Effect of two different plant growth regulators on production traits of sunflower

Vplyv dvoch rôznych rastlinných regulátorov rastu na produkčné ukazovatele slnečnice ročnej

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Abstract

The plant growth regulators (PGR) are an organic compounds that modify plant physiological processes. PGR applied to the field crops promotes photosynthesis, stimulates plant growth, improves flowering and protects plants against unfavourable year weather conditions. Listed is an assumption to the yield of high quality. The effects of year weather conditions, biological material (hybrids) and foliar application of two different PGR (Terra-Sorb® Foliar – containing free amino acids and Unicum® – containing Abiestins®) on the yield-forming parameters, seed yield and the oil content in seeds of three selected hybrids of sunflower (NK Brio, NK Neoma, NK Ferti) were studied in this paper. The field poly-factorial experiments were realized during two growing seasons of 2012 and 2013. The experimental area is situated in the maize-growing region (climatic region: warm; climatic sub-region: mild dry or dry; climatic zone: warm and dry, with mild winter and long sunshine) and soil is silt loam Haplic Luvisol. The climatic conditions in chosen experimental years were different in quantities and distribution of precipitation at main growth period of sunflower plants (June to August) and allows evaluating the yield stability between used hybrids and foliar treatments. The results showed that the application of selected PGR has contributed to an increase of sunflower seed yield, mainly through increase the weight of thousand seeds (r_p = 0.761; P < 0.001). Similarly, oil content in seeds was significantly higher in treatments with PGR, especially with preparation Terra-Sorb® Foliar containing free amino acids. The study describes the relationship between quality (oil content in seeds) and quantity (seed yield) of sunflower production (r_p = –0.41; P < 0.01). Results showed that PGR can be an important rationalization tool of the sunflower cultivation technology.

Keywords: oil content, plant growth regulators, sunflower, seed yield, yield-forming parameters

Abstrakt

Rastlinné regulátory rastu (PGR) predstavujú organické zlúčeniny, ktoré usmerňujú fyziologické procesy v rastlinách. PGR aplikované na poľné plodiny podporujú fotosyntézu, stimulujú rast rastlín, podporujú kvitnutie a chránia rastliny pred nepriaznivými poveternostnými podmienkami. Uvedené je predpokladom pre vysoké a kvalitné úrody. V štúdii bol skúmaný efekt poveternostných podmienok ročníka, genetického materiálu (hybridov) a foliárnej aplikácie dvoch rôznych PGR (Terra-Sorb® Foliar – obsahujúci voľné aminokyseliny a Unicum® – obsahujúci Abiesetíny®) na úrodu a úrodotvorné prvky troch vybraných hybridov slnečnice ročnej (NK Brio, NK Neoma, NK Ferti). Poľné polyfaktorové pokusy boli realizované počas dvoch pestovateľských sezón 2012 a 2013. Pokusná lokalita sa nachádza v teplej kukuričnej výrobnej oblasti (klimatická oblasť: teplá; klimatická podoblasť: suchá; klimatický okrsok: teplý, suchý s miernou zimou a dlhým slnečným svitom; pôda: hnedozem kultizemná). Poveternostné podmienky vybraných experimentálnych rokov boli odlišné v množstve a v distribúcii zrážok v rozhodujúcich rastových fázach rastlín slnečnice ročnej (jún až august) čo umožnilo hodnotiť úrodovú stabilitu hybridov ošetrených danými prípravkami. Výsledky ukázali, že aplikácia vybraných PGR prispela k zvýšeniu úrody, hlavne prostredníctvom zvýšenia hmotnosti tisíc nažiek (r_p = 0,761; P < 0,001). Podobne bol pri ošetreniach PGR preukazne vyšší aj obsah oleja v nažkách, najmä pri prípravku Terra-Sorb® Foliar, ktorý obsahoval voľné aminokyseliny. Štúdia popisuje vzťah medzi kvalitou (obsah oleja v nažkách) a kvantitou (úroda nažiek) produkcie slnečnice ročnej (r_p = –0,41; P < 0,01). Na základe výsledkov experimentu je možné považovať foliárnu aplikáciu PGR na porasty slnečnice ročnej za významný racionalizačný prvok technológie jej pestovania.

Kľúčové slová: obsah oleja, rastlinné regulátory rastu, slnečnica ročná, úroda nažiek, úrodotvorné prvky

Detailný abstrakt

V súčasnosti je slnečnica ročná (*Helianthus annuus* L.) považovaná za štvrtú najvýznamnejšiu olejninu sveta. Celková zberová plocha predstavuje približne 25 miliónov ha, na ktorej sa v priemere vyprodukuje 36 miliónov ton nažiek. Vysoké úrody však poskytujú iba porasty kompletné a vývojovo homogénne pri rešpektovaní limitujúcich faktorov produktivity. Efekt limitujúcich faktorov produktivity slnečnice ročnej je možné eliminovať napr. aplikáciou rastlinných stimulátorov rastu (PGR), ktorú možno v rámci manažmentu agronomických prác považovať za dôležitý prvok úspešného pestovania rastlín. Cieľom príspevku bolo zhodnotiť vplyv poveternostných podmienok ročníka, biologického materiálu (hybridov) a foliárnej aplikácie dvoch rôznych PGR na úrodotvorné prvky, úrodu nažiek a obsah oleja v nažkách slnečnice ročnej. Poľný polyfaktorový experiment bol realizovaný v rokoch 2012 a 2013 na experimentálnej báze Strediska biológie a ekológie rastlín

Fakulty agrobiológie a potravinových zdrojov Slovenskej poľnohospodárskej univerzity (SPU) Nitre – Dolná Malanta. Pokusná lokalita sa nachádza v teplej kukuričnej výrobnej oblasti (klimatická oblasť: teplá; klimatická podoblasť: suchá; klimatický okrsok: teplý, suchý s miernou zimou a dlhým slnečným svitom; pôda: hnedozem kultizemná). Pestovateľská technológia slnečnice ročnej bola realizovaná na základe konvenčných prístupov pestovania. V experimente boli využité tri hybridy slnečnice ročnej: NK Brio (dvojlíniový hybrid, stredne neskorý, rýchly počiatočný rast, vysoká odolnosť voči suchu, normálny typ oleja, vysoký úrodový potenciál), NK Neoma (dvojlíniový hybrid, stredne neskorý, normálny typ oleja, odvodený od hybridu NK Brio, rezistentný voči imidazolinu) a NK Ferti (dvojlíniový stredne skorý hybrid, odvodený od hybridu NK Brio s vyšším obsahom kyseliny olejovej). V experimente boli založené tri varianty ošetrenia: (1) kontrolný variant – bez aplikácie PGR; (2) variant s foliárnou aplikáciou prípravku Terra-Sorb® Foliar, ktorý obsahuje voľné aminokyseliny a (3) variant s foliárnou aplikáciou prípravku Unicum®, ktorý obsahuje Abiesetíny®. PGR boli aplikované dva krát počas pestovateľskej sezóny v nasledovných dávkach: a) aplikácia PGR Terra-Sorb® Foliar bola realizovaná v dvoch rastových fázach (prvá v rastovej fáze 2 – 4 pravé listy a druhá 20 dní po prvej aplikácii), obe v dávke 1,5 l*ha^{-1}; b) aplikácia PGR Unicum® bola realizovaná v dvoch rastových fázach (prvá v rastovej fáze 2 – 4 pravé listy a druhá v rastovej fáze kvitnutie), obe v dávke 200 ml*ha^{-1}. Poveternostné podmienky vybraných experimentálnych rokov boli odlišné v množstve a v distribúcii zrážok v rozhodujúcich rastových fázach rastlín slnečnice ročnej (jún – august) čo umožnilo hodnotiť úrodovú stabilitu hybridov ošetrených danými prípravkami. Na základe výsledkov experimentu bol zistený štatisticky vysoko preukazný vplyv foliárneho ošetrenia PGR na hmotnosť úboru a hmotnosť tisíc nažiek. V rámci hodnotenia vplyvu foliárnych prípravkov na úrodu bolo zistené, že najvyššia úroda nažiek bola dosiahnutá na variante s aplikáciou prípravku Terra-Sorb v roku 2012 pri hybride NK Brio. V experimente bol zistený štatisticky vysoko preukazný vplyv ošetrenia na úrodu nažiek. V experimente bola zistená vo vzťahu k úrode nažiek pozitívna korelácia pri ukazovateľoch hmotnosť úboru a hmotnosť tisícich nažiek. S narastajúcou hmotnosťou úboru a hmotnosťou tisícich nažiek sa zvýšila úroda nažiek. Výsledky ukázali, že aplikácia vybraných PGR prispela k zvýšeniu úrody, hlavne prostredníctvom zvýšenia hmotnosti tisíc nažiek (r_p = 0,761; P < 0,001). Najvyšší obsah tukov bol zistený na kontrolnom variante v roku 2013 pri hybride NK Brio. Vplyv ošetrenia na obsah tukov bol vyhodnotený ako štatisticky vysoko preukazný. Štúdia popisuje vzťah medzi kvalitou a kvantitou produkcie slnečnice ročnej (r_p = –0,41; P < 0,01). Na základe výsledkov experimentu je možné považovať foliárnu aplikáciu PGR na porasty slnečnice ročnej za významný racionalizačný prvok technológie jej pestovania.

Introduction

Sunflower (*Helianthus annuus* L.) currently is the world's fourth most important oil crop with a harvested area of about 25 million hectares in which 36 million tons of seeds are produced on average. France is the largest producer in EU countries with a production of around 1.6 million tons. The production in Slovakia is around 0.2 million tons. The average world production of sunflower is 1.42 t*ha^{-1} approximately. The crop area, yield and overall production of sunflower have been

relatively stable in Slovakia in the past five years. The sunflower cultivated area was 0.084 million hectares, the yield reached 2.3 t*ha^{-1} and the total production reached 0.196 million tons in Slovakia in 2013 (FAO, 2013). Complete and homogeneous stands provide high yield while respecting limiting factors of productivity (Pasda and Diepenbrock, 1991; Zheljazkov et al., 2008). The limiting factors of productivity of sunflower mainly are soil and habitat conditions – geographic location, altitude, soil quality and its properties (Helmy and Ramadan, 2009), climate and weather conditions – temperature, precipitation, year (Wanjari et al., 2001), the ability of plants – photosynthetic activity, respiration, transpiration, size of assimilation system, the genetic basis of the hybrid, resistance to adverse factor and creation and reduction of yield-forming parameters (Gibbs, 2004; Dalai et al., 2008) and agricultural engineering and farming methods – crop rotation, forecrop, soil cultivation, seed treatment, sowing rate, nutrition and fertilization, application of plant growth regulators, sowing, protection against diseases and pests, the quality of the harvest (Marschner, 2003; Cerkal et al., 2011; Elezovic et al., 2012).

The agricultural practice that is successfully employed to eliminate the negative effects of stressful situation on crop productivity is the application of plant growth regulators (PGR) (Calvo et al., 2014). Is well documented the positive effect of foliar application of PGR with free amino acids as an active substance on yield of many crops (Tejada and Gonzales, 2003; Jablonskyte-Rašče et al., 2013), including sunflower (Rauf, 2008; Mátyás et al., 2014). It has been observed that application of PGR stimulates photosynthetic performance and antioxidative defence metabolism, in addition to water, light and mineral use efficiency, as well uptake of mineral nutrition. Finally, these plant responses minimise the negative effects of environmental stresses on crop productivity (Rhodes et al., 1999; Oosterhuis and Robertson, 2000; Djanaguiraman et al., 2004; Kovár and Černý, 2012).

Therefore, the objectives of this study were to evaluate the effect of foliar application of two different plant growth regulators on yield-forming parameters, seed yield and oil content in seeds of sunflower.

Materials and methods

Experimental area

This experiment was conducted in order to investigate the effects of year weather conditions, biological material (hybrids) and treatments by foliar preparations (containing the free amino acids or Abiestins®) on selected yield-forming parameters, seed yield and oil content in sunflower seeds. The experiment was performed during 2012 and 2013 at the research fields of the Plant Biology and Ecology Centre, the Faculty of Agrobiology and Food Resources of the Slovak University of Agriculture (SUA) in Nitra, Slovakia (48°19′25.41′′ N and 18°09′2.87′′ E, altitude 250 m above sea level). The experimental area is situated in the maize-growing region (climatic region: warm; climatic sub-region: mild dry or dry; climatic zone: warm and dry, with mild winter and long sunshine) and soil is, according to FAO classification, silt loam Haplic Luvisol (FAO, 2014; Šimanský and Kováčik, 2015). Climatic characteristics of the experimental area were obtained

from the Meteorological Station of Horticulture and Landscape Engineering Faculty of Slovak University of Agriculture in Nitra (Table 1).

Cultivation system

The experiments were established by block method with a completely randomised design of experimental field plot trial (60 m^2 per one plot) in three repetitions. Forecrop of sunflower (*Helianthus annuus* L.) in seven-plot crop rotation was winter wheat (*Triticum aestivum* L.). The soil cultivation (stubble ploughing, autumn deep ploughing) and method of crop stand establishment (alternate row distance 0.70 m, distance in row 0.22 m) were performed in accordance with the principles of conventional technology of sunflower cultivation. The soil fertilization was derived from soil agrochemical analysis for an expected yield of 3.0 $t*ha^{-1}$. The plants were fertilised (1) in 2012 with nitrogen at the rate of 107 $kg*ha^{-1}$ urea, followed by 50 $kg*ha^{-1}$ single superphosphate and of 200 $kg*ha^{-1}$ KCl, and (2) in 2013 at the rate of 200 $kg*ha^{-1}$ DASA® 26/13, using fertiliser applicator FERTI (FPM Agromehanica, Boljevac, Serbia). Fertilisers containing P and K were applied to the soil during autumn deep ploughing in autumn. Fertilizers containing N were applied to the soil during pre-sow ploughing in the spring.

Table 1. Sum of daily precipitation (mm) and mean daily air temperature (°C) during growth seasons of sunflower in 2012 and 2013

Tabuľka 1. Suma denných zrážok (mm) a priemerná denná teplota vzduchu (°C) počas pestovateľských sezón slnečnice ročnej v rokoch 2012 a 2013

Month	Climate normal (n) 1961 – 1990		Ideal requirement (i) (Černý et al., 2011)		2012		2013	
	$\sum_{mm}$	X_{td} °C	$\sum_{mm}$	X_{td} °C	$\sum_{mm}$	X_{td} °C	$\sum_{mm}$	X_{td} °C
IV.	39.0	10.4	27.50	10.00	39.80	12.07	23.00	11.65
V.	58.0	15.1	77.60	12.00	15.00	17.64	65.60	15.09
VI.	66.0	18.0	13.60	16.00	47.60	20.39	54.80	18.54
VII.	52.0	19.8	14.60	19.00	109.00	22.95	2.20	22.25
VIII.	61.0	19.3	95.40	18.00	15.40	22.87	70.00	20.89
IX.	40.0	15.6	12.20	15.00	31.40	18.02	60.80	13.63

$\sum_{mm}$ – sum of precipitation; X_{td} °C – mean daily air temperature

$\sum_{mm}$ – úhrn zrážok; X_{td} °C – priemerná denná teplota vzduchu

Plant material

Three hybrids of sunflower NK Brio (the variety of twice-cross hybrid, medium late, fast initial growth and a high tolerance to drought, normal oil type, high yield), NK Neoma (the variety of twice-cross hybrid, medium late, normal oil type, derived from hybrid NK Brio, resistant to imidazoline) and NK Ferti (the variety of twice-cross hybrid, medium early, derived from hybrid NK Brio, higher oil content) were used in the experiment.

Treatments

In experiment the three variants were established, as (1) control; (2) variant with application of preparation containing the free amino acid (9.3% of L-α amino acids as Asp, Ser, Glu, Gly, His, Arg, Thr, Ala, Pro, Cis, Tyr, Val, Met, Lys, Ile, Leu, Phe, Trp and 2.1% of N, as well as 0.07% of zinc, 0.04% of manganase and 0.02% of boron) with trade name Terra-Sorb® Foliar (Biobérica S.A., Barcelona, Spain) and (3) application of preparation containing the biologically active substances (Abiestins®, minimal content 40 g*L^{-1}) from near polar plants with trade name Unicum® (Ekoland Europe s.r.o., Praha, Czech Republic). The control variant was without foliar preparations. Preparations were applied manually with pressurized hand sprayer (capacity 10 L) Gamma10 (Mythos Di Martino, Mussolente, Italy) twice during the growing season at the following rates: a) application of Terra-Sorb® Foliar was done in two stages (first at 2 to 4 leaf stage and second 20 days after the first application), both in dose of 1.5 L*ha^{-1}; b) application of Unicum® was done in two stages (first at 2 to 4 leaf stage and second during flowering), both in dose of 200 mL*ha^{-1} (0.06% solution).

Calculation of yield-forming parameters and oil content measurement

Heads were harvested manually and taken to the laboratory, where yield-forming parameters were determined. The harvest was performed by small-plot combine CLAAS (CLAAS GmbH & Co. KGaA, Harsewinkel, Germany). The yield of achenes harvested from experimental area was re-calculated to unit tons per hectare (t*ha^{-1}). The oil content in seeds was determined by a standard method using the Soxhlet apparatus (Shahidi, 2005). Prior to extraction, the seeds were mechanically crushed using a laboratory homogenizer to an average particle size of 1 mm. The direct oil extraction was performed using petroleum ether reagent at 60°C. Total extraction time during the analysis was 60 minutes (15 min direct extraction samples immersed in the extraction reagent and 45 min exposure to reagent vapours). After extraction, the crude oil was directly weighed and oil content was recalculated in the sample.

Statistical analysis

The experimental data were graphically assessed as mean values for each experimental member with the corresponding standard deviation. Statistical analysis was performed using Statistica software, version 10 (StatSoft, Inc., Tulsa, Oklahoma, USA). The normality distribution and homogeneity of experimental results was tested by Kolmogorov-Smirnov and Lavene´s test. Statistical differences between the individual experimental members (hybrid, treatment, and year) were analyzed by multifactorial ANOVA analysis and homogenous groups were identified using Duncan´s post-hoc test at a significance level of $P < 0.05$. The correlation analysis between experimental traits was expressed by the Pearson correlation coefficient (r_p).

Results

Yield-forming parameters

Yield-forming parameters (head diameter, weight of head and weight of thousand seeds) were influenced by experimental factors as hybrid, treatment, year-round conditions and by its combined effect (Table 3). The results of combined ANOVA showed high significant influence of year-round weather conditions on head diameter, weight of head and weight of thousand seeds (Table 3). Results confirmed course of year-round weather conditions. The experimental years were unbalanced and very different. In view of the observed average monthly temperatures, as compared to the long-term climate normal (Table 1), both years can be considered as above average. In terms of precipitation during the growing season for both experimental years it was typical of an unequal course (Table 1). In this study significant influence of treatment on head diameter was not reported (Table 3), which probably results from water deficit in soil, mainly in 2013. Was found significant influence of treatment on weight of head and weight of thousand seeds (Table 3). The combined effect of hybrid*treatment had significant influence on head diameter. The weight of head and the weight of thousand seeds were influenced highly significantly (Table 3). The combined effect of hybrid*year had not significant influence on the head diameter. In weight of head and weight of thousand seeds was found high a significant influence of this interaction (Table 3). The combined effect of treatment*year had significant influence on head diameter and weight of head. The weight of thousand seeds was influenced highly significantly (Table 3). The interaction of hybrid*treatment*year did not have a significant effect on the head diameter and weight of head but it had a high significant influence on the weight of thousand seeds.

Seed yield

The seed yield of sunflower was more favourable in 2012 when the achieved seed yield was higher in comparison with 2013 (Table 2). The results of combined ANOVA showed high significant influence of year weather conditions on the yield of sunflower seeds (Table 3). After evaluation of effect of hybrids on the seed yield was found that the highest seed yield was achieved in 2013 with the NK Neoma hybrid, and the lowest in 2013 with NK Brio hybrid (Table 2). The effect of hybrids on the yield of seeds was highly significant (Table 3). After influence assessment of foliar preparations on the seed yield, was found that the highest seed yield was in variant with Terra-Sorb® Foliar preparation application in 2012 with NK Brio hybrid (Table 2). The lowest seed yield was found in variant with Unicum® preparation application in 2013 with NK Brio hybrid (Table 2). In experiments, was found high significant influence of treatment on the yield of seeds (Table 3). On the basis of experimental results, the foliar application of PGR on stands of sunflower can be considered as appropriate rationalization tool of its cultivation. In the experiment, was found a positive correlation between the yield of seeds and the weight of head and weight of thousands seeds. As weight of head and weight of thousand seeds increases, the yield of seeds also increases (Table 4). With the average of head, was found the negative correlation. With the increase in the head diameter was observed a decrease in the yield of seeds (Table 4). This phenomenon could be influenced

by two factors: first, that achenes were filled poorly, or second, it is possible that large inter-space occurred among the seeds. Less likely is the third possibility that it may be a combination of the two possible factors. The combine effect of hybrid*treatment was on yield of seeds high significant (Table 3). Combine effects hybrid*year, treatment*year and hybrid*treatment*year had a high significant effect on the yield of seeds (Table 3).

Table 2. Selected production traits of three sunflower hybrids treated with two different PGR during the seasons of 2012 and 2013. Data represents the mean ± standard deviation

Tabuľka 2. Vybrané produkčné ukazovatele troch hybridov slnečnice ročnej ošetrených dvoma rôznymi PGR v pestovateľských sezónach rokov 2012 a 2013. Dáta predstavujú priemer ± smerodajnú odchýlku

Year	Treatment	Hybrid	TSW (g)	Seed yield (t*ha^{-1})	Oil content (%)
2012	Untreated	NK Brio	59.16±0.21^{cB+}	2.17±0.08^{aA+}	51.20±1.91^{aA+}
		NK Neoma	54.03±0.11^{aB+}	2.62±0.07^{aA+}	52.31±1.71^{bA+}
		NK Ferti	58.23±0.13^{bB+}	2.49±0.08^{aA+}	49.76±1.53^{aA+}
		Mean	57.14±0.45	2.43±0.08	51.09±1.72
	Terra-Sorb® Foliar	NK Brio	63.20±0.14^{cA+}	3.35±0.18^{aB+}	50.19±0.43^{aB+}
		NK Neoma	48.80±0.19^{aA+}	2.35±0.11^{aB+}	55.79±0.47^{bB+}
		NK Ferti	56.16±0.17^{bA+}	2.91±0.22^{aB+}	54.62±0.40^{aB+}
		Mean	56.05±0.5	2.87±0.17	53.53±0.43
	Unicum	NK Brio	64.68±0.44^{cC+}	2.70±0.44^{aB+}	54.36±0.55^{aB+}
		NK Neoma	64.32±0.17^{aC+}	3.13±0.37^{aB+}	56.70±0.46^{bB+}
		NK Ferti	55.60±0.15^{bC+}	2.45±0.20^{aB+}	50.18±0.47^{aB+}
		Mean	61.53±0.25	2.76±0.34	53.75±0.49
2013	Untreated	NK Brio	34.60±0.83^{abB+}	1.84±0.05^{aC+}	61.84±0.50^{bC+}
		NK Neoma	39.05±4.92^{bB+}	2.78±0.02^{bC+}	52.25±0.60^{aC+}
		NK Ferti	26.44±0.33^{aB+}	2.29±0.02^{cC+}	55.72±0.47^{aC+}
		Mean	33.36±2.03	2.30±0.03	56.60±0.53
	Terra-Sorb® Foliar	NK Brio	29.23±2.00^{abA+}	2.08±0.10^{aB+}	58.47±0.50^{bA+}
		NK Neoma	26.93±0.90^{bA+}	1.49±0.04^{bB+}	52.75±0.53^{aA+}
		NK Ferti	28.41±0.41^{aA+}	2.11±0.02^{cB+}	54.06±0.38^{aA+}
		Mean	28.19±1.10	1.89±0.05	55.09±0.47
	Unicum	NK Brio	25.36±2.00^{abA+}	1.06±0.04^{aA+}	58.67±0.50^{bB+}
		NK Neoma	28.63±0.36^{bA+}	1.54±0.03^{bA+}	56.45±0.55^{aB+}
		NK Ferti	31.62±0.38^{aA+}	1.95±0.02^{cA+}	52.76±0.38^{aB+}
		Mean	28.54±0.91	1.52±0.03	55.96±0.48

Small and large letters indicate significant differences (Duncan´s test, α = 0.05) between hybrids and treatments, respectively. $^{+}$ indicates significant differences between seasons. TSW – weight of thousand seeds

Malé a veľké písmená indikujú významné rozdiely (Duncanov test, α = 0,05) medzi hybridmi a ošetreniami. $^{+}$ označuje významné rozdiely medzi pestovateľskými sezónami. TSW – hmotnosť tisíc nažiek

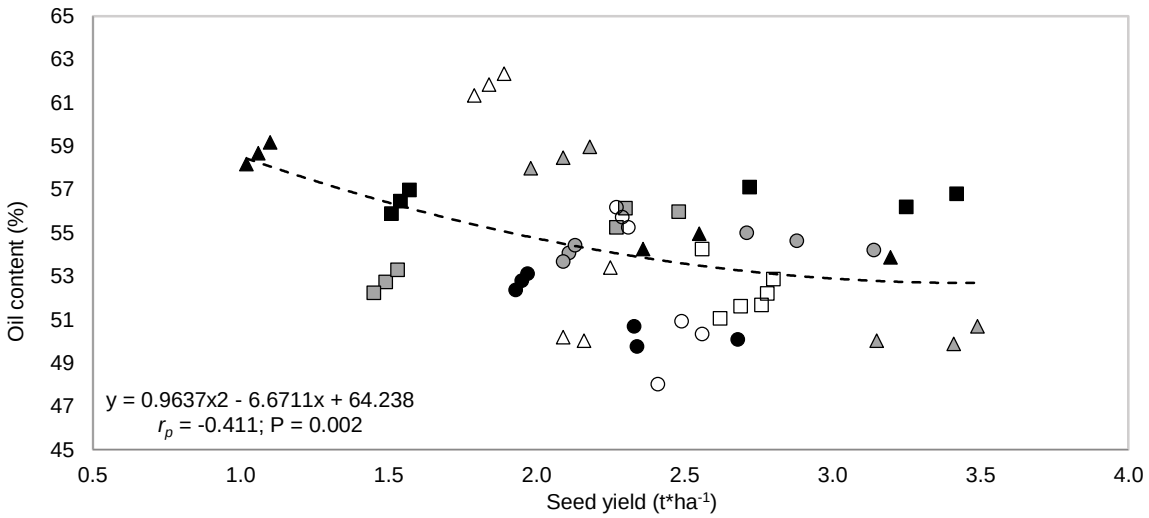
Table 3. Analysis of Variance in production traits of sunflower

Tabuľka 3. Analýza rozptylu produkčných ukazovateľov slnečnice ročnej

		Head diameter (mm)	Weight of head (g)	TSW (g)	Seed yield (t*ha^{-1})	Oil content (%)
Hybrid (H)	P	0.006	0.000	0.000	0.014	0.000
Treatment (T)	P	0.133	0.016	0.000	0.000	0.004
Year (Y)	P	0.000	0.000	0.000	0.000	0.000
H*T	P	0.036	0.000	0.000	0.000	0.000
H*Y	P	0.240	0.046	0.000	0.000	0.000
T*Y	P	0.029	0.007	0.000	0.000	0.000
H*T*Y	P	0.060	0.056	0.000	0.000	0.000

TSW – weight of thousand seeds; P – probability

TSW – hmotnosť tisíc nažiek; P – pravdepodobnosť



Relationship represented two growing seasons and application of PGR. Symbols: NK Brio – triangle, NK Neoma – square, NK Ferti – circle; untreated plants – white, Terra-Sorb® Foliar – gray, Unicum® – black. Dash line shows polynomial quadratic regression

Vzťah reprezentuje dve pestovateľské sezóny a aplikáciu PGR. Symboly: NK Brio – trojuholník, NK Neoma – štvorec, NK Ferti – kruh; neošetrené rastliny – biela, Terra-Sorb® Foliar – šedá, Unicum® – čierna. Prerušovaná čiara predstavuje polynomickú kvadratickú regresiu

Figure 1. The relationship between seed yield (t*ha^{-1}) and oil content in seeds (%) of sunflower

Obrázok 1. Vzťah medzi úrodou nažiek (t*ha^{-1}) a obsahom oleja v nažkách (%) slnečnice ročnej

Oil content in seeds

Was found that 2013 was more favourable for oil content than 2012 (Table 2). The results of the combined ANOVA showed that unbalanced course of year weather conditions had high a significant influence on oil content in sunflower seeds (Table 3). The assessment of hybrids effect on oil content showed that the highest oil content was achieved in 2013 with the NK Brio hybrid, the lowest in 2012 with the NK Ferti hybrid (Table 2). The effect of hybrids on oil content was highly significant (Table 3). The results of combined ANOVA showed that the effect of treatment on oil content was highly significant (Table 3).

Table 4. Correlation coefficients for production traits of sunflower treated with two different PGR during the seasons of 2012 and 2013

Tabuľka 4. Korelačné koeficienty produkčných ukazovateľov slnečnice ročnej ošetrenej dvoma rôznymi PGR počas pestovateľských sezón rokov 2012 a 2013

Traits	1	2	3	4	5
Oil content (1)	1.000				
Seed yield (2)	-0.411^{++}	1.000			
TSW (3)	-0.467^{+++}	0.761^{+++}	1.000		
Weight of head (4)	-0.365^{++}	0.522^{+++}	0.788^{+++}	1.000	
Head diameter (5)	0.444^{+++}	-0.502^{+++}	-0.485^{+++}	-0.158^{NS}	1.000

NS – not significant difference, $^{+}$; $^{++}$ and $^{+++}$ significant differences at level < 0.05; < 0.01 and < 0.001
TSW – weight of thousand seeds

NS – nepreukazný rozdiel, $^{+}$; $^{++}$ a $^{+++}$ charakterizujú preukazné rozdiely na úrovni < 0,05; < 0,01 a < 0,001. TSW – hmotnosť tisíc nažiek

In relation to the fat content a positive correlation was found with the head diameter. The higher head diameter also increased the fat content of seeds (Table 4). In experiments oil content had a negative correlation to the weight of head, weight of thousand seeds and the seed yield. With decreasing weight of head value, weight of thousands seeds and the yield of seeds, the oil content increased (Table 4). The quantitative relationship between sunflower seed yield and quality of production (r_p = –0.41; P < 0.01) is shown in Figure 1. All combined effects (G*T, G*Y, T*Y and G*T*Y) had high significant effect on oil content (Table 3).

Discussion

Yield-forming parameters

Researches Amjed et al. (2011), Rauf et al. (2012) and Mátyás et al. (2014) reported that the influence of the year-round weather conditions on the head diameter, weight of head and the weight of thousand seeds was highly significant which agrees with experimental findings. Amjed et al. (2011) and Mátyás et al. (2014) observed that head diameter was highly influenced by hybrids. Černý et al. (2013) found significant influence of the hybrids on the weight of head. Rondanini et al. (2003)

observed that the average weight of the seeds is the decisive yield-forming factor that plays an important role in assessing the production potential of the sunflower hybrids. It is well documented that drought-induced inhibition of growth is general response of plant to water deficit (Baldini et al., 1997; Rauf, 2008; Jones et al., 2009). On the other hand, Kheybari et al. (2013) found the significant effect of foliar-applied amino acids on head diameter. Hussain et al. (2012) and Mátyás et al. (2014) found high significant influence of the treatment on the weight of head and the weight of thousand seeds. The results of this study about the effect of applying different PGR on sunflower agree well with experimental results. Mátyás et al. (2014) described non-significant influence of the combined effect of hybrid*treatment on the head diameter and the weight of head but high significant effect on the weight of thousand seeds. The combine effect of hybrid*year had not significant influence on the head diameter (Mátyás et al., 2014) which agrees well with experimental findings. Chimenti et al. (2001) reported that the production process of sunflower is a result of the properties of the parental lines of hybrids, course of weather conditions and its interaction, which agrees which experimental findings. Mátyás et al. (2014) reported that the combined effect of treatment*year had significant influence on the head diameter and the weight of head and highly significant influence on the weight of thousand seeds. This observation agrees with results of experiment.

Seed yield

Pereyra-Irujo and Aguirrezábal (2007) and Mátyás et al. (2014) confirmed high significant influence of year weather conditions on the yield of sunflower seeds. Their results agree well with experimental findings. Results agree to Bakhat et al. (2006), Ibrahim (2012) and Mátyás et al. (2014) who confirmed significant influence of hybrids on the yield of sunflower seeds. Experimental finding does not confirm to Mátyás et al. (2014) who recorded the higher seed yield in the control variant. Achieved results agree well with Černý and Veverková (2012) who stated that effect of PGR on seed yield of sunflower seeds was significant. Mátyás et al. (2014) found positive correlation between yield of seeds and weight of thousand seeds, but negative correlation between yield of seeds and weight of head. Achieved results of experiment are contrary with studies of Beg and Aslam (1984) and Ali et al. (2007) who reported positive effect of head diameter on yield of seeds. Mátyás et al. (2014) described significant influence of hybrid*treatment combine effect on yield of seeds, which agrees well with experimental observations.

Oil content in seeds

Significant influence of year weather conditions on oil content in sunflower seeds described Pereyra-Irujo and Aguirrezábal (2007) and Echarte et al. (2013). Pereyra-Irujo and Aguirrezábal (2007), Gesch and Johnson (2013) and Yasin et al. (2013) claimed that sunflower hybrids shows differences in the oil content what correspond with experimental finding achieved. Achieved results agree well with Černý and Veverková (2012), who state significant influence of foliar preparations on oil content in sunflower seeds. Results of experiment not confirm state of Mátyás et al. (2014) who found in relation to the oil content positive correlation to the weight

of thousand seeds and yield of seeds. However, to the head diameter and weight of head listed author reported negative correlation.

Conclusions

The results of the field poly-factorial experiments, realised during two growing seasons of 2012 and 2013 showed that the foliar application of two different plant growth regulators (PGR) positively influences the production performance (trough yield-forming parameters and seed yield) as well oil content in seeds of selected sunflower hybrids (NK Brio, NK Neoma, NK Ferti) at two meteorologically different years. The sunflower seed yield was significantly increased, in particular through increase the weight of thousand seeds (r_p = 0.761; P < 0.001). Similarly the oil content in seeds was significantly higher in treatments with PGR, especially with Terra-Sorb® Foliar preparation containing free amino acids. In this experiments the quality (oil content in seeds) had a negative correlation (r_p = –0.41; P < 0.01) to the quantity (seed yield) of sunflower production. On the basis of the experimental results the foliar application of PGR can be considered as an important rationalisation tool of the sunflower cultivation technology.

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