Original scientific paper
Journal of Central European Agriculture, 2024, 25(3), p.675-685
DOI: /10.5513/JCEA01/25.3.4196

# Formation of quantitative and qualitative parameters of sunflower (*Helianthus annuus* L.) after application of stimulating substances

# Formovanie kvantitatívnych a kvalitatívnych parametrov slnečnice ročnej (*Helianthus annuus* L.) po aplikácii stimulačných prípravkov

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Received: November 30, 2023; accepted: June 28, 2024

## ABSTRACT

A small-plot field experiment with sunflower (*Helianthus annuus* L.) was carried out at the research base of the Slovak University of Agriculture in Nitra. The experimental area is characterized as a warm and dry agroclimatic region with silt loam Haplic Luvisol. The realized field experiment was aimed at evaluating the quantitative and qualitative production parameters in the conditions of differentiated agroecological factors of the environment and the influence of stimulating substances on the formation of the final production. Within the evaluated parameters, a highly significant influence of year ($P < 0.01$) was confirmed in the formation of thousand seeds weight (TSW), seed yield and the oil content. It was indicated a significant effect of the year ($P < 0.05$) in the formation of head diameter and a non-significant effect ($P > 0.05$) in the parameter of number of plants per unit area. Agroecologically more favourable environmental conditions were recorded in 2019, when a higher number of plants (+1 173 pcs/ha; rel. 1.93%), higher head diameter (+14.81 mm; rel. 5.72%), thousand seeds weight (TSW) (+9.84 g; rel. 11.66%), oil content (+2.11%; rel. 4.81%) was indicated. Statistical analysis of the experimental results confirmed a highly significant influence of stimulating substances ($P < 0.01$) on the parameters of TSW and oil content of sunflower seeds. The experimental data confirmed the non-significant effect of stimulating preparations ($P > 0.05$) on the formation of the number of plants per unit area, head diameter and seed yield. In the range of applied stimulating substances, the treatment T1 (preparation P1 applied in the phase of 6 – 8 leaves in dose of 0.2 l/ha) was recorded as the most effective treatment, where the highest number of plants (+1 106 pcs/ha; rel. 1.84%), head diameter (+31.17 mm; rel. 13.38%), TSW (+15.60 g; rel. 21.28%), seed yield (+0.43 t/ha; rel. 11.83%) was indicated. The implementation of stimulating substances can be considered as a rationalizing element of the cultivation technology of sunflowers.

**Keywords:** oil content, stimulating substances, sunflower, yield-forming parameters

## ABSTRAKT

Maloparcelkový poľný experiment so slnečnicou ročnou (*Helianthus annuus* L.) bol realizovaný vo výskumnej báze Slovenskej poľnohospodárskej univerzity v Nitre. Experimentálna oblasť je charakterizovaná ako teplý a suchý agroklimatický región s hlinitým až ílovito-hlinitým pôdnym druhom. Realizovaný poľný pokus bol zameraný na monitoring kvantitatívnych i kvalitatívnych parametrov produkcie v diferencovaných podmienkach agroekologických faktorov prostredia a vplyvu stimulačne pôsobiacich látok na tvorbu finálnej produkcie. V rozsahu sledovaných parametrov bol potvrdený vysoko preukazný vplyv ročníka ($P < 0,01$) na formovanie hmotnosti tisícich nažiek (HTN), úrody nažiek a obsahu oleja. Preukazný vplyv ($P$ < 0,05) bol indikovaný pri formovaní priemeru úboru a nepreukazný vplyv ročníka ($P$ > 0,05) bol indikovaný pri parametri počet rastlín na jednotku plochy. Agroekologicky vhodnejšie podmienky prostredia boli zaznamenané v roku 2019, kedy bol indikovaný vyšší počet rastlín (+1 173 ks.ha$^{-1}$; rel. 1,93 %), vyšší priemer úboru (+14,81 mm; rel. 5,72 %), hmotnosť tisícich nažiek (HTN) (+9,84 g; rel. 11,66 %), obsah oleja (+2,11 %; rel. 4,81 %). Štatistická analýza experimentálnych výsledkov potvrdila vysoko preukazný vplyv stimulačne pôsobiacich látok ($P$ < 0,01) na parametre HTN a olejnatosť nažiek slnečnice ročnej. Experimentálne údaje potvrdili nepreukazný vplyv stimulačne pôsobiacich prípravkov ($P$ > 0,05) na utváranie počtu rastlín na jednotku plochy, priemeru úboru a úrody nažiek. V rozsahu aplikovaných stimulačných látok bol variant T1 (prípravok P1 aplikovaný v rastovej fáze 6 – 8 listov v dávke 0,2 l/ha) indikovaný ako vysoko efektívna aplikácia. Na tomto variante bol indikovaný najvyšší počet rastlín (+1 106 ks.ha$^{-1}$; rel. 1,84 %), priemer úboru (+31,17 mm; rel. 13,38 %), HTN (+15,60 g; rel. 21,28 %) a úroda nažiek (+0,43 t.ha$^{-1}$; rel. 11,83 %). Implementáciu stimulačne pôsobiacich prípravkov možno považovať za racionalizačný prvok pestovateľskej technológie slnečnice ročnej.

**Kľúčové slová:** obsah oleja, slnečnica ročná, stimulačné prípravky, úrodotvorné parametre

## INTRODUCTION

Sunflower (*Helianthus annuus* L.) is classified as the fourth most important oil crop in the world with an annual production of 50 million tons. The top producers in the world are the Russian Federation, Ukraine, and Argentina, which provide more than 50% of world production (Fernández-Martínez et al., 2009; FAO, 2022). Sunflower is used in the food industry (Salgado et al., 2012), in the segment of gluten-free production (Zorzi et al., 2020), as animal feed (Anal, 2017) in the chemical, cosmetic and energy sectors (De Oliveira Filho and Egea, 2021).

The formation of sunflower quantitative and qualitative parameters during the growing season is conditioned by the function and frequency of many factors, which in mutual interaction create a complex structure of growth, physiological and biochemical processes (Acciu and Tabăra, 2013). Agroecological conditions is a decisive factor that directly affects the crop formation parameters (Veverková and Černý, 2012).

Abiotic stress during the vegetation is negatively correlated with physiological and metabolic processes, which significantly eliminates plant productivity (Çiçek et al., 2019). Physiological stress affects the ontogenesis of sunflowers, disturbs phenological phases and vegetation ends prematurely (De la Haba et al., 2014). High temperature (Miladinović et al., 2019), soil salinity (Di Caterina et al., 2007) and water stress (Pekcan et al., 2016) significantly affect the formation of quantitative (Prasad et al., 2008) and qualitative production parameters (Khan et al., 2018). The elimination of negative factors during the growing season supports the formation of crop production parameters (Human et al., 1990).

In the context of climate change, it is necessary to identify the physiological, molecular, and genetic components that eliminate the influence of water stress. Considering the complexity of the individual factors, innovative management procedures are being developed that can support crop production, increase seed yield, and stimulate drought tolerance (Debaeke et al., 2017).

In agricultural practice, the application of stimulating preparations is used to eliminate the negative effects of a stressful situation and to support plant productivity (Calvo et al., 2014). These substances contain organic compounds, hormones, antioxidants, minerals, and secondary metabolites that positively affect physiological, biochemical processes, support photosynthesis, induce tolerance to biotic and abiotic stress, and support growth and development (Van Oosten et al., 2017; Ur Rehman et al., 2018).

The new direction of management is to develop a system for the efficient use of modern tools to manage the different stages of plant growth and development with the aim of increasing the yield and quality of sunflower seeds (Kamalovna and Juraevna, 2021).

The aim of this contribution was to evaluate the impact of the year's weather conditions and stimulating substances on the formation of sunflower quantitative and qualitative production parameters.

## MATERIAL AND METHODS

### *Experimental area*

A small-plot field experiment was carried out at the research fields of the Slovak University of Agriculture in Nitra (N 48°19′25.41′′ E 18°09′2.89′) in 2018 and 2019. This Central European Region is characterized as very warm and dry with a sum of average air temperatures (TS>10 °C) for the main growing season of 3 000 °C and above. The soil in this area has been classified as silt loam Haplic Luvisol (Šimanský and Kováčik, 2015). Weather conditions during the monitored vegetation periods were provided by the agrometeorological station of the Institute of Landscape Engineering of the Faculty of Horticulture and Landscape Engineering in Nitra (Figure 1, Figure 2).

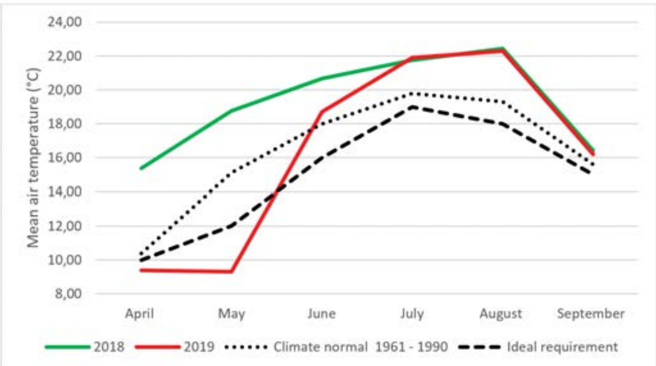


**Figure 1.** Monthly variations in air temperature (°C) of experimental seasons compared to climate normal and ideal requirement of sunflower

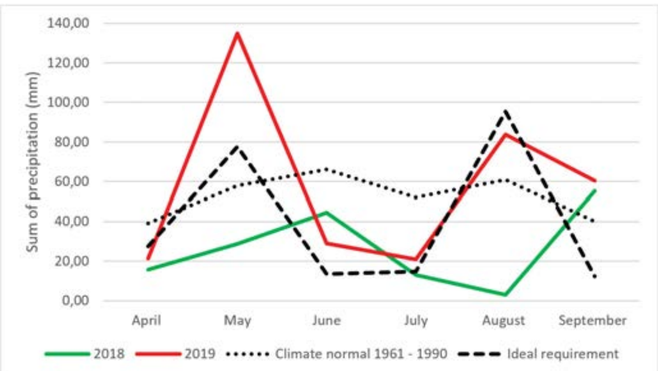


**Figure 2.** Monthly variations in precipitation (mm) of experimental seasons compared to climate normal and ideal requirement of sunflower

### *Experimental material*

*Hybrids of sunflower*

In the experiments were included sunflower hybrids cultivated by Clearfield technology.

Hybrid 1 (H1) is classified as a medium-early and medium-tall hybrid, characterized by high plasticity, and resistance to pathogens such as *Sclerotinia sclerotiorum*, *Plasmopara halstedii*, *Diaporthe helianthi* and *Verticillium dahliae*. It has a very good health status and provides very fast initial growth with a high yield potential.

Hybrid 2 (H2) is classified as a medium-tall hybrid with a semi-overhanging sunflower head from ClearField technology, it is characterized by high oil production potential and good resistance to diseases such as *Diaporthe helianthi* and *Sclerotinia sclerotiorum*.

*Fertilizers with stimulant preparations*

Two preparations (P1 and P2) were included in the experiment, which was applied in three variants (T1, T2, T3). A comprehensive overview of application dates and doses is provided below (Table 1).

- Preparation 1 (P1) is produced from hydrolyzed plant proteins, formulated with NPK.
  - Total amount of N 1.0%
  - P in the form of $P_2O_5$ 10.0%
  - K in the form of $K_2O$ 10.0%
  - Organic material 8.0%
  - Free amino acids 4.0%
  - B (Boron) 0.25%
  - Mo (Molybdenum) 0.20%
  - Cytokinins 0.03%
- Preparation 2 (P2) is a foliar fertilizer containing orthosilicic acid with other microelements, which have a positive effect on physiological processes and plant health.
  - Si (Silicon) 2.5%
  - Cu (Copper) 1.0%
  - Zn (Zinc) 0.6%
  - B (Boron) 0.3%
  - Mo (Molybdenum) 0.2%

**Table 1.** Date of application and application doses of stimulating preparations

| | Treatments | Applied dose | Growth phase |
|---|---|---|---|
| 1 | Control variant | Without the application of substance | |
| 2 | P1 (Treatment 1 – T1) | 0.2 l/ha | BBCH 15 (6 – 8 leaves unfolded) |
| | P1 (Treatment 2 – T2) | 0.2 l/ha | BBCH 55 (beginning of flowering) |
| | P1 (Treatment 3 – T3) | 0.2 l/ha | BBCH 15 + BBCH 55 (both growth phases) |
| 3 | P2 (Treatment 4 – T4) | 0.6 l/ha | BBCH 15 (6 – 8 leaves unfolded) |
| | P2 (Treatment 5 - T5) | 0.6 l/ha | BBCH 55 (beginning of flowering) |
| | P2 (Treatment 6 – T6) | 0.6 l/ha | BBCH 15 + BBCH 55 (both growth phases) |

***Experimental methods***

In the crop rotation system, sunflower was included after the pre-crop winter wheat (*Triticum aestivum* L.). Soil preparation (stubble plowing, followed by deep plowing) was carried out according to the principle of conventional technology of sunflower cultivation (Lal, 1991). Fertilizing was realized based on the results of agrochemical analysis of soil samples taken in autumn and spring. The determination method and the number of individual elements is presented below (Table 2, Table 3).

**Table 2.** Agrochemical analysis of soil samples taken in autumn

| Nutrient and determination method | 2017 | 2018 |
|---|---|---|
| P (mg/kg) colorimetrically by Mehlich III | 23.80 | 63.75 |
| K (mg/kg) flame photometry by Mehlich III | 255.00 | 425.00 |
| Na (mg/kg) flame photometry by Mehlich III | 300.00 | 65.00 |
| Mg (mg/kg) AAS by Mehlich III | 813.10 | 331.60 |
| Zn (mg/kg) AAS by DTPA | 0.86 | 1.96 |
| pH KCl (0.2 mol/dm$^3$ KCl) (pH units) | 6.98 | 6.49 |

AAS - atomic absorption spectrophotometer; DTPA - Diethylenetriamine pentaacetic acid

The application of industrial fertilizers on base N, P, K (20-20-15) in a dose of 200 kg in 2018 and the urea (46%) in a dose of 215 kg in 2019 was calculated by methods of balanced fertilization (Kováčik and Ryant, 2019). Fertilization was carried out for the expected sunflower seed yield of 3 tons per hectare (t/ha) according to Ernst et al. (2022).

**Table 3.** Agrochemical analysis of soil samples taken in spring

| Nutrient and determination method | 2018 | 2019 |
|---|---|---|
| IN (mg/kg) ammonium and nitrate nitrogen | 18.55 | 14.80 |
| $NO_3^-$ -N (mg/kg) colorimetrically - phenol 2,4 – disulfonic acid | 8.80 | 7.80 |
| $NH_4^+$ -N (mg/kg) colorimetrically – Nessler's reagent | 9.75 | 7.00 |

IN – inorganic nitrogen

The experimental fields had an area of 60 m$^2$ (3 m × 20 m). Sowing was carried out by 4-row seeder with 0.70 m length between rows and 0.22 m was the distance in a row. Field experiments were based on the method of randomized split plot design in three replications (Ehrenbergerová, 1995).

The crop was harvested at full maturity, in the growth phase BBCH 99, with a modified small-area harvester (CLAAS KGaA mbH, Harsewinkel, Germany). The seed yield of the experimental area was converted to units of tons per hectare (t/ha). The number of plants was determined during the pre-harvest canopy inventory. The yield-forming parameters were evaluated in the laboratory of the Institute of Agronomic Sciences, Slovak University of Agriculture in Nitra. The diameter was determined by diagonal measurement of the head using a tape measure in three replications. The thousand seed weight was analyzed by the Numirex seed counter (MEZOS spol. s.r.o., Hradec Králové, Czech Republic) and by laboratory scale (KERN & Sohn GmbH, Balingen, Germany). Qualitative parameters were determined by the extraction method using a Soxhlet extraction apparatus with a seed weight of 200 g, in accordance with the methodology of Shahidi (2005). The analysis was conducted at the Institute of Nutrition and Genomics, Slovak University of Agriculture in Nitra.

### *Statistical analysis*

The experimental results were analyzed by TIBCO Statistica®, Version 14.0 (TIBCO Software Inc., Palo Alto, California, USA). A multifactor ANOVA was used for the individual treatment comparison at *P* = 0.05, with separation of the means by Tukey´s HSD multiple-range test. For correlation, simple regression analysis is used simple correlation coefficient according to Pearson.

## RESULTS

The analysis of experimental results confirmed a non-significant relationship between the year weather conditions and the number of plants per unit area (*P* = 0.08) (Table 4). In 2018, the average number of plants was 59 575 pcs/ha (pieces per hectare), in 2019 the value was at the level of 60 748 pcs/ha (+1 173 pcs/ha; rel. 1.93%, compared to 2018) (Table 5).

The effect of stimulating substances on the formation of plant numbers was non-significant (*P* = 0.71) (Table 4). By the control variant, the average value was at the level of 60 070 pcs/ha. The highest number of plants was monitored by treatment T1 61 176 pcs/ha (+1 106 pcs/ha; rel. 1.84%). The lowest value was noted by treatment T3 59 228 pcs/ha (-842 pcs/ha; rel. 1.40%, compared to the control variant) (Table 5).

The statistical analysis revealed that the interaction between the factors of Year and Treatment did not attain significance (*P* = 0.57) (Table 4). In various growing seasons, inconclusive differences were confirmed. Importantly, non-significant differences were also found after evaluating the treated variants (Table 5).

The influence of year weather conditions on head diameter was significant (*P* = 0.03) (Table 4). In 2018 the average value for head diameter was 244.14 mm, while in year 2019 it was at the level of 258.95 mm (+14.81 mm; rel. 5.72%) (Table 5).

**Table 4.** Analysis of variance (ANOVA) of experimental factors of sunflower production in the monitored years 2018 – 2019

| Variability source | Monitored parameters | | | | |
|---|---|---|---|---|---|
| | Number of plants (pcs/ha) | Head diameter (mm) | TSW (g) | Seed yield (t/ha) | Oil content (%) |
| | *P* – values | | | | |
| Year | 0.081 | 0.034* | 0.000** | 0.000** | 0.000** |
| Treatment | 0.708 | 0.111 | 0.002** | 0.088 | 0.000** |
| Year × Treatment | 0.565 | 0.257 | 0.006** | 0.939 | 0.000** |

* Significant effect by 0.95 confidence intervals

** Significant effect by 0.99 confidence intervals

**Table 5.** Average values and significance inside factors at the 95% level (Tukey test)

| Factor | | Number of plants (pcs/ha) | Head diameter (mm) | TSW (g) | Seed yield (t/ha) | Oil content (%) |
|---|---|---|---|---|---|---|
| Year | 2018 | 59 575 ± 2 658[a] | 244.14±17.63[a] | 74.59±9.52[a] | 4.24±0.37[b] | 43.85±1.77[a] |
| | 2019 | 60 748 ± 992[a] | 258.95±28.20[b] | 84.43±6.38[b] | 3.57±0.18[a] | 45.96±1.90[b] |
| Treatment | Control | 60 070±1 822[a] | 233.00±20.66[a] | 73.28±4.48[a] | 3.65±0.37[a] | 44.28±0.67[d] |
| | T1 | 61 176±1 560[a] | 264.17±10.53[a] | 88.88±5.66[b] | 4.08±0.44[a] | 41.11±0.93[c] |
| | T2 | 60 824±1 656[a] | 261.50±11.48[a] | 82.30±5.80[ab] | 4.02±0.49[a] | 44.50±1.95[e] |
| | T3 | 59 228±3 686[a] | 246.83±22.26[a] | 76.03±7.62[a] | 3.75±0.44[a] | 45.74±1.41[a] |
| | T4 | 59 587±2 264[a] | 241.33±22.25[a] | 81.31±10.71[ab] | 4.05±0.56[a] | 46.55±0.81[b] |
| | T5 | 60 307±1 579[a] | 249.83±32.82[a] | 77.95±13.18[a] | 3.82±0.40[a] | 45.67±0.89[a] |
| | T6 | 59 938±1 444[a] | 264.17±32.86[a] | 76.84±10.25[a] | 3.98±0.40[a] | 46.47±1.46[b] |

T1, T2, T3 – treatment by preparation P1; T4, T5, T6 – treatment by preparation P2
Small letters (a, b) indicate a significant difference (Tukey´s HSD test, α = 0.05) between years and treatments

The effect of stimulating substances on the formation of head diameter was non-significant (*P* = 0.11) (Table 4). The average value of the control variant was 233 mm. After the application of the stimulating substances, a positive influence on the head diameter was recorded with the highest value by treatment T1. The same positive effect was also indicated by treatment T6 with a head diameter of 264.17 mm (+31.17 mm; rel. 13.38%). The least effective application was recorded by treatment T4, where the head diameter was at the level of 241.33 mm (+3.33 mm; rel. 3.58%, compared to the control variant) (Table 5).

The statistical analysis revealed that the interaction between the factors of Year and Treatment did not reach significance (*P* = 0.26) (Table 4). However, significant disparities were observed within the factors across different growing seasons. Notably, no statistically meaningful distinctions were found among treated variants (Table 5).

Statistical analysis confirmed a highly significant effect (*P* = 0.00) of year weather conditions on the formation of thousand seed weight (TSW) (Table 4). In 2018, a significant decrease in TSW was observed, with a recorded value of 74.59 g. This value marked a notable contrast to the TSW recorded in 2019, which stood at 84.43 g, reflecting an increase of 9.84 g or 11.66% relative to the preceding year (Table 5).

The effect of stimulating substances on the formation of TSW was highly significant (*P* = 0.00) (Table 4). The average value of TSW by the control variant was at the level of 73.28 g. The highest TSW was recorded by treatment T1 88.88 g (+15.60 g; rel. 21.28%). The lowest value was monitored by treatment T3 76.03 g (+2.75 g; rel. 3.75%, compared to the control variant) (Table 5). In the context of evaluating factor interactions, statistical significance (*P* = 0.01) was detected between the Year and Treatment variables (Table 4). Nevertheless, notable disparities were observed among different growth seasons, as well as equivalent differentiations within the treated variants (Table 5).

The influence of year weather conditions on the formation of seed yield was highly significant (*P* = 0.00) (Table 4). In the year 2018, the seed yield was noted at the level of 4.24 t/ha, while in 2019 the seed yield was recorded at the level of 3.57 t/ha (-0.67 t/ha; rel. 15.68%, compared to the previous year) (Table 5).

The formation of seed yield was non-significantly affected by the application of stimulating substances ($P$ = 0.09) (Table 4). By the control variant, the seed yield was monitored at the level of 3.65 t/ha. The highest yield was indicated by treatment T1 4.08 t/ha (+0.43 t/ha; rel. 11.83%). The lowest yield was recorded by treatment T3 3.75 t/ha (+0.10 t/ha; rel. 2.73%, compared to the control variant) (Table 5).

Interaction between factors Year and Treatment was non-significant ($P$ = 0.94) (Table 4). Within the analyzed factors, a significant difference was observed between the evaluated years, while the interaction between treated variants was found to be non-significant (Table 5).

The oil content was significantly affected by agroecological conditions during the growing seasons ($P$ = 0.00) (Table 4). In 2018, the oil content was 43.85%, while in year 2019 it was 45.96% (+2.11%; rel. 4.81%, compared to 2018) (Table 5).

The oil content exhibited a significant increase due to the application of stimulating substances ($P$ = 0.00) (Table 4). By the control variant, the oil content was recorded at the level of 44.28%. The highest oil content was indicated by treatment T4 at 46.55% (+2.26%; rel. 5.10%). The lowest value of oil content was recorded by treatment T1 41.11% (-3.18%; rel. 7.18%, compared to the control variant) (Table 5).

By the assessment of the mutual interaction between the factors of Year and Treatment, a notable level of significance was attained ($P$ = 0.00) (Table 4). The results notably illustrated a significant disparity among growing seasons, coupled with substantiated significance observed between the treated variants (Table 5).

The correlation was determined using Pearson's simple correlation coefficient. The scale for assessing the coefficients was taken from Evans (1996). Evaluation of correlation coefficients confirmed a moderate positive correlation between parameters of TSW and head diameter. Within the monitored production parameters, a very weak correlation was recorded between parameters TSW and the number of plants as well as between the seed yield and the number of plants per unit area. Between oil content and head diameter was a very weak positive correlation (Table 6).

**Table 6.** Correlation coefficients of sunflower production parameters

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Number of plants (1) | 1,000 | | | | |
| Head diameter (2) | -0,054$^{NS}$ | 1,000 | | | |
| TSW (3) | 0,120$^{NS}$ | 0,474$^{**}$ | 1,000 | | |
| Seed yield (4) | 0,044$^{NS}$ | -0,181$^{NS}$ | -0,275$^{*}$ | 1,000 | |
| Oil content (5) | -0,039$^{NS}$ | 0,037$^{NS}$ | -0,038$^{NS}$ | -0,445$^{**}$ | 1,000 |

$^{NS}$ - not significant (very weak); *weak correlation; **moderate correlation; TSW – thousand seed weight

Correlation analysis confirmed a moderate negative correlation between the yield and oil content of the seeds. A weak negative correlation was recorded in the relation of the seed yield to the parameters of TSW. A very weak negative correlation was recorded by the interaction of seed yield and head diameter as well as between the number of plants per unit area and head diameter. A very weak negative correlation was monitored between seed oil content and parameters of the number of plants per unit area and TSW (Table 6).

## DISCUSSION

### *Agroecological condition of the year*

The results of the experimental data confirmed that all monitored quantitative and qualitative parameters during the observed growing season are variable due to the meteorological effects of the environment. The analysis of the experimental results confirmed the non-significant impact of the year on the number of plants per unit area, which declares the optimal sowing parameters and the emergence of sunflowers for both growing seasons. The optimal number of plants per unit area in the temperate climate zone is at the level of 50 000 – 60 000 pcs/ha, while a lower growing clip can negatively affect the yield-producing elements of sunflowers (Ion et al., 2015). This statement is consistent with the results of this study.

The interaction between agroecological conditions of the year and the formation of the head diameter was significant. Glijin et al. (2013) state that head diameter is positively correlated with seed yield because head diameter affects the number and weight of the seeds. This fact is incompatible with the results of this work. At higher values of heed diameter, a decrease in seed yield was observed (Table 4). The reduction of seed yield on larger sunflower heads could have been induced by environmental factors, such as weather conditions, pest and bird pressure, as well as by harvesting mechanization. The obtained results contradict the studies of Beg and Aslam (1984) and Ali et al. (2007).

Within the other monitored quantitative (TSW, seed yield) or qualitative parameters (oil content), a highly significant influence of weather conditions was confirmed. High proven effect of year weather conditions on head diameter, head weight, TSW, seed yield, and oil content was demonstrated in the contributions of Pereyra-Irujo and Aguirrezábal (2007), Echarte et al. (2013), Mátyás et al. (2014) and Kovár et al. (2016).

***Stimulating substances***

The formation of seed yield is positively correlated with the number of plants per unit area up to the optimal growing clip (McMaster et al., 2012; Ion et al., 2015). Stimulating substances contain organic elements that affect growth and physiological processes and have a positive impact on quantitative and qualitative parameters (Anton et al., 1995; Bakht et al., 2010). Stimulating substances don't affect the number of plants per unit area (Tahsin and Kolev, 2006). This statement is in accordance with the results of this research, where a non-significant effect of the applied preparations on the number of plants per unit area was confirmed (Table 4).

Stimulating substances have been shown to have a positive impact on various aspects of sunflower seed characteristics, including head diameter, TSW, yield, and oil content (Abdel-Hafeez et al., 2019). Previous studies by Poonia (2000) and Glijin et al. (2013) have also supported the beneficial effects of these substances on head diameter. However, our findings indicate a non-significant effect of stimulating substances on head diameter formation (Table 4), despite observing a higher head diameter in the treated variants (Table 5).

The application of compost, natural mineral elements and organic fertilizers can positively affect the formation of TSW and can support the formation of seed yield (Mahrous et al., 2014). A higher TSW, fewer undeveloped seeds and, higher seed oil content were confirmed after the application of hormones and growth regulators in the submission of Vasudevan et al. (1996). After the application of biostimulators higher value of TSW was monitored also in the contribution of Yeremenko et al. (2017), which is consistent with the results of this work, where a significant effect of stimulating substances to the formation of TSW was confirmed (Table 4).

The positive effect of stimulating substances on the formation of seed yield was confirmed in the submissions of Vasudevan et al. (1996), Mahrous et al. (2014), Abdel-Hafeez et al. (2019). Biostimulators affect the pollen fertility and reduce the number of undeveloped seeds (Yeremenko et al., 2017). A higher seed yield after the application of growth stimulators was confirmed in Tahsin and Kolev (2006). Stimulators improve physiological processes and increase pollen fertility. The results of experiment confirmed an increase in seed yield in the treated variants (Table 5). However, the effect of the applied substances on the seed yield was non-significant (Table 4).

The positive influence of biofertilizers on the formation of quantitative and qualitative parameters was demonstrated in the submissions of Patra et al. (2013), Bera et al. (2014) and Abdel-Hafeez et al. (2019). This statement aligns with our experimental findings, which demonstrate a significant effect of stimulating substances on the oil content of seeds (Table 4). Increase of oil content can be caused by the correct operation of morphological, physiological, or biochemical processes

(Prakash et al., 2008). An appropriate combination of biofertilizers can increase seed yield and oil content of sunflower (Bera et al., 2014).

## CONCLUSION

The field polyfactorial experiment was carried out during the growing season in 2018 – 2019. Statistical analysis of the results confirmed that the variability of agroecological conditions during the growing season significantly affects the formation of quantitative and qualitative production parameters. The statistical results confirmed the highly significant effect of the year's weather conditions on the formation of seed yield, TSW, and oil content ($P < 0.01$). The effect of year conditions on the head diameter was significant at $P < 0.05$. In terms of production parameters formation, the agroecological conditions were more favorable during 2019, when a higher number of plants, head diameter, TSW and seed oil content were recorded. Foliar application of biostimulators positively affects the formation of production parameters during two meteorologically different years. Statistical analysis confirmed the highly significant effect of biostimulators on seed oil content and TSW ($P < 0.01$). The TSW parameter was in a positive correlation with head diameter (r = 0.474). The highest values of head diameter, TSW and seed yield were recorded by treatment T1. The application of preparation P2 (Preparation 2) was less effective. Based on the experimental results, the foliar application of biostimulators can be considered as an important rationalization tool of sunflower cultivation technology.

## ACKNOWLEDGMENTS

This publication was supported by the Scientific Grant Agency (VEGA) of the Ministry of Education, Science, Research and Sport of the Slovak Republic, project no. 1/0655/23, by the Grant Agency of the Slovak University of Agriculture in Nitra 04-GASPU-2021, GAFAPZ 2/2022, and GAFAPZ 9/2023 and by the Operational Program Integrated Infrastructure for the project: National infrastructure for supporting technology transfer in Slovakia II – NITT SK II, co-financed by the European Regional Development Fund.

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