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YIELD AND QUALITY OF CONFECTIONERY SUNFLOWER SEEDS AS AFFECTED BY FOLIAR FERTILIZERS AND PLANT GROWTH REGULATORS IN THE LEFT-BANK FOREST-STEPPE OF UKRAINE

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Abstract

A three years (2016-2018) field experiment was conducted in the Left-Bank Forest-Steppe of Ukraine to assess the influence of 7 different treatments with foliar fertilizers and plant growth regulators (control; Sol Bor + Basfoliar 6-12-6; Basfoliar 6-12-6; Wuxal Bio Aminoplant + Wuxal Boron; Wuxal Boron; Spectrum Askorist + Spectrum B + Mo; Spectrum B + Mo) on seed yield and quality of 3 new confectionery sunflower genotypes (Confeta F1, Lakomka, Oniks). Foliar applications largely had a favourable effect on all parameters studied (plant height, leaf surface area, number of seeds per head, seed weight per head, 1000-seed weight, seed yield, and protein content) compared to the control. Significantly (P<0.05) higher average seed yield occurred in the variety Lakomka (2.42 t/ha). Again, the greatest average protein content was obtained from Lakomka (23.0%). Sequential foliar application of Sol Bor + Basfoliar 6-12-6 thrice gave significantly (P<0.05) greater average seed yield (2.37 t/ha) for all three genotypes combined compared to the other treatments. Based on foliar sprays, the increase in protein content ranged from 0.1-0.5% compared to the control.

Key words: *confectionery sunflower, foliar fertilizer, plant growth regulator, seed quality, seed yield.*

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is among the four key oilseed plants worldwide (along with palm, soy, and rapeseed) and recognized as one of the two most indispensable oil crops in Europe, together with rapeseed (Jocić et al., 2015). Ukraine has maintained its spot as leading producer of sunflower seeds globally for the past 10 years. It is recently reported in 2018 that, Ukraine currently (2017-2018) ranks first in sunflower production in the world with an output of 13.70 million metric tons (MMT), representing 28.9% of the total global sunflower output of 47.41 MMT [United States Department of Agriculture (USDA), 2018].
Breeding for protein content and enhancement of amino acid level of sunflower seeds received huge interest, especially in areas where soybean and rapeseed were not the key crops (Fick & Miller, 1997). Apparently, the principal production standards for confectionery hybrids which increase their market value are: seed yield, seed protein content, mass of 1000 seeds, hull/kernel ratio and dehullability of the seed (Hladni & Miladinović, 2019). Also, studies on confectionery sunflower breeding is directed at increasing genetic potential for yield, yield stability, health safety, and nutritional value, besides increasing production efficiency (Hladni et al., 2011). Indeed, Jocić et al. (2015) advised that, newly developed confectionery hybrids should exhibit higher yield potential, higher self-fertility rate, and larger seeds with high oleic acid and vitamin E (tocopherol) content to enrich their nutritional value and extend seed shelf life. Thus, specific aims in confectionery sunflower breeding include, increase of total protein content in seed beyond 25%, increase of essential amino acid content, 1000-seed mass, kernel content, and reduction of oil content in the seed to 40% with concomitant increase of oil stability, uniform seed size and color, and enhanced seed hulling.
Relatedly, it is recommended that, confectionery sunflower seed must preferably exceed 80 g 1000-seed weight, oil content less than 30%, bigger seed size, lower cadmium rate, and higher protein, oleic acid, and vitamin E (tocopherol) content (Lofgren, 1997;

Jovanović et al., 1998). Yet, it is also stated that confectionery sunflower seeds have high 1000-seed weight that is often above 100 g (Dozet & Jovanović, 1997). Also, seeds of confectionery sunflower notably possess an enormous share of hull, normally 40–50% (Jovanović, 2001).

In spite of these unique qualities/characteristics, environmental factors seems to limit current sunflower yields to the production range of 1.5-3.0 t/ha (Kaya, 2015), for a high genetic potential for seed yield exceeding 5 t/ha (Jocić et al., 2015). Recently, Kaya (2015) recommended that Breeders should pay particular attention to eliminating or minimizing extreme environmental factors to guarantee a minimum of 4 t/ha sunflower yields. A vital reserve for the attainment of plant biological potential is the application of foliar fertilizers and plant growth regulators (PGRs). Foliar fertilization of crops offers a valuable supplement to the application of nutrients through the soil and in certain conditions, foliar fertilization is more economical and effective (Fageria et al., 2009). Of significance, this mode of fertilizer application guarantees instant uptake and translocation of nutrients to several plant organs via the leaf tissues and thus supports prompt correction of nutrient deficiencies (Fageria et al., 2009). Besides, foliar fertilization is endorsed for integrated plant production as it not only increases crop yield and quality, but is as well ecologically safe (Fageria et al., 2009; El-Aal et al., 2010; Zodape et al., 2011). This is because the nutrients are directly delivered to the plant in limited amounts, thereby assisting to reduce the environmental impact linked with soil fertilization (Fernández & Eichert, 2009).

PGRs according to Oosterhuis and Robertson (2000) involve a wide-ranging category of compounds that promote, inhibit, or otherwise alter plant physiological or morphological processes. It is also acknowledged that, the agricultural practice that is effectively employed to eliminate the negative impacts of stressful condition on crop productivity is the application of PGRs (Calvo et al., 2014). The positive effect of foliar fertilizers and plant growth regulators on yield and quality of sunflower is also reported (Vyakaranahal et al., 2001; Shaker & Mohammed, 2011; Hassanlouee & Baghbani, 2013; Mátyás et al., 2014; Khan et al., 2015; Klimenko, 2015; Mekki, 2015; Ernst et al., 2016; Eremenko, 2018; Melnyk et al., 2019). However, recently in 2019, Melnyk and collaborators seems to be the first to have reported in the Left-Bank Forest-Steppe of Ukraine, the effect of foliar fertilizers and plant growth regulators on productivity and quality of high-oleic sunflower (Melnyk et al., 2019). The influence of these foliar applications on confectionery sunflower genotypes in the Left-Bank Forest-Steppe of Ukraine is yet to be documented. Besides, market demands and production area of confectionery sunflower indicate a steady increase globally and in Eastern Europe too, owing to its nutritional value and use in human nutrition (Hladni & Miladinović, 2019). In the year 2017, 740 sunflower genotypes were registered and approved for distribution in Ukraine, with 22 classified as confectionery types [Ukrainian Institute for Plant Variety Examination (UIPVE), 2017].

The present study therefore investigates the influence of foliar fertilizers and plant growth regulators on seed yield, yield components and quality of confectionery sunflower under the climatic condition of the Left-Bank Forest-Steppe of Ukraine.

MATERIALS AND METHODS

A three-year (2016-2018) field research was performed in Poltava region in the Left-Bank Forest-Steppe of Ukraine. The experimental site was located about 10 km SW from Poltava (Latitude: 49.6; Longitude: 34.9; 113 m above sea level) on black soil, typical for coarse-medium loam. Seeds of three confectionery sunflower genotypes (Confeta F1, Lakomka, Oniks) were sown in first decade of May and harvested in the third decade of September of the investigated years. The origins of the genotypes are as follows: Confeta F1 (May Agro Tohumsulk Sanayive Tisaret A.S., Turkey); Lakomka (State Scientific Institution All-Russian Research Institute of oil crops named after. V.S. Pustovoit, Russia); Oniks (Department of Crop Production of Sumy National Agrarian University, Ukraine).

Data on rainfall and air temperature during the growing period were acquired from Poltava

Regional Center for Hydrometeorology of Ukraine. Analysis of weather conditions, in particular Hydrothermal coefficient (HTC) as described by Selyaninov (1937), revealed that the growing season for the research years were characterized as follows: 2016 - sufficiently wet (normal moisture) year (HTC = 1.00); 2017 - extremely dry year (HTC = 0.45); 2018 - moderately dry year (HTC = 0.59). HTC were calculated using the formula: HTC = $\Sigma p \times 10/\Sigma t$, where Σp is the amount of precipitation/rainfall (mm), for a period with an average daily air temperature above Σt is the sum of temperatures (°C), for the period with average daily air temperature above 10°C. The key weather indexes for the studied periods are given in Table 1.

Table 1. Weather indexes for the period of field trials with confectionery sunflower

Year	2016		2017		2018		Long-term average	
Month	AT (°C)	RA (mm)	AT (°C)	RA (mm)	AT (°C)	RA (mm)	AT (°C)	RA (mm)
May	15.1	109.4	14.8	39.4	18.1	30.6	15.8	47.9
June	19.9	71.4	20.1	41.2	20	48.6	19.4	63.2
July	22.6	40.3	21.5	29.9	22.6	49.8	21.8	60.7
August	22.6	62.7	24	7.2	23	2.2	20.9	38.3
September	15.2	7	18	16.6	18.4	51.8	14.9	7
Total	95.4	290.8	98.4	134.3	102.1	183	92.8	217.1

Note: AT - Air Temperature; RA - Rainfall Amounts.

The trials were established in a Randomized Complete Block Design (RCBD) with 4 replications on a plot size of 25 m^2. The main plots had the sunflower genotypes while the sub plots were 7 different foliar applications (control; Sol Bor + Basfoliar 6-12-6; Basfoliar 6-12-6; Wuxal Bio Aminoplant + Wuxal Boron; Wuxal Boron; Spectrum Askorist + Spectrum B + Mo; Spectrum B + Mo). Seeds were sown for a plant density of 40,000 plants/ha with 4 rows in each plot. An inter row space of 70 cm was maintained. Application of background fertilizer to the soil was at the rate of $N_{94}P_{48}K_{48}$. Sowing was done using the New Holland tractor with 8 rows Baural Planter Maxima in the unit. Chemical and mechanical methods were employed to effectively control weeds in high debris field conditions. Soil herbicide Prim Extra TZ Gold 500 SC (4.5 l/ha), composing the active substances S-Metolachlor (290 g/l) + Atrazine (370 g/l), was also applied. All other cultural practices including pest and disease control were executed.

Foliar fertilizers and plant growth regulators were sprayed sequentially twice or thrice on sub plots at recommended rates as follows: Sol Bor (3 l/ha); Basfoliar 6-12-6 (6 l/ha); Wuxal Bio Aminoplant (3 l/ha); Wuxal Boron (3 l/ha); Spectrum Askorist (3 l/ha); Spectrum B+Mo (2.5 l/ha). Foliar applications were undertaken at the following stages using the BBCH scale: BBCH 15-17; BBCH 27-37; and BBCH 47-57 (Meier, 2001). Accordingly, Sol Bor, Wuxal Bio Aminoplant and Spectrum Askorist were applied first, before respectively adding Basfoliar 6-12-6, Wuxal Boron and Spectrum B + Mo twice. These new set of foliar fertilizers (Basfoliar 6-12-6, Wuxal Boron and Spectrum B + Mo) were also applied in sequence twice on sub-plots lacking the first applications. Hence, there were double applications (Basfoliar 6-12-6, Wuxal Boron, Spectrum B + Mo) and triple applications (Sol Bor + Basfoliar 6-12-6; Wuxal Bio Aminoplant + Wuxal Boron; Spectrum Askorist + Spectrum B + Mo). Plots with no foliar applications served as control. Foliar preparations were obtained from popular companies including: ADOB (Sol Bor, Basfoliar 6-12-6); Unifer (Wuxal Bio Aminoplant, Wuxal Boron); and Spectrum-Agro (Spectrum Askorist, Spectrum B + Mo). Nutrient compositions of foliar fertilizers and plant growth regulators are presented (Table 2).

Table 2. Nutrient compositions of foliar applications

Foliar applications	N	P_2O_5	K_2O	MgO	Mn	Cu	Fe	B	Zn	Mo	Amino acids	*EM B
Sol Bor (%)								15.0				
Basfoliar 6-12-6 (%)	7.2	14.4	7.2	0.012	0.012	0.012	0.012	0.012	0.06	0.005		
Wuxal Bio Aminoplant (g/l)	22.6	22.6	22.6								141.3	
Wuxal Boron (g/l)	110	137.0			0.69	0.69	1.37	95.9	0.69	0.014		
Spectrum Askorist (%)	3.7	1.76	3.0		0.02	0.003	0.01	0.014	0.01	0.001		20
Spectrum B+Mo (%)								15.0		0.75		

*Seaweed extract of *Ascophyllum nodosum*

Data on the following parameters were collected and/or determined from two inner rows of 5 representative tagged plants at reproductive stage (R-1 to R-4) prior to flowering (Schneiter and Miller, 1981): plant height; width of 7th leaf and length of 7th leaf, before leaf surface area was calculated using the method described by Osipova and Litun (1988). Harvesting was done manually at physiological maturity by harvesting the 5 tagged plants from two inner rows per plot. Accounting, measurement, and related observations were undertaken according to the methods of field experience by Dospekhov (1985). Seed protein content was determined using an infrared analyzer SupNir 2700. Data were subjected to statistical analysis of variance (ANOVA) followed by least significant difference (LSD) test at 5% level of probability ($p<0.05$) using the software Statistica (version 8) (StatSoft. Inc.).

RESULTS AND DISCUSSIONS

Among the three confectionery sunflower genotypes investigated, Lakomka created a significantly ($P<0.05$) taller average plant (192.6 cm) (Table 3). The difference in average plant height between Confeta F1 (139.3 cm) and Oniks (114.0 cm) is also significant.

Table 3. Effect of foliar applications on average plant height of confectionery sunflower genotypes for the investigated period (2016-2018) (cm)

Foliar applications (Factor B)	Genotypes (Factor A)			
	Confeta F1	Lakomka	Oniks	Average (Factor B)
Control	138.0	191.4	109.4	146.3
Sol Bor + Basfoliar 6-12-6	138.1	193.3	111.4	147.6
Basfoliar 6-12-6	138.6	192.7	111.3	147.5
Wuxal Bio Aminoplant + Wuxal Boron	140.9	193.0	118.3	150.7
Wuxal Boron	139.3	193.8	116.2	149.8
Spectrum Askorist + Spectrum B + Mo	140.2	192.2	116.1	149.5
Spectrum B + Mo	139.7	192.0	115.6	149.1
Average (Factor A)	139.3	192.6	114.0	

The least significant difference (LSD) at $p<0.05$: A - 1.12; B - 1.71 cm

When Wuxal Bio Aminoplant was applied once before spraying Wuxal Boron twice (sequential triple application), it generated the tallest average plant (150.7 cm). However, this did not result in a significantly ($P<0.05$) taller plant compared to foliar applications of Wuxal Boron (149.8 cm), Spectrum Askorist + Spectrum B + Mo (149.5 cm), and Spectrum B + Mo (149.1 cm). Except for Sol Bor + Basfoliar 6-12-6 (147.6 cm) and Basfoliar 6-12-6 (147.5 cm), all other foliar applications produced a significantly higher plant height than the control (146.3 cm). Regarding all the individual genotypes, the control had the least average plant height compared to each foliar spray. The increase in average plant height due to foliar sprays ranged from 1.2-4.4 cm. Similar effects were recently reported for high oleic sunflower in that, the least plant height was recorded for the control (Melnyk et al., 2019).

The greatest influence on plant height was caused by the genotypes with a share of 93.5%. The second factor was the combination of genotypes and foliar applications (6%) whiles foliar applications was next with a share of 0.2%. Other factors had a 0.3% influence on plant height. In contrast, it is reported that, the greatest effect on plant height emanated from the combination of hybrids and foliar applications with a share of 75.6%, before hybrids (19.1%), foliar applications (3.1%) and other factors (2.2%). The difference in the level of influence of these factors could be due to differences in genetics since the previous study involved high oleic sunflower hybrids whiles the present research is based on the confectionery sunflower genotypes.

Leaf area growth determines light interception and is a chief parameter that determines plant productivity (Gifford et al., 1984; Koester et al., 2014). Also, Leaf area and Leaf area index are notably good surrogate measures of plant and crop photosynthesis which is a central factor of growth rate and ultimate seed yield (Al-Amery et al., 2011). Lakomka formed significantly ($P<0.05$) larger mean leaf surface area (0.76 m^2/plant) than Confeta F1 (0.72 m^2/plant) and Oniks (0.59 m^2/plant). Additionally, that of Confeta F1 was significantly larger than Oniks (Table 4). With respect to foliar applications, triple applied Spectrum Askorist + Spectrum B + Mo formed the largest average leaf surface area (0.72 m^2/plant) but was only significantly ($P<0.05$) higher than foliar application of Basfoliar 6-12-6 (0.68 m^2/plant), Wuxal Boron (0.68 m^2/plant) and control (0.65 m^2/plant). Also, all foliar applications generated a significantly larger leaf surface area than the control. In a related study with sunflower, similar results were recently reported (Al-Amery et al., 2011; Melnyk et al., 2019). There was a 0.03-0.07 m^2/plant extension in leaf surface area based on foliar applications.

Table 4. Effect of foliar applications on mean leaf surface area of confectionery sunflower genotypes for the investigated period (2016-2018) (m^2/plant)

Foliar applications (Factor B)	Genotypes (Factor A)			Average (Factor B)
	Confeta F1	Lakomka	Oniks	
Control	0.67	0.71	0.57	0.65
Sol Bor + Basfoliar 6-12-6	0.70	0.82	0.62	0.71
Basfoliar 6-12-6	0.68	0.77	0.60	0.68
Wuxal Bio Aminoplant + Wuxal Boron	0.77	0.76	0.58	0.70
Wuxal Boron	0.75	0.72	0.57	0.68
Spectrum Askorist + Spectrum B + Mo	0.76	0.79	0.60	0.72
Spectrum B + Mo	0.74	0.76	0.59	0.70
Average (Factor A)	0.72	0.76	0.59	

The least significant difference (LSD) at $p<0.05$: A - 0.02; B - 0.03 m^2/plant

In all the genotypes, three-fold foliar spray formed a larger leaf surface area compared to their respective two-fold spray only. As well, all the varieties/hybrid formed a higher leaf surface area for the foliar sprays than control, except Oniks, which formed equal leaf surface area in the control and foliar applied Wuxal Boron (0.57 m^2/plant). Together, genotypes and foliar applications influenced leaf surface area the greatest with a share of 58.2 %. This was followed by only genotypes (33.1 %) before foliar applications (2.9%). Other factors had an influence of 11.9%. Likewise, Melnyk et al. (2019) recently reported that, together, hybrids and foliar applications had the largest influence on leaf surface area with a share of 47.5%. This was followed by only foliar applications (29.9%) before hybrids (10.7%), while other factors had an effect of 11.9%.

Lakomka produced a significantly ($P<0.05$) greater average number of seeds per head (789.3 pcs) among the three studied genotypes (Table 5). The next highest number of seeds per head was generated by Oniks (710.6 pcs), which was also significantly higher than Confeta F1 (388.2 pcs).

Regarding foliar sprays, double applied Basfoliar 6-12-6 and triple applied Sol Bor + Basfoliar 6-12-6 respectively caused a significantly ($P<0.05$) higher number of seeds per head (643.6 and 640.7 pcs) compared to the control (621.0 pcs) but not for the other foliar applications. The others caused a lesser number of seeds per head in a decreasing sequence as follows: Spectrum B + Mo (629.3 pcs), Wuxal Boron (624.8 pcs), Spectrum Askorist + Spectrum B + Mo (624.3 pcs), and Wuxal Bio Aminoplant + Wuxal Boron (621.9 pcs). These other foliar applications also did not result in a significantly higher number of seeds per head compared to control. Working with high-oleic sunflower in the same environmental condition, Melnyk et al. (2019) recently reported similar results. However, all of these same foliar applications caused a significant increase in this parameter. The inconsistencies could be due to differences in genetics of confectionery and high oleic sunflower. The increases in average number of seeds per head presently due to foliar sprays were in the range of 0.9-22.6 pcs.

Table 5. Effect of foliar applications on average number of seeds per head of confectionery sunflower genotypes for the studied period (2016-2018) (pcs)

Foliar applications (Factor B)	Genotypes (Factor A)			
	Confeta F1	Lakomka	Oniks	Average (Factor B)
Control	381.7	776.0	705.3	621.0
Sol Bor + Basfoliar 6-12-6	383.9	827.7	710.4	640.7
Basfoliar 6-12-6	395.8	821.3	713.6	643.6
Wuxal Bio Aminoplant + Wuxal Boron	386.9	771.5	707.4	621.9
Wuxal Boron	400.6	768.6	705.1	624.8
Spectrum Askorist + Spectrum B + Mo	379.9	779.0	713.9	624.3
Spectrum B + Mo	388.8	780.9	718.3	629.3
Average (Factor A)	388.2	789.3	710.6	

The least significant difference (LSD) at p<0.05: A - 20.11; B - 13.22 pcs

Furthermore, triple foliar spray of Wuxal Bio Aminoplant + Wuxal Boron on Confeta F1 generated a little higher number of seeds per head (386.9 pcs) compared to only dual applied Wuxal Boron (400.6 pcs), but the reverse was obtained for Lakomka and Oniks. For all 3 genotypes, dual application of only Spectrum B + Mo produced a slightly greater number of seeds per head (Confeta F1, 388 pcs; Lakomka, 780.9 pcs; Oniks, 718.3 pcs) than triple applied Spectrum Askorist + Spectrum B + Mo (Confeta F1, 379.9 pcs; Lakomka, 779.0 pcs; Oniks, 713.9 pcs). Largely, all foliar sprays resulted in somewhat higher number of seeds per head than the control, except that, for Lakomka, foliar sprayed Wuxal Bio Aminoplant + Wuxal Boron produced a lesser number of seeds per head (771.5 pcs) compared to the control (776.0 pcs). Similar exception occurred for Oniks sprayed with Wuxal Boron, generating 705.1 pcs and control 705.3 pcs.

For all 3 genotypes, Lakomka generated a significantly ($P<0.05$) greater average seed weight per head (65.4 g) (Table 6). The difference between Oniks (55.9 g) and Confeta F1 (51.5 g) is also significant. Among the foliar sprays, spraying of Sol Bor + Basfoliar 6-12-6 in sequence thrice, caused the greatest average seed weight per head (59.6 g). In a descending order, the other foliar applications with their corresponding average seed weight per head were as follows: Basfoliar 6-12-6 (58.5 g), Wuxal Bio Aminoplant + Wuxal Boron (57.8 g), Spectrum Askorist + Spectrum B + Mo (57.6 g), Spectrum B + Mo (57.2 g), Wuxal Boron (57.0 g), and control (55.6 g). All foliar applications generated a significantly ($P<0.05$) higher average seed weight per head than the control, except for Wuxal Boron and Spectrum B + Mo. Additionally, the differences among Sol Bor + Basfoliar 6-12-6, Basfoliar 6-12-6, and Wuxal Bio Aminoplant + Wuxal Boron are not significant ($P<0.05$). A similar result was reported for the application of boron fertilizers (Vyakaranahal, 2001). In the present work, the seed weight per head had an increase of 1.4–4 g based on foliar sprays. The seed weights per head for the triple foliar applications were a bit greater than for dual applications in all 3 confectionery genotypes. As well, in all the genotypes, each foliar spray produced a little greater seed weight per head compared to their respective control.

Table 6. Effect of foliar applications on average seed weight per head of confectionery sunflower genotypes for the investigated period (2016-2018) (g)

Foliar applications (Factor B)	Genotypes (Factor A)			
	Confeta F1	Lakomka	Oniks	Average (Factor B)
Control	49.2	62.7	54.8	55.6
Sol Bor + Basfoliar 6-12-6	51.4	70.6	56.9	59.6
Basfoliar 6-12-6	51.1	68.0	56.3	58.5
Wuxal Bio Aminoplant + Wuxal Boron	53.9	63.8	55.6	57.8
Wuxal Boron	53.0	63.1	55.0	57.0
Spectrum Askorist + Spectrum B + Mo	51.1	65.2	56.4	57.6
Spectrum B + Mo	50.9	64.5	56.1	57.2
Average (Factor A)	51.5	65.4	55.9	

The least significant difference (LSD) at p<0.05: A - 2.12; B - 1.85 g

The greatest average1000-seed weight was created in Confeta F1 (132.1 g) and this was significantly (P<0.05) greater than the other two genotypes (Lakomka and Oniks) (Table 7). As well, Lakomka had significantly greater 1000-seed weight (82.9 g) than Oniks (78.6 g). However, it should be noted that the huskiness (husk content) of Confeta F1 was also the highest (52.2%). Respectively, Lakomka and Oniks had a lesser husk content of 32.4% and 30.2%.

Table 7. Effect of foliar applications on average 1000-seed weight of confectionery sunflower genotypes for the investigated period (2016-2018) (g)

Foliar applications (Factor B)	Genotypes (Factor A)			
	Confeta F1	Lakomka	Oniks	Average (Factor B)
Control	124.6	80.8	77.7	94.4
Sol Bor + Basfoliar 6-12-6	133.9	85.3	80.1	99.8
Basfoliar 6-12-6	129.1	82.8	78.9	96.9
Wuxal Bio Aminoplant + Wuxal Boron	139.3	82.7	78.6	100.2
Wuxal Boron	132.3	82.1	78.0	97.5
Spectrum Askorist + Spectrum B + Mo	134.5	83.7	79.0	99.1
Spectrum B + Mo	130.9	82.6	78.1	97.2
Average (Factor A)	132.1	82.9	78.6	

The least significant difference (LSD) at p<0.05: A - 4.19; B - 6.40 (g)

Among the foliar sprays, Wuxal Bio Aminoplant + Wuxal Boron caused the greatest average 1000-seed weight (100.2 g). But, this was not significantly (P<0.05) greater than the other treatments. The rest of the foliar sprays generated the following average 1000-seed weights in a reducing sequence: Sol Bor + Basfoliar 6-12-6 (99.8 g), Spectrum Askorist + Spectrum B + Mo (99.1 g), Wuxal Boron (97.5 g), Spectrum B + Mo (97.2 g), Basfoliar 6-12-6 (96.9 g), and control (94.4 g). Within the genotypes, sequential foliar sprays three-times generated a slightly greater mass of 1000 seeds than their corresponding double sprays. In addition, all foliar applications gave a slightly higher 1000-seed weight than the control. Due to foliar applications, average 1000-seed weight increased by 2.5-5.8 g. The greatest influence was caused by genotypes (share 83.6%). This was followed by combination of genotypes and foliar applications (11.4%) before foliar applications only (0.5%). Other factors had a 4.5% influence.

Lakomka produced significantly (P<0.05) higher average seed yield (2.42 t/ha) than Oniks (2.33 t/ha) and Confeta F1 (2.15 t/ha) (Table 8). Also, there was a significant difference between the seed yield of Oniks and Confeta F1.

Table 8. Effect of foliar applications on average seed yield of confectionery sunflower genotypes for the studied period (2016-2018) (t/ha)

Foliar applications (Factor B)	Genotypes (Factor A)			Average (Factor B)
	Confeta F1	Lakomka	Oniks	
Control	2.05	2.32	2.28	2.22
Sol Bor + Basfoliar 6-12-6	2.14	2.61	2.37	2.37
Basfoliar 6-12-6	2.13	2.52	2.34	2.33
Wuxal Bio Aminoplant + Wuxal Boron	2.24	2.36	2.31	2.30
Wuxal Boron	2.21	2.33	2.29	2.28
Spectrum Askorist + Spectrum B + Mo	2.13	2.41	2.35	2.30
Spectrum B + Mo	2.12	2.39	2.34	2.28
Average (Factor A)	2.15	2.42	2.33	

The least significant difference (LSD) at $p<0.05$: A - 0.02; B - 0.03 t/ha

Foliar spray of Sol Bor + Basfoliar 6-12-6 produced significantly greater average seed yield (2.37 t/ha) than all other treatments as follows: Basfoliar 6-12-6 (2.33 t/ha); Wuxal Bio Aminoplant + Wuxal Boron or Spectrum Askorist + Spectrum B + Mo (2.30 t/ha); Wuxal Boron or Spectrum B + Mo (2.28 t/ha). As well, all foliar applications produced a significantly higher average seed yield than the control (2.22 t/ha). Similar results were recently reported (Al-Amery et al., 2011; Shaker & Mohammed, 2011; Khan et al., 2015; Ernst et al., 2016; Melnyk et al., 2019). Previously, Reddy et al. (2003) suggested that, increased achene (seed) yield of sunflower might be due to active role of boron in translocation of photosynthates particularly when applied at ray floret stage. Also, Al-Amery et al. (2011) reported that, the greatest effect of foliar applied boron is an increase in seed yield, and this partially might be due to reduction in seed sterility. Moreover, Brighenti and Castro (2008) demonstrated that, seed yield was increased by foliar application of boron on sunflower, and indicated that boron consumption increased the pollen fertility. Except for Wuxal Bio Aminoplant, all foliar applications contain boron in the present study. Hence, similar reasons are attributable in the present study for the increased seed yield. The increase in average seed yield in the present study ranged from 0.06-0.15 t/ha because of foliar applications. However, Černý and Veverková (2012) found no statistically significant effect on sunflower seed yield after foliar application of two PGRs (Atonik and Pentakeep - V).

For all the genotypes, sequential foliar applications in threefold generated slightly higher seed yield than their corresponding applications in twofold. As well, all foliar applications for each genotype produced a little higher seed yield than the control. The greatest effect on average seed yield was triggered by the combined factors of genotypes and foliar applications (share is 74.7%). The second greatest influence was by genotypes (17.9%) and the third by foliar applications (2.7%). Other factors had a 4.7% effect on the average seed yield.

The main interest in confectionery sunflower is the seed protein content. Among the 3 genotypes investigated, Lakomka produced the highest average protein content (23.0%), followed by Confeta F1 (21.7%) and the least by Oniks (21.2%) (Figure 1).

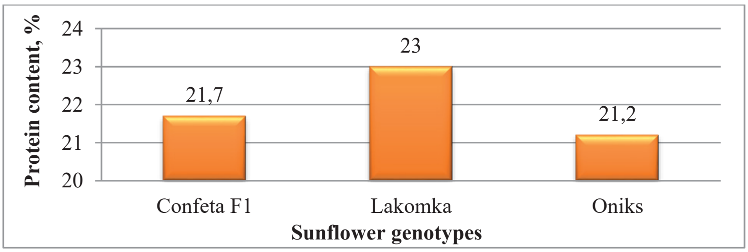

Figure 1. Effect of foliar applications on average protein content of confectionery sunflower genotypes

Sequential foliar application of either Wuxal Bio Aminoplant + Wuxal Boron thrice or Wuxal Boron twice, generated the highest average protein contents (22.2%) and was followed by applying Spectrum B + Mo (22.1%) (Figure 2).

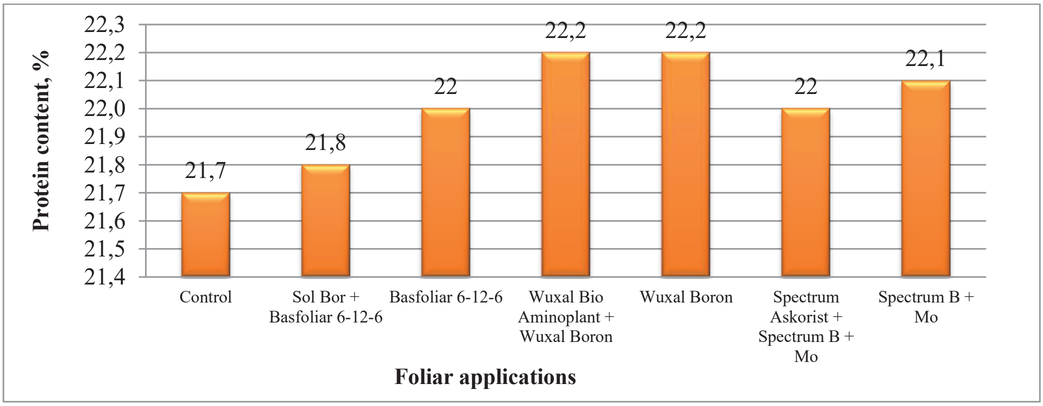

Figure 2. Average protein content of the combined sunflower genotypes as influenced by foliar applications

The next greatest average protein content (22.0%) was caused by either spraying Basfoliar 6-12-6 twice or Spectrum Askorist + Spectrum B + Mo thrice. The lowest average protein content occurred in the control (21.7%) after Sol Bor + Basfoliar 6-12-6 (21.8%).

There was an increase in average protein content from 0.1-0.5% as per the foliar sprays with average protein content for the various genotypes fluctuating between 20.7-23.2%. In a related study with high oleic sunflower hybrids using these same foliar applications, Melnyk et al. (2019) similarly reported increases in average oil content and oleic acid content by 0.6-1.6% and 1.8-4.1%, respectively.

CONCLUSIONS

Foliar applications generally had a favourable effect on all parameters studied (plant height, leaf surface area, number of seeds per head, seed weight per head, 1000-seed weight, seed yield, and protein content) compared to the control.

Significantly ($P<0.05$) higher average seed yield occurred in the variety Lakomka (2.42 t/ha). Again, the greatest protein content was obtained from Lakomka (23.0%).

Sequential foliar application of Sol Bor + Basfoliar 6-12-6 thrice gave significantly ($P<0.05$) greater average seed yield (2.37 t/ha) for the combined genotypes compared to all other treatment. Based on foliar sprays, the increase in seed yield ranged from 0.06-0.15 t/ha when compared to control. Foliar sprays also caused increases in protein content between 0.1-0.5% compared to the control with average protein content for the various genotypes fluctuating between 20.7-23.2%.

In order to ensure stable high yield (2.42 t/ha) with high-quality confectionery sunflower seeds, there should be foliar application of Sol Bor (3.0 l/ha) at BBCH 15-17 and Basfoliar 6-12-6 (6.0 l/ha) at BBCH 27-37 and BBCH 47-57 on the Lakomka variety.

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