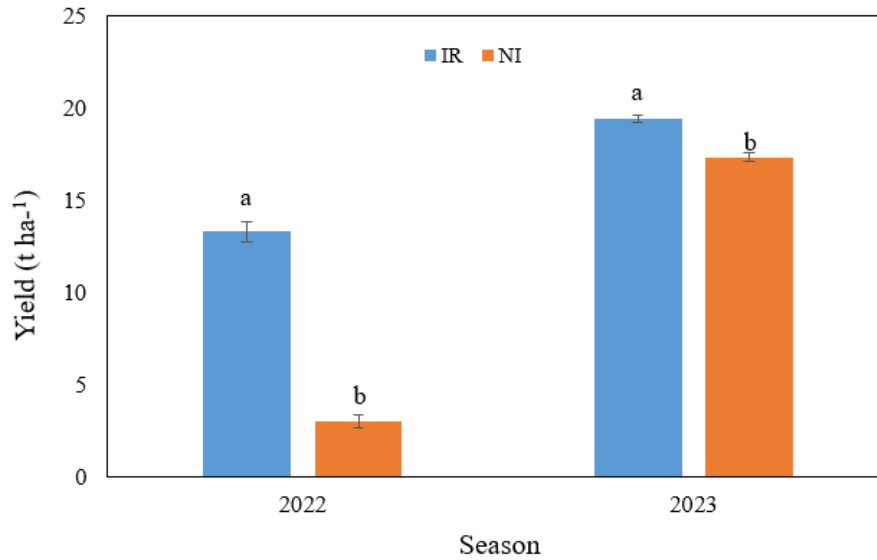
Precision drip irrigation produced an average yield improvement of 5.8 t ha<sup>-1</sup> yield improvement in the two seasons (Figure 4). Overall, the cob diameter, cob length, weight of seeds per cob, cob weight, 1000 seed weight, and seed number per cob, and grain yield were significantly optimized by precision drip irrigation in both growing seasons.

The interaction between water management regimes  $\times$  biostimulant and micronutrients on weight of 1000 seeds was significant only in 2023 growing season. As such, T2 had the higher performance under precision drip irrigation with 1000 seed weight of 569.9g.

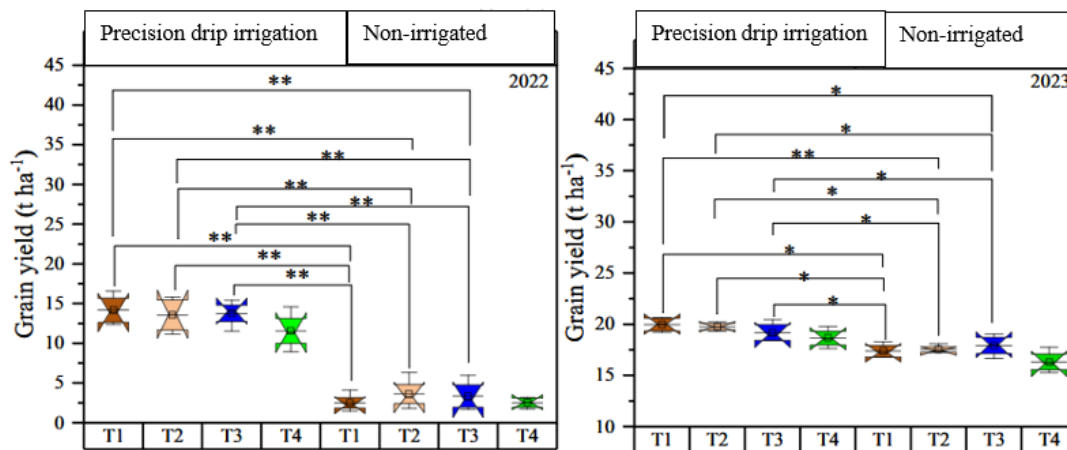


**Figure 3** Electron transport rate (ETR) under biostimulant and micronutrient treatments for precision drip irrigation (IR) and non-irrigated (NI) conditions at different stages of maize growth. a) V12 (season 2022), b) VT (season 2022) c) R2 (season 2022), d) V12 (season 2023), e) VT (season 2023), f) R2 (season 2023). T1 – biostimulant, T2 and T3 – chemical fertilizers containing different micronutrients, T4 – control. Significance levels: ns (not significant), \* ( $p < 0.05$ ), \*\* ( $p < 0.01$ ), \*\*\* ( $p < 0.001$ ). Uncompared treatments did not differ significantly. (Debrecen, 2022-2023).

The biostimulant as well as micronutrients application significantly improved yield in 2023 season, irrespective of the water management regime. Thus, the recorded yield for 2023 season was  $18.7 \text{ t ha}^{-1}$  in both T1 and T2, and  $18.6 \text{ t ha}^{-1}$  in T3 as compared to  $17.5 \text{ t ha}^{-1}$  in the control. In other words, T1 and T2 produced yield improvement of  $1.2 \text{ t ha}^{-1}$  (6.9%) and T3 had  $1.1 \text{ t ha}^{-1}$  (6.3%). Putting this in general context, it appears that compared to the control, each of the treatments T1, T2 and T3 produced an overall yield improvement of  $1.0 \text{ t ha}^{-1}$ . Meanwhile for growing season 2022, the biostimulant and micronutrients application had yield between  $8.4 - 8.6 \text{ t ha}^{-1}$  compared to  $7.1 \text{ t ha}^{-1}$  in the control. As such, though the positive effect was also evident in growing season 2022, biostimulant as well as micronutrients application effects were suboptimal. Analysing the biostimulant and the micronutrients effects in the two water management regimes shows higher yield under precision drip irrigation. Specifically, T1 had highest yield of  $14.2$  and  $20.8 \text{ t ha}^{-1}$  under precision drip irrigation as compared to  $2.5$  and  $17.4 \text{ t ha}^{-1}$  under non-irrigated conditions in growing season 2022 and 2023, respectively (Figure 5).



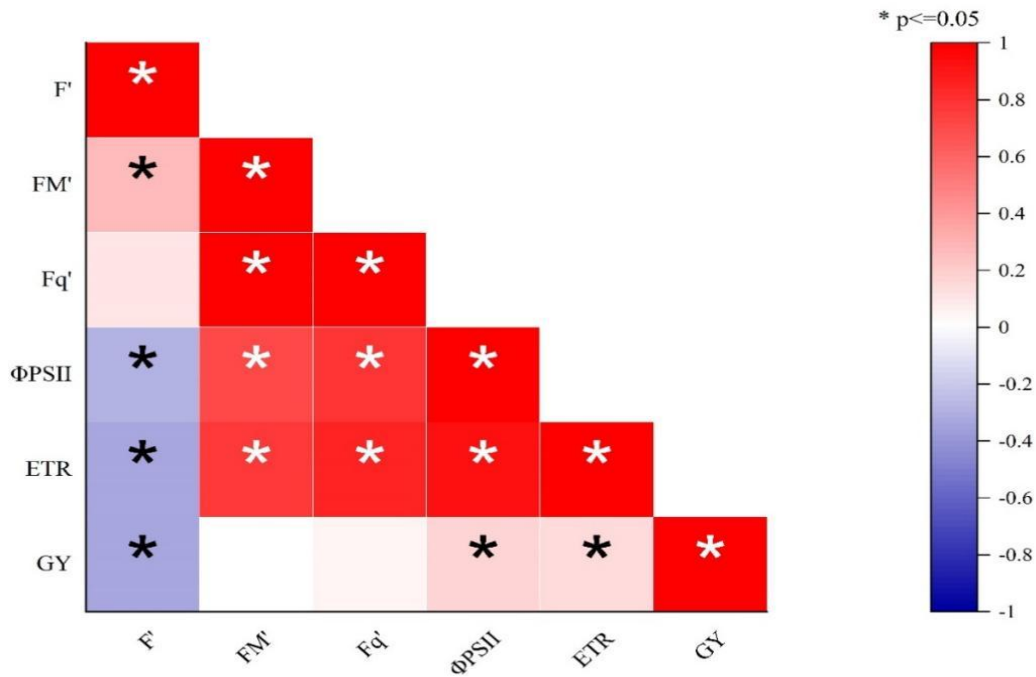
**Figure 4** Variation in grain yield as affected by water management in 2022 and 2023 seasons. IR- precision drip irrigation, and NI -non-irrigated conditions.



**Figure 5** Biostimulant and micronutrients affect maize grain yield under precision drip irrigation and non-irrigated conditions (Ocwa *et al.*, 2024).

In terms of nexus, the results indicated a positive correlation between  $Fm'$ ,  $Fq'$ ,  $\Phi PSII$  and ETR and a negative correlation between  $F'$  and  $\Phi PSII$ , ETR and yield (Figure 6). Contrary,  $F'$  had a significant positive correlation with  $Fm'$ . Additionally,  $Fm'$  had no correlation with grain yield. To put this in context, the yield,  $\Phi PSII$  and ETR positive correlation is an evidence of  $\Phi PSII$  and ETR being useful indicators of micronutrients and biostimulants application as well as drip irrigation effect on maize yield and overall productivity. However, variation in the photochemical parameters across maize growth stages suggests that these parameters can be used to detect and mitigate the negative

effects of water stress on maize yield and yield components in the early stages. If correctly implemented, this enhances the sustainability of agronomic interventions, as early corrective measures facilitate achievement of planned crop yield.



**Figure 6** Correlation between quantum efficiency of photosystem II, chlorophyll fluorescence, and maize yield (Ocwa *et al.*, 2024).

Precision drip irrigation had suboptimal effects on grain quality, although there was a conspicuous reduction in grain protein content by -2.1% and -0.5% in 2022 and 2023 seasons, respectively as well as 0.4% reduction in oil content in 2022 season. Also, precision drip irrigation improved starch by 2.3% in 2022 season. On the other hand, the biostimulant (T1) and micronutrients treatments (T2 and T3) effect on oil, starch and protein content of grain were all suboptimal.

#### 4. New scientific results

1. Precision drip irrigation at the VT and R2 growth stages has the capacity to enhance plant height, and LAI by an average of 85.3%, and 127.6%, respectively. However, the optimisation efficacy increases with increase in the severity of water stress and elevated temperatures that seasonally differ.
2. Grain quality attributes including oil, starch, and protein content are only significantly affected by precision drip irrigation in seasons where drought and temperature stress are high, for this study in 2022 season where there was 0.3% and 2.3% improvement in oil and starch content, and -2.1% reduction in protein content by precision drip irrigation.
3. The response of quantum photosynthetic yield and electron transport rate to nutrients supplied by the biostimulant and chemical fertilizers improves with precision supply of moisture at sensitive stages of maize depending on the overall climate conditions of the given season. T1 had significantly higher (0.9 or 90%)  $\Phi$ PSII as compared to T2 and T3 under non-irrigated conditions at the VT growth stage. Since quantum photosynthetic yield was positively correlated with grain yield, it can be used as a good indicator of the efficacy of biostimulants and micronutrients on vegetative and yield productivity and as a guide to make necessary nutrient supply corrections during active phenophases of maize.
4. The biostimulant (T1) as well as micronutrients (T2 and T3) application significantly improved yield irrespective of the water management regime with each treatment producing an overall yield improvement of close to 1.0 t ha<sup>-1</sup>. Comparatively, T1 had yield of 14.2 and 20.8 t ha<sup>-1</sup> under precision drip irrigation as compared to 2.5 and 17.4 t ha<sup>-1</sup> under non-irrigated conditions in the growing seasons 2022 and 2023, respectively. In this, the fact that all the three treatments under water regimes had positive impact on yield suggest the need to have integrated application to achieve their optimum effect. Additionally, the biostimulants (T1) and micronutrients (T2 and T3) produced suboptimal effects on grain quality attributes under both precision drip irrigation and non-irrigated conditions.

## 5. Practical application of results

1. Utilization of precision drip irrigation based on season specific climate conditions. This study demonstrates a clear difference in the amount of irrigation water supplied to maize during the two seasons since water supply was remotely controlled via a mobile phone application (Hydrawise application (Hunter)). The growing season 2022 used additional 55.6 mm of water compared to 2023 since it had higher drought intensity. In this regard, season specific precision drip irrigation ensures judicious utilization of water since no irrigation is started when the probability of rain reaches 80%. This saves water as compared to irrigation methods that supply moisture in a generic routine.
2. Guide to careful moisture supply just after irrigation installation, since in this study, even with 15 days gap in the installation of irrigation systems in the two seasons, chlorophyll content still reduced at V12 leaf stage that preceded irrigation and nutrients supply.
3. Early detection of efficacy of exogenously supplied nutrients on the productivity of maize. The suboptimal sole efficacy of the biostimulant and micronutrients on quantum photosynthetic yield and electron transport rate aligned with the results of final grain yield. In this case, if a deficiency of a nutrient is detected at the growth stage, then correction through extra supply can be implemented to reduce the anticipated negative effect on the final grain yield.
4. Identified grey areas of research for the tested biostimulant and micronutrients in Hungary. The fact that the soil was deficient in nitrogen based on soil tests means that there is need to develop appropriate nitrogen supply mainly through soil application based on the nitrate directive by the EU, and in case additional nutrient supply is needed, then foliar fertilisation could be used in appropriate doses. However, rigorous investigations are required to ascertain appropriate soil chemical nitrogen supply that can be combined with foliar biostimulant application to obtain optimum maize productivity while protecting the environment. In addition, this study guides that foliar zinc application in zinc rich soil is counterproductive.

## 6. Bibliography

1. *Antal, J.- Buzás, I.- Debreczeni, B.- Fekete, A.- Nagy, M.- Patócs, I.:* 1987. Újműtrágyázásiirányelvek, Budapest. pp 1-85.
2. *Barrett, C.B.:* 2010. Measuring food insecurity. *Science*, 327:825–828.
3. *Biswa, T.:* 2022. Climate Change and Its Impact on Soil Fertility and Life Forms. In: *Research Anthology on Environmental and Societal Impacts of Climate Change*. pp 27.
4. *Bonea, D.- Urechean, V.:* 2011. The evaluation of water stress in maize (*Zea mays* L.) using selection indices. *Romanian Agricultural Research*, 28:79-86.
5. *Du, R.- Li, Z.- Xiang, Y.- Sun, T.- Liu, X.- Shi, H.- Li, W.- Huang, X.- Tang, Z.- Lu, J.- Chen, J.- Zhang, F.:* 2024. Drip fertigation increases maize grain yield by affecting phenology, grain filling process, biomass accumulation and translocation: a 4-year field trial. *Plants*, 13:1903.
6. *Faraloni, C.- Cutino, I.- Petruccelli, R.- Leva, A.R.- Lazzeri, S.- Torzillo, G.:* 2011. Chlorophyll fluorescence technique as a rapid tool for in vitro screening of olive cultivars (*Olea europaea* L.) tolerant to drought stress. *Environmental and Experimental Botany*, 73:49-56.
7. *Illés, Á.- Szabó, A.- Mousavi, S.M.N.- Bojtor, C.- Vad, A.- Harsányi, E.- Sinka, L.:* 2022. The Influence of precision dripping irrigation system on the phenology and yield indices of sweet maize hybrids. *Water*, 14(16):2480.
8. *Ladha, J.K.- Tirol-Padre, A.- Reddy, C.K.- Cassman, K.G.- Verma, S.- Powlson, D.S.- van Kessel, C.- de Richter, B.- Chakraborty, D.- Pathak, D.:* 2016. Global nitrogen budgets in cereals: a 50-year assessment for maize, rice and wheat production systems. *Scientific Reports*, 6:19355.
9. *Li, Y.- Liu, H.- Huang, G.- Zhang, R.- Yang, H.:* 2016. Nitrate nitrogen accumulation and leaching pattern at a winter wheat cropping field in the North China Plain. *Environmental Earth Sciences*, 75: 118.
10. *Li, M.- Ma, Z.- Lv, M.:* 2017. Variability of modeled runoff over China and its links to climate change. *Climate Change* 144: 433–445.
11. *Patil, B.-Chetan, H. T.:* 2018. Foliar fertilization of nutrients. *Marumegh*, 3(1): 49-53.

12. *Hu, F.- Zhang, Y.- Guo, J.:* 2023. Effects of drought stress on photosynthetic physiological characteristics, leaf microstructure, and related gene expression of yellow horn. *Plant Signaling & Behavior*, 18:1:2215025
13. *Baker, N.R.:* 2008. Chlorophyll Fluorescence: A Probe of Photosynthesis In Vivo. *Annual Review of Plant Biology*, 59:89-113.
14. *Janka, E.- Korner, O.- Rosenqvist, E.- Ottosen, C.:* 2015. Using the quantum yields of photosystem II and the rate of net photosynthesis to monitor high irradiance and temperature stress in chrysanthemum (*Dendranthema grandiflora*). *Plant Physiology and Biochemistry*, 90:14e22
15. *Szabó, A.- Széles, A.- Illés, Á.- Bojtor, C.- Mousavi, S.M.N.- Radóczy, L.- Nagy, J.:* 2022. Effect of different nitrogen supply on maize emergence dynamics, evaluation of yield parameters of different hybrids in long-term field experiments. *Agronomy*, 12, 284.
16. *Flexas, J.- Escalona, J. M.- Medrano, H.:* 2002. Water stress induces different levels of photosynthesis and electron transport rate regulation in grapevines. *Plant, Cell and Environment*, 22: 39–48.
17. *Ocwa, A.- Bojtor, C.- Illés, A.- Ssemugenze, B.- BalaouT, I.- Rátónyi, T.- Széles, A.- Harsányi, E.:* 2024. Precision drip irrigation system and foliar application of biostimulant and fertilizers containing micronutrients optimize photochemical efficiency and grain yield of maize (*Zea mays* L). *Journal of Soil Science and Plant Nutrition*, 24: 7786–7800.
18. *Pool, S.- Francés, F.- Garcia-Prats, A.- Pulido-Velazquez, M.- SanchisIbor, C.-Schirmer, M.- Yang, H.- Jimenez-Martinez, J.:* 2021. From flood to drip irrigation under climate change: Impacts on evapotranspiration and groundwater recharge in the Mediterranean region of Valencia (Spain). *Earth's Future*, 9: e2020EF001859.
19. *Ram, H.- Choudhary, R.L.- Kumar, R.- Meena, R.K.-Ola, B.L.:* 2017. Precision nutrient management for higher nutrient use efficiency in field crops. ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India, pp 123-128.
20. *Simkó, A.- Gáspár, S.G.- Kiss, L.- Makleit, P.- Veres, S.:* 2020. Evaluation of nitrogen nutrition in diminishing water deficiency at different growth stages of maize by chlorophyll fluorescence parameters. *Plants*, 9(6): 676.

21. Sun, X.- Li, Y.- Heinen, M.- Ritzema, H.- Hellegers, P.- van Dam, J.: 2023. Fertigation strategies to improve water and nitrogen use efficiency in surface irrigation system in the north China Plain. *Agriculture*, 13:17
22. Xiang, Y.- Cheng, R.- Wang, M.- Ding, Y.: 2024. Response of Matching Degree between Precipitation and Maize Water Requirement to Climate Change in China. *Agronomy*, 14:181.
23. Sui, J.- Wang, J.- Gong, S.- Xu, D.- Zhang, Y.- Qin, Q.: 2018. Assessment of maize yield-increasing potential and optimum N level under mulched drip irrigation in the Northeast of China. *Field Crops Research* 215, 132-139.
24. Tejada, M.- Rodríguez-Morgado, B.- Gómez, I.- Franco-Andreu, L.- Benítez, C.- Parrado, J.: 2016. Use of biofertilizers obtained from sewage sludges on maize yield. *European Journal of Agronomy*, 78:13-19.
25. Tian, Z.- Zhang, M.- Liu, C.- Xiang, Y.- Hu, Y.- Wang, Y.- Liu, E.- Wu, P.- Ren, X.- Jia, Z.- Siddique, H.M.K.-Zhang, P.: 2024. Optimizing fertilization depth to promote yield performance and economic benefit in maize for hybrid seed production. *European Journal of Agronomy* 159:127245.
26. Wu, D.- Xu, X.X.- Chen, Y.L.- Shao, H.: 2019. Effect of different drip fertigation methods on maize yield, nutrient and water productivity in two-soils in Northeast China. *Agricultural Water Management*, 213: 200–211.
27. Yin, X.- Sun, Z.- Struik, P.C.- Van Der Putten, P.E.L.-Van Ieperen, W.- Harbinson, J.: 2011. Using a biochemical C4 photosynthesis model and combined gas exchange and chlorophyll fluorescence measurements to estimate bundle-sheath conductance of maize leaves differing in age and nitrogen content. *Plant, Cell and Environment*, 34: 2183–2199.
28. Zhang, T. B.- Zou, Y. F.- Kisekka, I.- Biswas, A.- Cai, H. J.: 2021. Comparison of different irrigation methods to synergistically improve maize's yield, water productivity and economic benefits in an arid irrigation area. *Agricultural Water Management*, 20:243.

## 7. Publications



UNIVERSITY of  
DEBRECEN

UNIVERSITY AND NATIONAL LIBRARY  
UNIVERSITY OF DEBRECEN

H-4002 Egyetem tér 1, Debrecen

Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

Registry number: DEENK/161/2025.PL  
Subject: PhD Publication List

Candidate: Akasairi Ocwa  
Doctoral School: Kálmán Kerpely Doctoral School  
MTMT ID: 10086967

### List of publications related to the dissertation

#### Foreign language scientific articles in Hungarian journals (1)

1. **Ocwa, A.**, Ssemugenze, B., Harsányi, E.: Seed treatment with *Bacillus* bacteria improves maize production: a narrative review.  
*Acta agrar. Debr.* 2024 (1), 105-111, 2024. ISSN: 2416-1640.  
DOI: <http://dx.doi.org/10.34101/ACTAAGRAR/1/12043>

#### Foreign language scientific articles in international journals (3)

2. **Ocwa, A.**, Mohammed, S., Mousavi, S. M. N., Illés, Á., Bojtor, C., Ragán, P., Rátónyi, T., Harsányi, E.: Maize Grain Yield and Quality Improvement Through Biostimulant Application: a Systematic Review.  
*J Soil Sci Plant Nutr.* 24, 1609-1649, 2024. ISSN: 0718-9508.  
DOI: <http://dx.doi.org/10.1007/s42729-024-01687-z>  
IF: 3.4 (2023)
3. **Ocwa, A.**, Bojtor, C., Illés, Á., Ssemugenze, B., Balaout, I., Rátónyi, T., Széles, A., Harsányi, E.: Precision drip Irrigation System and Foliar Application of Biostimulant and Fertilizers Containing Micronutrients Optimize Photochemical Efficiency and Grain Yield of Maize (*Zea mays* L).  
*J Soil Sci Plant Nutr.* 24, 7786-7800, 2024. ISSN: 0718-9508.  
DOI: <http://dx.doi.org/10.1007/s42729-024-02074-4>  
IF: 3.4 (2023)
4. **Ocwa, A.**, Harsányi, E., Széles, A., Holb, I., Szabó, S., Rátónyi, T., Mohammed, S.: A bibliographic review of climate change and fertilization as the main drivers of maize yield: implications for food security.  
*Agric & Food Secur.* 12 (1), 1-18, 2023. EISSN: 2048-7010.  
DOI: <http://dx.doi.org/10.1186/s40066-023-00419-3>





Foreign language abstracts (14)

5. **Ocwa, A.**, Ssemugenze, B., Kuunya, R., Gumisiriya, C., Balaout, I., Bojtor, C., Illés, Á., Harsányi, E.: Improving the agronomic performance of maize: differential responses to precision irrigation.  
In: Proceedings of the Plants 2025: From Seeds to Food Security, Sciforum MDPI, Barcelona, 1, 2025, (Plants 2025 Conference, ISSN 2223-7747 ; 2025)
6. Ssemugenze, B., **Ocwa, A.**, Kuunya, R., Gumisiriya, C., Bojtor, C., Illés, Á., Nagy, J.: Physiological Growth Improvement of Maize (*Zea mays* L.) through Foliar Fertilisation under Irrigated Conditions.  
In: Proceedings of the Plants 2025: From Seeds to Food Security, Sciforum MDPI, Barcelona, 1, 2025, (Plants 2025 Conference, ISSN 2223-7747 ; 2025)
7. **Ocwa, A.**, Ssemugenze, B., Harsányi, E.: Bibliometric analysis of cereal grain quality.  
In: 8th Cereals and Europe Spring Meeting : Book of Abstracts. Ed.: Peter Weegels, Dubravka Novotni, Artion Conferences and Events, Zagreb, Croatia, 40, 2024.
8. **Ocwa, A.**, Illés, Á., Bojtor, C., Ssemugenze, B., Harsányi, E.: Biostimulating effects of *Bacillus simplex* on the photochemical yield and grain yield of maize under surface drip irrigation.  
In: 15th Egerton University Biennial International Conference : Programme and book of abstracts. Ed.: M.K. Charimbu, Egerton University, Egerton, Kenya, 31, 2024.
9. Ssemugenze, B., Bojtor, C., Illés, Á., Nagy, J., **Ocwa, A.**, Tóth, B.: Investigation of the effects of foliar fertilization on two maize hybrids' physiological characteristics under irrigated conditions.  
In: The 3rd International Electronic Conference on Plant Sciences: Program and Abstract Book / Jayanta Kumar Patra, Mauro Commisso, Antonella Vitti et al, -, Online, 123, 2024.
10. **Ocwa, A.**, Ssemugenze, B., Kuunya, R., Ahmed, O. M. M., Harsányi, E.: Is precision irrigation a panacea to water shortage in crop production?  
In: II. Magyar Agrártudományi Doktoranduszok Szimpóziuma : Absztraktkötet. Szerk.: Hajdú Péter, Doktoranduszok Országos Szövetsége, Budapest, 51, 2024. ISBN: 9786156457431
11. Bojtor, C., Nagy, J., Széles, A., Harsányi, E., Ssemugenze, B., **Ocwa, A.**, Illés, Á.: Nitrogen use efficiency of maize in different fertilisation levels based on long-term field experiment.  
In: 2nd International Congress on Sustainable Development in the Human Environment - Current and Future Challenges : Proceedings book. Eds.: Atilgan Atilgan, Infrastructure and Ecology of Rural Areas Association, Antalya, 33, 2024. ISBN: 9786258254600
12. Ssemugenze, B., Illés, Á., Bojtor, C., **Ocwa, A.**, Nagy, J.: Optimization of maize grain yield and quality using different nitrogen doses.  
In: 8th Cereals and Europe Spring Meeting : Book of Abstracts / Peter Weegels, Dubravka Novotni, Artion Conferences and Events, Zagreb, 41, 2024.





13. **Ocwa, A.**, Bojtor, C., Illés, Á., Ssemugenze, B., Harsányi, E.: Effect of biostimulant application on the photosynthetic efficiency of maize.  
In: Scientific Conference of PhD Students of FAFR, FBFS and FHLE SUA in Nitra with international participation - Proceedings of abstracts on occasion of the Science and Technology Week in the Slovak Republic. Ed.: Monika Tóthová, Judita Lidiková, Kristína Candráková, Dominik Holly, Slovak University of Agriculture in Nitra, Slovakia, Nitra, 52, 2023. ISBN: 9788055226606
14. Ssemugenze, B., Illés, Á., Bojtor, C., **Ocwa, A.**, Nagy, J.: Effect of foliar fertilization on NDVI and SPAD of maize (*Zea mays* L.) hybrids.  
In: Scientific Conference of PhD Students of FAFR, FBFS and FHLE SUA in Nitra with international participation - Proceedings of abstracts on occasion of the Science and Technology Week in the Slovak Republic. Ed.: Monika Tóthová, Judita Lidiková, Kristína Candráková, Dominik Holly, Slovak University of Agriculture in Nitra, Slovakia, Nitra, 57, 2023. ISBN: 9788055226606
15. **Ocwa, A.**, Mohammed, S., Ssemugenze, B., Harsányi, E.: Precision nutrient application technologies in crop production.  
In: 20th Wellmann International Scientific Conference : Book of Abstracts. Eds.: Ingrid Gyalai; Szilárd Czóbel, University of Szeged Faculty of Agriculture, Hódmezővásárhely, 37, 2023. ISBN: 9789633069240
16. **Ocwa, A.**, Mohammed, S., Harsányi, E.: Foliar fertilizer and crop production: a review.  
In: Book of abstracts /szerk. Tamás Monostori, Adrienn Szarvas, Levente Komarek, Ágnes Süli, Júlia Hupuczi, István Majzinger, University of Szeged, Hungary, 15, 2022. ISBN: 9789633068601
17. **Ocwa, A.**, Mohammed, S., Abakeer, R. A., Harsányi, E.: Literature exploration of fertilizers use in enhancing maize production in Africa: 1980-2020.  
In: Leveraging on research and innovation for sustainable development. Proceedings of the 2nd Postgraduate Students Conference (Virtual). / (eds.) Kerich, E., Lutta, S., Alkamoi, B, University of Eldoret, Kenya, 40, 2022.
18. **Ocwa, A.**, Mohammed, S., Vad, A., Ragán, P., Rátonyi, T., Harsányi, E.: Mapping evidence of the role of foliar fertilizers in mitigating abiotic stress effects on maize: A review.  
In: International Congress on Sustainable development in the Human Environment - Current & Future Challenges. ICSDEV (2022)(Alanya) : Proceedings book. Eds.: Anna Krakowiak-Bal, Atilgan Atilgan, Roman Rolbiecki, Hakan Aktas, Infrastructure and Ecology of Rural Areas Association, Kraków, 201, 2022. ISBN: 9788396606211





### List of other publications

#### Foreign language scientific articles in international journals (8)

19. Kishajja, N., **Ocwa, A.**, Kuunya, R., Ssemugenze, B., Heil, B.: Climate change mitigation and livelihood components under smallholder coffee farming: a bibliographic and systematic review.  
*Agric & Food Secur.* 14 (1), 1-15, 2025. ISSN: 2048-7010.  
DOI: <http://dx.doi.org/10.1186/s40066-025-00522-7>
20. Ssemugenze, B., **Ocwa, A.**, Kuunya, R., Gumisiriya, C., Bojtor, C., Nagy, J., Széles, A., Illés, Á.: Enhancing Maize Production Through Timely Nutrient Supply: The Role of Foliar Fertiliser Application.  
*Agronomy-Basel.* 15 (1), 1-17, 2025. EISSN: 2073-4395.  
DOI: <https://doi.org/10.3390/agronomy15010176>  
IF: 3.3 (2023)
21. Altouma, A., Bashir, B., Ata, B., **Ocwa, A.**, Alsalman, A., Harsányi, E., Mohammed, S.: An environmental impact assessment of Saudi Arabia's vision 2030 for sustainable urban development: a policy perspective on greenhouse gas emissions.  
*Environ Sustain Indic.* 21, 1-13, 2024. EISSN: 2665-9727.  
DOI: <http://dx.doi.org/10.1016/j.indic.2023.100323>  
IF: 5.4 (2023)
22. Mohammed, S., Gill, A. R., Ghosal, K., Al-Dalahmeh, M., Alsafadi, K., Szabó, S., Oláh, J., Alkerdi, A., **Ocwa, A.**, Harsányi, E.: Assessment of the environmental Kuznets curve within EU-27: Steps toward environmental sustainability (1990-2019).  
*Env. Sci. Ecotechnol.* 18, 1-13, 2024. ISSN: 2666-4984.  
DOI: <http://dx.doi.org/10.1016/j.ese.2023.100312>  
IF: 14 (2023)
23. Bua, B., Mawa, M. E., Ayiga, J., **Ocwa, A.**: Determination of Mealybug Population Density for Transmission of Pineapple Mealybug Wilt Disease in Central Uganda.  
*Int. J. Agro.* 2024, 1-7, 2024. ISSN: 1687-8159.  
DOI: <http://dx.doi.org/10.1155/2024/5126341>  
IF: 1.5 (2023)
24. Appiah, E. A., Balláné Kovács, A., **Ocwa, A.**, Csajbók, J., Kutasy, E.: Enhancing Alfalfa (*Medicago sativa* L.) Productivity: Exploring the Significance of Potassium Nutrition.  
*Agronomy-Basel.* 14 (8), 1-20, 2024. EISSN: 2073-4395.  
DOI: <http://dx.doi.org/10.3390/agronomy14081806>  
IF: 3.3 (2023)





25. Ssemugenze, B., **Ocwa, A.**, Bojtor, C., Illés, Á., Esimu, J., Nagy, J.: Impact of research on maize production challenges in Hungary.  
*Heliyon*. 10 (6), 1-14, 2024. ISSN: 2405-8440.  
DOI: <http://dx.doi.org/10.1016/j.heliyon.2024.e26099>  
IF: 3.4 (2023)
26. Harsányi, E., Bashir, B., Arshad, S., **Ocwa, A.**, Vad, A., Alsalman, A., Bácskai, I., Rátónyi, T., Hijazi, O., Széles, A., Mohammed, S.: Data Mining and Machine Learning Algorithms for Optimizing Maize Yield Forecasting in Central Europe.  
*Agronomy-Basel*. 13 (5), 1-22, 2023. EISSN: 2073-4395.  
DOI: <http://dx.doi.org/10.3390/agronomy13051297>  
IF: 3.3

Foreign language conference proceedings (1)

27. **Ocwa, A.**, Acaye, F., Abakeer, R. A., Ahmed, A. E. M., Sidahmed, H. M. I., Harsányi, E.: Electrical conductivity and germinability of millet seeds from different accessions.  
In: Conference Proceedings of the "Challenges of nowadays in the light of sustainability" 8thVUA YOUTH scientific session. Ed.: Róbert Magda, Farheen Naz, Hungarian University of Agriculture and Life Sciences, Gödöllő, 267-273, 2021. ISBN: 9789632699684

Foreign language abstracts (18)

28. Ahmed, O. M. M., Kuunya, R., **Ocwa, A.**, Tamás, A., Rátónyi, T.: Impact of Different Tillage Practices on Maize (*Zea mays* L.) Production.  
In: Proceedings of the Plants 2025: From Seeds to Food Security, Sciforum MDPI, Barcelona, 1, 2025, (Plants 2025 Conference, ISSN 2223-7747 ; 2025)
29. Kuunya, R., Ahmed, O. M. M., Ssemugenze, B., **Ocwa, A.**, Tamás, A., Ragán, P.: Impact of Winter Ploughing Tillage on Moisture Content and Grain Hardness in Wheat: A Statistical Analysis of Harvested Samples.  
In: Proceedings of the Plants 2025: From Seeds to Food Security, Sciforum MDPI, Barcelona, 1, 2025, (Plants 2025 Conference, ISSN 2223-7747 ; 2025)
30. Balaout, I., **Ocwa, A.**, Zelenák, A., Bojtor, C., Illés, Á., Széles, A.: Response of maize yield, dry matter and nutrient accumulation to drip irrigation: a sustainable approach to food security.  
In: Proceedings of the Plants 2025: From Seeds to Food Security, Sciforum MDPI, Barcelona, 1, 2025, (Plants 2025 Conference, ISSN 2223-7747 ; 2025)
31. Kuunya, R., Ahmed, O. M. M., **Ocwa, A.**, Tamás, A., Ragán, P.: Analysing the relationship between coefficient of consolidation and impact value on irrigated cropped chernozemic soils.  
In: Scientific Conference of PhD Students of FAFR, FBFS and FHLE SUA in Nitra with international participation: Book of abstracts, Slovak University of Agriculture in Nitra, Nitra, 25, 2024. ISBN: 9788055228310





32. Illés, Á., Nagy, J., Széles, A., Harsányi, E., Ssemugenze, B., **Ocwa, A.**, Bojtor, C.: Analysis of the relationship between flight parameters, nutrient levels and hybrids in a small plot field experiment using a multispectral UAV.  
In: 2nd International Congress on Sustainable Development in the Human Environment - Current and Future Challenges : Proceedings book. Eds.: Atilgan Atilgan, Infrastructure and Ecology of Rural Areas Association, Antalya, 34, 2024. ISBN: 9786258254600
33. Kuunya, R., Ahmed, O. M. M., **Ocwa, A.**, Tamás, A., Ragán, P.: Examining the correlation between consolidation coefficient and impact value of dry humus-rich surface soils.  
In: The 4th International Electronic Conference on Agronomy : Program and book of abstracts / Oscar Vicente, MDPI, Switzerland, 90, 2024.
34. Okiria, A. L., Edep, T., Kabaale, P. F., **Ocwa, A.**: Farming systems potentate sustainable soil management and crop production in Africa.  
In: The 4th International Electronic Conference on Agronomy : Program and book of abstracts / Oscar Vicente, MDPI, Switzerland, 36, 2024.
35. Akuo, R., Okiria, A. L., **Ocwa, A.**: Germinability and electrical conductivity of seeds of groundnut varieties.  
In: The 4th International Electronic Conference on Agronomy : Program and book of abstracts, MDPI, Switzerland, 186, 2024.
36. Kuunya, R., **Ocwa, A.**, Ssemugenze, B., Széles, A., Ragán, P.: Management of biodegradable farm waste using black soldier fly larvae.  
*An. Uni. Oradea Fasc. Ecotoxi. Zoteh. Tehno. Industr. Alimentara.* 23, 5, 2024. ISSN: 1583-4301.
37. Kuunya, R., Zagyi, P., Ssemugenze, B., Széles, A., **Ocwa, A.**, Ragán, P.: Relay cropping as a tool for improving the resilience and sustainability of the environment: a bibliographic analysis.  
In: 21st Wellmann International Scientific Conference Book of abstracts / felelős kiadó Edit Mikó, szerk. Ingrid Melinda Gyalai, Szilárd Czóbel, University of Szeged Faculty of Agriculture, Hódmezővásárhely, 25, 2024. ISBN: 9789633069806
38. Kuunya, R., Horváth, É., **Ocwa, A.**, Ssemugenze, B., Széles, A., Ragán, P.: Remote sensing technology as a better technique for assessing land degradation.  
In: LXV. Georgikon Napok Tudományos Konferencia = 65th Georgikon Days Scientific Conference / szerk. Pőr Csilla, Szabó-Soós Adrienn, Szabó Péter, Magyar Agrár- és Élettudományi Egyetem Georgikon Campus, Keszthely, 27-28, 2024. ISBN: 9786156338105
39. Kuunya, R., **Ocwa, A.**, Ragán, P.: Soil tests as a tool for monitoring soil variability in crop production: Bibliographic analysis.  
In: 15th Egerton University Biennial International Conference : Programme and book of abstracts / M.K. Charimbu, Egerton University, Egerton, Kenya, 3, 2024.





40. Ssemugenze, B., **Ocwa, A.**, Tóth, B., Nagy, J.: Waste sludge composition and potential use as a fertilizer - a review.  
In: 20th Wellmann International Scientific Conference : Book of Abstracts. Eds.: Ingrid Gyalai; Szilárd Czóbel, University of Szeged Faculty of Agriculture, Hódmezővásárhely, 34, 2023. ISBN: 9789633069240
41. Ategeka, S., Tóth, E., Akankwasa, J. W., Edep, T., **Ocwa, A.**: Wildlife-crop raiding dynamics around Budongo forest in Uganda.  
In: Doktoranduszok Országos Szövetsége Közgazdaságtudományi osztályának II. Rurális Konferenciája Absztraktkötet / Földi Péter, Viktor Patrik, Doktoranduszok Országos Szövetsége, Komárom: TéKa, Budapest, 7, 2023. ISBN: 9788097415280
42. **Ocwa, A.**, Mohammed, S., Harsányi, E.: Arable Land Trend Analysis and Implications for Major Cereal Crop Yields in Hungary.  
In: XI. Interdiszciplináris Doktorandusz Konferencia : Absztraktkötet . Ed.: Kajos Luca Fanni; Bali Cintia; Puskás Tamás; Horváth-Polgár Petra Ibolya; Glázer-Kniesz Adrienn; Tislér Ádám; Kovács Eszter, Pécsi Tudományegyetem Doktorandusz Önkormányzat, Pécs, 15, 2022. ISBN: 9789636260699
43. Edep, T., **Ocwa, A.**, Ategeka, S., Nagy, A.: A review of Fall armyworm (Spodoptera frugiperda) management strategies in maize production.  
In: XI. Interdiszciplináris Doktorandusz Konferencia 2022. november 25-26 = 11th Interdisciplinary Doctoral Conference 25-26th of November 2022 : absztraktkötet = Book of Abstracts. Szerk.: Kajos Luca Fanni; Bali Cintia; Puskás Tamás; Horváth-Polgár Petra Ibolya; Glázer-Kniesz Adrienn; Tislér Ádám; Kovács Eszter, Pécsi Tudományegyetem Doktorandusz Önkormányzat, Pécs, 16, 2022.
44. Sidahmed, H. M. I., Ali, A., Alrasheed, R., **Ocwa, A.**, Nagy, J.: Genetic variability of maize genotypes for growth, yield, and yield component.  
In: Wellmann International Scientific Conference : Book of Abstracts. Ed.: Orsolya Kiss, University of Szeged, Hódmezővásárhely, 75, 2022. ISBN: 9789633068601
45. Abakeer, R. A., **Ocwa, A.**, Mousavi, S. M. N., Vad, A., Nagy, J.: The impact of soil amendments on sweet maize (*Zea mays* L. var. *saccharata*) agronomic characteristics and yield.  
In: Leveraging on Research and Innovation for Sustainable Development. Conference Proceedings of the 2nd Postgraduate Students Conference (virtual). Eds.: Emmy Kerich, Samuel Lutta, Boniface Alkamoi, University of Eldoret, Eldoret (Kenya), 53, 2022.

**Total IF of journals (all publications): 41**

**Total IF of journals (publications related to the dissertation): 6,8**

The Candidate's publication data submitted to the Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

25 April, 2025



## **8. Acknowledgement**

This academic journey has been successfully because of immense support from different stakeholders. My appreciation goes to the government of Hungary through Tempus Foundation for the Stipendium Hungaricum Scholarship and all the support rendered during the whole study period. Also, my gratitude goes to the government of the Republic of Uganda through the Ministry of Education and Sports for support. To my supervisor Prof. Dr. Harsányi Endre, your mentorship and overall support can not be quantified, thank you very much.

My appreciation also goes to administration and staff of Kálmán Kerpely Doctoral School, Institute of Land Use, Engineering and Precision Farming Technology for all the support and guidance that enabled this academic journey to be successful.

In a special way, I want to thank Dr. Mohammed Safwan, Dr. Bojtor Csaba, Dr. Illés Árpád, Dr. Seyed Mohammad Nasir Mousavi, and Mr. Fejer Peter from the Institute of Land Use, Engineering and Precision Farming Technology for the support in experimental work, scholarly writing, and guidance in the overall Ph.D. journey. Your experiences kept me steady.

To my wife Mrs. Namusisi Annet Ocwa, and our beloved children; Miss: Imukeka Jordan Ocwa, Adie Michelle Ocwa, and Amita Angel Ocwa, you endured tough life in my absentia, but your love and support kept me focused.

To my colleagues and/or friends: Ssemugenze Brian, Ahmed Abdelhakam Esmail Mohamed, Juhász Csaba, Kuunya Ronald, Nyandi Muhoja Sylvester, Sawadi Ndunguru Francisco, Melash Anteneh Agezew, Reda Gebrehaweria Kidane, Edep Tito, Kabaale Fred Peter, Ibtissem Balaout, Hajer Sidahmed, and Costa Gumisiriya, thank you very much for the life experiences shared including your support.

I also want to appreciate Dr. Awio Thomas of Africa Rice Centre, and Prof. Bosco Bua of Kyambogo University for the inspiration, support, and encouragement.

Finally, to everyone who is not listed here but provided support, thank you very much.