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PRODUCTIVITY AND QUALITY OF HIGH-OLEIC SUNFLOWER SEEDS AS INFLUENCED BY FOLIAR FERTILIZERS AND PLANT GROWTH REGULATORS IN THE LEFT-BANK FOREST-STEPPE OF UKRAINE

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Abstract

Ukraine has maintained its position as leading producer of sunflower seeds in the world for the past decade. Concerning diet, higher oleic acids are ideal. Sunflower (Helianthus annuus L.*) hybrids have high genetic potential for seed yield above 5 t/ha and oil content in seed greater than 50%. Yet, environmental factors seems to limit current sunflower yields to the production range of 1.5-3.0 t/ha. A three years field experiment was conducted in the Left-Bank Forest-Steppe of Ukraine (Latitude: 49.6; Longitude: 34.9; altitude 113 m) to assess the influence of seven different foliar applications of 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 productivity and quality of five new high oleic sunflower hybrids (SY Experto, Antratsyt, ES Ballistic, Oplot, PR64H32). Foliar applications positively influenced all parameters studied (plant height, leaf surface area, number of seeds per head, seed yield, oil content and oleic acid content). The highest average seed yields occurred in the hybrids PR64H32 (3.73 t/ha) and SY Experto (3.69 t/ha) with no significant difference (P<0.05). However, PR64H32 generated a significantly (P<0.05) higher average seed yield than the other hybrids. Except for Wuxal Boron (sprayed twice sequentially) with an average seed yield of 3.53 t/ha, sequential spraying of Wuxal Bio Aminoplant + Wuxal Boron thrice on all hybrids, ensured a significantly higher average seed yield (3.58 t/ha) than the other foliar sprays. Based on foliar sprays, the increase in seed yields ranged from 0.19-0.36 t/ha when compared to control. Foliar sprays also caused increases in oil content between 0.6-1.6% compared to the control with average oil content for the various hybrids fluctuating between 48.4-49.3%. Average oleic acid content ranged from 71.5-83.7% for the investigated hybrids and foliar applications increased the average oleic acid content by 1.8-4.1%. The combined factors of hybrid and foliar applications had the greatest influence on seed yield (share of 62.6%) than hybrid - 29.1%; foliar applications - 6.3%; other factors - 2.0%.*

Key words*: high- oleic sunflower, productivity, foliar fertilizer, plant growth regulator, seed quality.*

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is among the four most important oilseed plants globally (along with palm, soy, and rapeseed) and branded as one of the two most essential oil crops in Europe, together with rapeseed (Jocić et al., 2015). Ukraine has maintained its position as leading producer of sunflower seeds in the world for the past decade. It is recently reported in 2018 that, Ukraine currently (2017-2018) ranks first in sunflower production worldwide with an output of 13.70 million metric tons (MMT) which represents 28.9% of the entire global sunflower output of 47.41 MMT (United States Department of Agriculture - USDA, 2018).

High oleic sunflower oil has the highest oleic acid content (over 90%) compared to all vegetable oils present in the global market (Jocić et al., 2015), and it has greater oil resistance to auto-oxidation, which prevents the build-up of toxic products during oil processing, storage, and direct uses (Kaya et al., 2015). Concerning diet, higher oleic acid (70%) and lower linoleic acids (20%) are desired. Hence, breeding for oil quality in sunflower has chiefly focused on modifying the relative amount of fatty acids by raising oleic acid to have stable and healthy oil and enhancing stearic acid for a stable and healthy fat (Zambelli et al., 2015).

It is recently indicated that, the major goal in sunflower breeding is to create hybrids with high genetic potential for seed yield beyond 5 t/ha and oil content in seed greater than 50%

that provide high oil yield per hectare of over 2.5 t/ha (Jocić et al., 2015).

In spite of this well documented potential, environmental factors seems to limit current sunflower yields to the production range of 1.5-3.0 t/ha (Kaya, 2015). Just recently, Kaya (2015) advised that Breeders should pay meticulous attention to eliminating or minimizing extreme environmental factors to ensure that a minimum of 4 t/ha sunflower yields are reached.

An important reserve for the realization of plant biological potential is the application of foliar fertilizers and plant growth regulators (PGRs). Foliar fertilization of crops provides a valuable supplement to the application of nutrients via the soil and under certain circumstances, foliar fertilization is more economic and effective (Fageria et al., 2009). Of significance, this mode of applying fertilizers ensures immediate uptake and translocation of nutrients to various plant organs via the leaf tissues and thus enables rapid correction of nutrient deficiencies (Fageria et al., 2009). Moreover, foliar fertilization has been recommended for integrated plant production since it not only increases crop yield and quality but is also environmentally safe (Fageria et al., 2009; El-Aal et al., 2010; Zodape et al., 2011), because the nutrients are directly delivered to the plant in limited amounts, thereby helping to reduce the environmental impact associated with soil fertilization (Fernández and Eichert, 2009).

PGRs according to Oosterhuis and Robertson (2000) encompass a broad category of compounds that promote, inhibit, or otherwise modify plant physiological or morphological processes. It is also known that 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 (PGRs) (Calvo et al., 2014).

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

MATERIALS AND METHODS

A three years (2016, 2017 and 2018) field research was conducted 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; altitude 113 m) on black soil, characteristic for coarse-medium loam. Seeds of five high oleic sunflower hybrids (SY Experto, Antratsyt, ES Balistic, Oplot, and PR64H32) were sown in first decade of May and harvested in the third decade of September of the research years. The origins of the hybrids are as follows: SY Experto (Syngenta Crop Protection AG., Switzerland); Antratsyt (Selection and Genetics Institute - National Center of Seed Science and Variety studiesof the Ukrainian Academy of Agrarian Sciences, Ukraine); ES Balistic (Euralis Semences, France); PR64H32 (Pioneer Seed Holding, GmbH, Austria).

Data on rainfall and air temperature for the growing period was obtained from Poltava Regional Center for Hydrometeorology of Ukraine. Analysis of weather conditions, particularly Hydrothermal coefficient (HTC) as described (Selyaninov, 1937), showed that the vegetative period for the research years had the following characteristics: 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 computed by 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 10°C; Σt is the sum of temperatures (°C), for the period with average daily air temperature beyond 10°C. The main meteorological indexes for the studied periods are presented in Table 1.

The experiments 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 hybrids while the sub plots were 7 different foliar fertilizer 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 at a plant density of 60,000 plants/ha with 4 rows in each plot. An inter row distance of 70 cm was maintained. Background fertilizer was applied to the soil at the rate of $N_{94}P_{48}K_{48}$. The sowing was carried out by the 8 rows Baural Planter Maxima in the unit with the NewHolland tractor. Chemical and mechanical measures were used to effectively control weeds in high debris field conditions. Soil herbicides Prim Extra TZ Gold 500 SC (4.5 l/ha) was applied. All other cultural practices including, pest and disease control were performed.

Table 1. Meteorological indexes during the period of field trials with sunflower

Year	2016		2017		2018		Long-term average	
Month	AT, °C	R, mm	AT, °C	R, mm	AT, °C	R, mm	AT, °C	R, 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.

Foliar fertilizers and plant growth regulators were applied sequentially 2-3 times 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). The first application was done at the vegetative stage (V-8 to V-10) and the second and third applications at reproductive stage before flowering (R-1 to R-4) (Schneiter and Miller, 1981). Thus, 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 twice on sub-plots without 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 fertilization served as control. Nutrient compositions of foliar fertilizers and plant growth regulators are shown (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	*EMB
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 typical tagged plants at reproductive phase before flowering (R-1 to R-4) (Schneiter and Miller, 1981): plant height; width of 7th leaf and length of 7th leaf before leaf surface area was determined using the method described by Osipova and Litun (1988).

Harvesting was done through manual approach at maturity by harvesting the five tagged plants from two inner rows in each plot. Accounting, measurement, and related observations were undertaken in accordance with methods of field experience by Dospekhov (1985).

The oil and oleic acid contents of the seeds were determined by employing the device Spinlock Magnetic Resonance Solutions. Data were subjected to statistical analysis of variance (ANOVA) followed by least significant difference (LSD) test at 5% level of probability ($p<0.05$) employing the Statistica 8 software (Stat Soft. Inc.).

RESULTS AND DISCUSSIONS

Among the five high oleic hybrids studied, SY Experto had the highest average plant height (179.9 cm) (Table 3). This was followed by ES

Balistic (179.5 cm), PR64H32 (177.4 cm), Antratsyt (170.1 cm) and the least average plant height were recorded for Oplot (166.3 cm). Except for ES Balistic, there was a significant difference ($P<0.05$) between SY Experto and the other hybrids. As well, the other hybrids were significantly taller than the shortest hybrid (Oplot).

Table 3. Effect of foliar applications on average plant heights of sunflower for the studied period (2016-2018) (cm)

Foliar applications (Factor B)	Sunflower hybrids (Factor A)					
	Antratsyt	ES Balistic	SY Experto	Oplot	PR64H32	Average
Control	164.6	175.5	177.6	162.3	173.5	170.7
Sol Bor + Basfoliar 6-12-6	172.0	180.9	182.7	165.7	178.5	176.0
Basfoliar 6-12-6	169.5	176.9	178.5	164.6	176.3	173.2
Wuxal Bio Aminoplant + Wuxal Boron	172.9	181.7	183.4	169.9	180.9	177.8
Wuxal Boron	173.3	184.7	180.8	167.7	175.9	176.5
Spectrum Askorist + Spectrum B + Mo	170.0	176.2	179.1	167.5	179.9	174.5
Spectrum B + Mo	168.5	180.3	177.5	166.2	176.9	173.9
Average	170.1	179.5	179.9	166.3	177.4	
The least significant difference (LSD) at $p<0.05$: A - 0.92; B - 1.09 cm						

With regards to foliar applications, triple application of Wuxal Bio Aminoplant + Wuxal Boron generated a significantly higher average plant height (177.8 cm) than for Wuxal Boron (176.5 cm), Sol Bor + Basfoliar 6-12-6 (176.0 cm), Spectrum Askorist + Spectrum B + Mo (174.5 cm), Spectrum B + Mo (173.9 cm), Basfoliar 6-12-6 (173.2 cm) and control (170.7 cm) (Table 3). The least plant height was recorded for the control (170.7 cm). Thus, for the combined hybrids, each foliar application resulted in an average plant height that is significantly ($P<0.05$) higher than the control (no spray). Generally, the triple applications resulted in slightly higher plant heights than double applications. However, double application of Wuxal Boron alone resulted in a slightly higher plant height for Antratsyt (173.3 cm) and ES Balistic (184.7 cm) compared to their respective individual triple application of Wuxal Bio Aminoplant + Wuxal Boron (Antratsyt - 172.9 cm; ES Balistic -184.7 cm). Similar result was obtained for ES Balistic when Spectrum Askorist + Spectrum B + Mo were individually applied thrice (176.2 cm), with the double application of Spectrum B + Mo alone producing a slightly higher plant height (180.3 cm). For all hybrids, all foliar applications resulted in a slightly higher plant height except for SY Experto for which the control was higher (177.6 cm) than double application of Spectrum B + Mo (177.5 cm).

The greatest influence on plant height was caused by the combination of hybrids and foliar applications with a share of 75.6%. The second factor was hybrids (19.1%) whiles foliar applications was next with a share of 3.1%. Other factors had a 2.2% influence on plant height. Leaf area growth determines light interception and is an important parameter in determining plant productivity (Gifford et al., 1984; Koester et al., 2014).

Table 4. Effect of foliar applications on average leaf surface area of sunflower for the studied period (2016-2018) (m^2)

Foliar applications (Factor B)	Sunflower hybrids (Factor A)					
	Antratsyt	ES Balistic	SY Experto	Oplot	PR64H32	Average
Control	0.62	0.58	0.60	0.65	0.59	0.61
Sol Bor + Basfoliar 6-12-6	0.67	0.65	0.68	0.73	0.67	0.68
Basfoliar 6-12-6	0.70	0.63	0.65	0.70	0.65	0.67
Wuxal Bio Aminoplant + Wuxal Boron	0.73	0.65	0.70	0.73	0.71	0.70
Wuxal Boron	0.73	0.70	0.67	0.69	0.69	0.70
Spectrum Askorist + Spectrum B + Mo	0.64	0.63	0.68	0.70	0.65	0.66
Spectrum B + Mo	0.69	0.61	0.64	0.60	0.63	0.63
Average	0.68	0.64	0.66	0.68	0.66	
The least significant difference (LSD) at $p<0.05$: A - 0.00; B - 0.01 m^2						

Antratsyt and Oplot had equal and the largest average leaf surface area (0.68 m^2) (Table 4). The second largest were SY Experto and PR64H32 which also formed the same average leaf surface area of 0.66 m^2 while the least was generated by ES Balistic (0.64 m^2). All hybrids had a significantly ($P<0.05$) larger leaf surface area than ES Balistic. Both Antratsyt and Oplot also created a significantly larger average leaf surface area compared to the second largest (SY Experto and PR64H32).

Triple application of Wuxal Bio Aminoplant + Wuxal Boron or only double applied Wuxal Boron also generated equivalent and the largest average leaf surface area (0.70 m^2) (Table 4). These were followed in a decreasing sequence by the application of Sol Bor + Basfoliar 6-12-6 (0.68 m^2), Basfoliar 6-12-6 (0.67 m^2), Spectrum Askorist + Spectrum B + Mo (0.66 m^2), and Spectrum B + Mo (0.63 m^2). The smallest average leaf surface area occurred in the control (0.61 m^2). Thus, Wuxal Bio Aminoplant + Wuxal Boron or Wuxal Boron created a significantly ($P<0.05$) larger leaf surface area than the other treatments. Also, considering the total hybrids, each foliar application generated a significantly ($P<0.05$) larger average leaf surface area than the control.

Generally, spraying thrice on the hybrids resulted in slightly larger leaf surface area than double applications. However, for Antratsyt, the application of just Basfoliar 6-12-6 twice produced a slightly larger leaf surface area (0.70 m^2) than triple application of Sol Bor + Basfoliar 6-12-6 (0.67 m^2). Similar results were obtained for double spraying of only Spectrum B + Mo (0.69 m^2) and triple applied Spectrum Askorist + Spectrum B + Mo (0.64 m^2). Still, for Antratsyt, triple application of Wuxal Bio Aminoplant + Wuxal Boron or Wuxal Boron sprayed only twice produced the same leaf surface area (0.73 m^2). Additionally, for ES Balistic, leaf surface area generated by applied Wuxal Boron alone (0.70 m^2) was a little larger than triple applied Wuxal Bio Aminoplant + Wuxal Boron (0.65 m^2). For all the hybrids, all treatments resulted in a larger leaf surface area than the control except for Oplot for which control was a bit larger (0.65 m^2) than spraying with only Spectrum B + Mo twice (0.60 m^2).

Together, hybrids and foliar applications influenced leaf surface area the greatest with a share of 47.5%. This was followed by only foliar applications (29.9%) before hybrids (10.7%). Other factors had an influence of 11.9%.

The hybrid PR64H32 produced the greatest average number of seeds per head (1305.6 pcs) and was followed in a reducing manner by: SY Experto (1272.0 pcs), Oplot (1164.0 pcs), ES Balistic (1089.9 pcs), and Antratsyt (1035.7 pcs) (Table 5). All the hybrids had significantly ($P<0.05$) higher average number of seeds compared to Antratsyt. Additionally, PR64H32 produced a significantly higher average number of seeds than the other hybrids.

The average maximum number of seeds per head among the hybrids was achieved through triple application of Wuxal Bio Aminoplant + Wuxal Boron (1195.8 pcs). The rest were as follows in a decreasing manner: Wuxal Boron (1187.2 pcs), Sol Bor + Basfoliar 6-12-6 (1187.0 pcs), Spectrum Askorist + Spectrum B + Mo (1174.2 pcs), Spectrum B + Mo (1169.8 pcs), and the minimum was obtained from the control (1132.2 pcs). Combining all the hybrids, each foliar application generated a significantly higher average number of seeds compared to the control (1132.2). However, the difference between the greatest number of seeds based on triple application of Wuxal Bio Aminoplant + Wuxal Boron and that of Wuxal Boron or Sol Bor + Basfoliar 6-12-6 was not statistically significant ($P<0.05$) but was significant for the others.

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

Foliar applications (Factor B)	Sunflower hybrids (Factor A)					
	Antratsyt	ES Balistic	SY Experto	Oplot	PR64H32	Average
Control	1007	1048	1213	1151	1242	1132.2
Sol Bor + Basfoliar 6-12-6	1044	1112	1292	1160	1327	1187.0
Basfoliar 6-12-6	1046	1111	1207	1176	1299	1167.8
Wuxal Bio Aminoplant + Wuxal Boron	1052	1098	1310	1173	1346	1195.8
Wuxal Boron	1031	1103	1309	1172	1321	1187.2
Spectrum Askorist + Spectrum B + Mo	1043	1075	1291	1152	1310	1174.2
Spectrum B + Mo	1027	1082	1282	1164	1294	1169.8
Average	1035.7	1089.9	1272.0	1164.0	1305.6	
The least significant difference (LSD) at p<0.05: A - 13.05; B -15.45 pcs.						

Mostly, applications in threefold resulted in a little increase in the number of seeds per head than for just double sprayings of the hybrids. However, for Antratsyt, triple application of

Sol Bor + Basfoliar 6-12-6 produced just a little lower number of seeds per head (1044 pcs) than for just double application of Basfoliar 6-12-6 (1046 pcs). Similarly, for Oplot, Sol Bor + Basfoliar 6-12-6 produced 1160 pcs while only Basfoliar 6-12-6 generated 1176 pcs. Again, for Oplot, there was a lower number of seeds per head for applied Spectrum Askorist + Spectrum B + Mo (1152 pcs) compared to only Spectrum B + Mo (1164 pcs). Also, for ES Balistic, triple application of Wuxal Bio Aminoplant + Wuxal Boron generated somewhat lower number of seeds per head (1098 pcs) than for applying Wuxal Boron only twice (1103 pcs). All foliar sprays on a particular hybrid gave a higher number of seeds per head than the control except for dual application of Basfoliar 6-12-6 on SY Experto. The combined factors of hybrids and foliar applications gave the greatest influence of 52.6% on number of seeds per head. Hybrids were next with a share of 43.6% and were followed by foliar applications (1.5%) before lastly other factors (2.4%).

Seed yield is the main criterion for economic evaluation of the implementation of the potential of modern hybrids.

The highest average seed yield was produced by the hybrid PR64H32 (3.73 t/ha) (Table 6). The other hybrids generated the following average seed yields in a decreasing order: SY Experto (3.69 t/ha), ES Balistic (3.39 t/ha), Oplot (3.31 t/ha), and Antratsyt (3.13 t/ha). Except for SY Experto, there was a significant difference ($P<0.05$) between the average seed yield of PR64H32 and the other hybrids. In a recent related study without foliar applications, Melnyk et al. (2019) reported similar but lower average seed yields for the same hybrids as follows: SY Experto (3.51 t/ha); PR64H32 (3.41 t/ha); ES Balistic (3.17 t/ha), Oplot (3.14 t/ha), and Antratsyt (2.68 t/ha). The higher seed yields in the present study could be attributed to the foliar applications.

Among the foliar applications on all hybrids, except for Wuxal Boron with an average seed yield of 3.53 t/ha, spraying of Wuxal Bio Aminoplant + Wuxal Boron thrice ensured a significantly higher average seed yield (3.58 t/ha) than the other foliar sprays: Sol Bor + Basfoliar 6-12-6 (3.51 t/ha), Spectrum Askorist + Spectrum B + Mo (3.46 t/ha), Basfoliar 6-12-6 (3.45 t/ha), Spectrum B + Mo (3.41 t/ha) and control (3.22 t/ha). Furthermore, there was a significant difference in average seed yield between a particular foliar application and the control.

Table 6. Effect of foliar applications on average seed yields of sunflower for the studied period (2016-2018) (t/ha)

Foliar applications (Factor B)	Sunflower hybrids (Factor A)					
	Antratsyt	ES Balistic	SY Experto	Oplot	PR64H32	Average
Control	2.95	3.17	3.41	3.13	3.43	3.22
Sol Bor + Basfoliar 6-12-6	3.12	3.47	3.73	3.38	3.83	3.51
Basfoliar 6-12-6	3.13	3.42	3.69	3.31	3.70	3.45
Wuxal Bio Aminoplant + Wuxal Boron	3.22	3.47	3.84	3.47	3.90	3.58
Wuxal Boron	3.21	3.51	3.80	3.35	3.78	3.53
Spectrum Askorist + Spectrum B + Mo	3.13	3.35	3.72	3.28	3.80	3.46
Spectrum B + Mo	3.12	3.33	3.67	3.26	3.69	3.41
Average	3.13	3.39	3.69	3.31	3.73	
The least significant difference (LSD) at $p<0.05$: A-0.04; B-0.05 t/ha						

The seed yields for the triple foliar sprays were mainly higher than just double spraying the same foliar fertilizers and plant growth regulators. However, for Antratsyt, foliar applied Sol Bor + Basfoliar 6-12-6 in threefold produced a slightly lower seed yield (3.12 t/ha) compared to double application of Basfoliar 6-12-6 without Sol Bor (3.13 t/ha). Similarly, for ES Balistic, there was a lower seed yield for triple spraying of Wuxal Bio Aminoplant + Wuxal Boron (3.47 t/ha) than for only dual applied Wuxal Boron (3.51 t/ha).

Additionally, for every hybrid, all foliar sprays resulted in a higher seed yield than control. The greatest influence on average seed yield was caused by the combined factors of hybrids and foliar applications (share is 62.6%). The second greatest influence was by hybrid (29.1%) and the third by foliar applications (6.3%). Other factors had the least influence on the average seed yield (share is 2.0%).

The main requirements for oil seeds are the oil content. Among the studied hybrids, PR64H32 generated the highest average (49.3%).

It then decreases for the other hybrids in the following order: SY Experto (48.9%), Antratsyt (48.5%), ES Balistic (48.4%), and Oplot (47.6%). Foliar applications caused a 0.6-1.6% increase in oil content. Recently, without foliar applications on these same five hybrids, average oil content ranging between 45.2-49.4% was reported (Melnyk et al., 2019). On the other hand, the highest average oleic acid content was produced by SY Experto (83.7%) (Figure 1). In a decreasing manner, the rest of the hybrids produced these average oleic acids as follows: ES Balistic (80.6%), PR64H32 (79.4%), Oplot (75.3%), and Antratsyt (71.5%). The increase in oleic acid contents due to foliar sprays ranges between 1.8-4.1%. For each hybrid, oleic acid was higher than the oil content. Strikingly, Melnyk et al. (2019) reported a slightly higher oleic acid content (ranging between 75.8-88.5%) in same hybrids without foliar spraying.

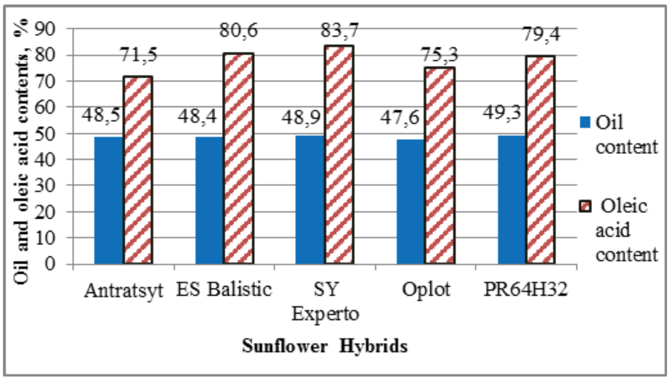

Figure 1. Average oil and oleic acid contents of investigated hybrids as influenced by foliar sprays (2016-2018) (%)

CONCLUSIONS

Foliar applications had a favourable effect on all parameters studied (plant height, leaf surface area, number of seeds per head, seed yield, oil content and oleic acid content) compared to the control. The highest average seed yields occurred in the hybrids PR64H32 (3.73 t/ha) and SY Experto (3.69 t/ha) as was for oil content PR64H32 (49.3%) and SY Experto (48.9%). Sequential foliar application of Wuxal Bio Aminoplant + Wuxal Boron thrice or Wuxal Boron twice, respectively gave the greatest average seed yield for all hybrids combined (3.58 t/ha or 3.53 t/ha) compared to the control (3.22 t/ha). Based on foliar sprays, the increase in seed yields ranged from 0.19 - 0.36 t/ha when compared to control. Foliar sprays also caused increases in oil content between 0.6-1.6% compared to the control with average oil content for the various hybrids fluctuating between 48.4-49.3%. Average oleic acid content ranged from 71.5-83.7% for the investigated hybrids and foliar applications increased the average oleic acid content by 1.8-4.1%. The combined factors of hybrid and foliar applications had the greatest influence on seed yield (share of 62.6%); hybrid - 29.1%; foliar applications - 6.3%; other factors - 2.0%. To guarantee higher yields (3.69-3.73 t/ha) and quality seeds, sequential foliar application of Wuxal Bio Aminoplant + Wuxal Boron thrice or Wuxal Boron twice on hybrids PR64H32 and SY Experto is recommended.

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