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Influence of Foliar Top Dressing with Microfertilizers on Sunflower Growth, Development and Productivity

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ABSTRACT

The purpose of the research is to determine the duration of the interphase period, total water consumption, plant height, yield and quality of sunflower seeds, depending on the characteristics of hybrids and foliar top dressing with microfertilizers. Methods. Experimental studies were conducted during 2020–2021 in the experimental field of Mykolaiv National Agrarian University (Ukraine). Results. It was determined that all the studied microfertilizers extended the duration of interfacial periods of sunflower plants. The largest total water consumption of sunflower plants (2259 m^3/ha) was formed in the hybrid NK Kamen in the variant with foliar top dressing with microfertilizer Quantum, which was 0.9–6.5% more than in the same variant with hybrids Darius and Tutti. The highest height of sunflower plants among the hybrids submitted for study was formed by Darius – 165.7–170.9 cm, which was 5.0–5.7% higher than the height of plants of the NK Kamen hybrid and 7.2–8.0% more than the height of Tutti hybrid. It was found that the highest yield of sunflower seeds (2.55 t/ha) on average over the years of research was formed in the hybrid NK Kamen in the variant with foliar top dressing with microfertilizer Quantum, which exceeded its level in the non-fertilized control by 18.6% and the average yield for all variants of the experiment by 12.3%. The highest yield of sunflower seeds (2.56 t/ha) among the hybrids submitted for study was provided by NK Kamen in 2021, which was 12.3% more than in the Darius hybrid and 6.6% more than in the Tutti hybrid. Foliar top dressing with microfertilizers significantly affected the quality indicators of seeds of the studied sunflower hybrids. The maximum fat content values (from 50.1 up to 52.7%, depending on the hybrid) were achieved by applying Quantum microfertilizer in the 5-6-leaf phase. The conditional yield of oil from seeds in this variant of nutrition is also determined to be the maximum – from 1.13 up to 1.34 t/ha, depending on the hybrid. Less effective for the growth and development of plants and the formation of their productivity was the preparation Rostok, with the introduction of which the duration of the growing season increased by 1-2 days; total water consumption increased by 29–35 m^3/ha; the height increased by 1.1–4.6 cm; seed yield increased by 0.80–0.28 t/ha; the content fat in seeds increased by 0.02–0.03%; oil seed yield increased by 0.12–0.15 t/ha.

Keywords: sunflower hybrids, microfertilizers, foliar top dressing, plant height, seed yield, seed fat content.

INTRODUCTION

For the agro-industrial complex of Ukraine, sunflower, as the main oilseed crop, has become the main crop rotation (Voliak, 2021; Domaratskiy, 2021). The demand for sunflower oil and seed processing products is constantly growing, which contributes to the expansion of acreage for this crop around the world (Slobodianyk et al., 2020). Sunflower acreage in Ukraine is constantly growing and in 2021 it has reached 6.6 million hectares (Plant Growing in Ukraine, 2022). In 2021/2022, a record global gross harvest of sunflower seeds over the past 10 years was collected as 57.2 million tons, while the share of Ukraine was 31% or 17.5 million tons, which allowed it to take the first place among the leading countries of the world. In terms of sunflower seed yield, Ukraine also occupies a leading position. Thus, in 2021, the crop yield was obtained at the

level of 2.46 t/ha (FAOSTAT, 2022). In addition, Ukraine is a leader in the production and export of oil in the world. Thus, in 2021/22 MP, 5.7 million tons of oil were exported, or 47% of world exports (FAOSTAT, 2022). However, according to FAO forecasts, due to the war of the Russian Federation against Ukraine, there will be a significant decrease in sunflower acreage and also a decrease in its yield due to violations of cultivation technology, in particular the food system, which will lead to an increase in raw material prices (FAO, 2022). Therefore, one of the main tasks of modern agricultural production is to find new ways and means to increase the yield and quality of products.

The introduction of new sunflower hybrids which are resistant to adverse environmental factors into production and ensuring an optimal nutrition regime is a prerequisite for increasing yields (Yeremenko et al., 2020). Modern sunflower hybrids have a high yield potential, which for experienced producers reaches 4.0–5.0 t/ha. With the right cultivation technology, such a yield can be obtained stably over the entire area. But some erroneous approaches to this crop significantly limit the yield of sunflower. First of all, this applies to the nutrition mode (Domaratskiy et al., 2018; 2020; 2023).

In addition to macronutrients, trace elements also play an important role for the growth and development of sunflower plants: such as boron, copper, iron, manganese, zinc, molybdenum, etc. (Biesalski et al., 2018). It is important to give the plant elements of nutrition not only in the necessary time, but also in a balanced ratio. A deficiency of each of them can lead to metabolic disorders and physiological processes that can later cause a decrease in yield and deterioration of its quality (Junhao et al., 2020). Plants which are provided with trace elements consume and absorb basic fertilizers much better (by 10–30%), they develop well and better resist diseases, pests, frosts, droughts and other stressful factors (Assunção et al., 2020).

Most trace elements are active catalysts that accelerate biochemical reactions and affect their direction. That is why trace elements can not be replaced with any substances, and their lack can negatively affect the growth and development of plants (Chrysargyris et. al. 2022). Microelement chelates activate the main processes of seed germination: such as hydrolysis of protein, carbohydrate and fat reserves, redox reactions, thereby affecting the acceleration of seed germination (dynamics of emergence), increasing their vital activity, field germination, growth of aboveground mass and root system (Dimkpa et al., 2016). (Gamayunova et. al., 2020) it is proved that in modern economic conditions it is advisable to increase the volume of use of liquid mineral fertilizers, the effectiveness of which depends to a lesser extent on the level of soil moisture. The most effective method of introducing trace elements is foliar nutrition during the growing season by spraying plants in critical phases of development (Patil et al., 2018; Panfilova et. al., 2021). Therefore, fertilizers for foliar top dressing of sunflower, containing trace elements, are becoming more and more relevant, as they contribute to an increase in seed damage by 10–12% (Oad, 2018).

Up to date, there are a large number of preparations for foliar nutrition of sunflower plants which affect the growth and development of plants. The most common complex microfertilizers in Ukraine are the brands of LLC SPC "Reakom", NPK "Kvadrat" LLC "Rostok" and the company "Nanomix". But their influence on the formation of productivity of various sunflower hybrids is insufficiently studied and covered in the world scientific literature. In addition, comparing these preparations simultaneously with each other will allow you to identify the best variant.

MATERIALS AND METHODS

Field research was conducted during 2020–2021 yrs in the experimental field of the Training Scientific and Practical Center of the Mykolaiv National Agrarian University, which was located in the southern part of the Mykolaiv region in the Southern steppe zone of Ukraine, the climate of which was characterized by pronounced aridity in the presence of significant thermal resources and limited provision of atmospheric precipitation.

The soil cover of the experimental field was represented by Southern low-humus powdery-heavy loamy chernozems. The presence of humus in the arable soil layer was 2.8%, nitrate nitrogen was 30.0, mobile phosphorus was 146.0, exchange potassium was 357.0 mg per 1 kg of soil. The reaction of the soil solution is close to neutral (pH 6.5–6.8), hydrolytic acidity is in the range of 2.00–2.52 mg. equiv. per 100 g of soil.

Agricultural techniques for growing sunflower seeds were generally accepted for the zone, with the exception of variants which were studied according to the experimental scheme. In all the years of research, the predecessor of sunflower was

winter wheat. The analysis of agroclimatic conditions was carried out using data from the PesslInstruments weather station (iMETOS), equipped with high-precision sensors. Weather conditions were different over the years of research. In 2020, only 9.0 mm of precipitation fell in April, while in 2021 it fell 47.0 mm, that is, 422.2% more. More precipitation (47.0 and 58.0 mm) in May – June fell in 2021, which was 20.5 and 48.7% more, respectively, than in 2020 (Fig. 1, 2).

So, the growing season of 2021 was more favorable for the growth and development of sunflower plants, the amount of precipitation for the reporting period was 162 mm, which was 58 mm more than in 2020. The average monthly air temperature in April was 12.6 °C (2020) and it was 8.1°C (2021); in May it was 18.7 (2020) and 15.2 °C (2021); in June it was 22.9 °C (2020) and 20.2 °C (2021); in July it was 25.6 °C (2020) and 24.7 °C (2021); in August it was 26.4 °C (2020) and 23.2 °C (2021). The experiment was laid by splitting the sections. The sown area of the plot was 56 m^2, the accounting area was 30 m^2, and the experiment was repeated four times.

The field experiment scheme included the following variants:

- factor A. Hybrids: 1. Darius (St.); 2. NK Kamen; 3.Tutti,
- factor B. Microfertilizers: 1. without microfertilizers (control); 2. Quantum (4 l/ha); 3. Rostok (4 l/ha); 4. Reakom (4 l/ha); 5. Nanomix (2 l/ha).

All the studied sunflower hybrids were listed in the state register of plant varieties suitable for distribution in Ukraine and recommended for

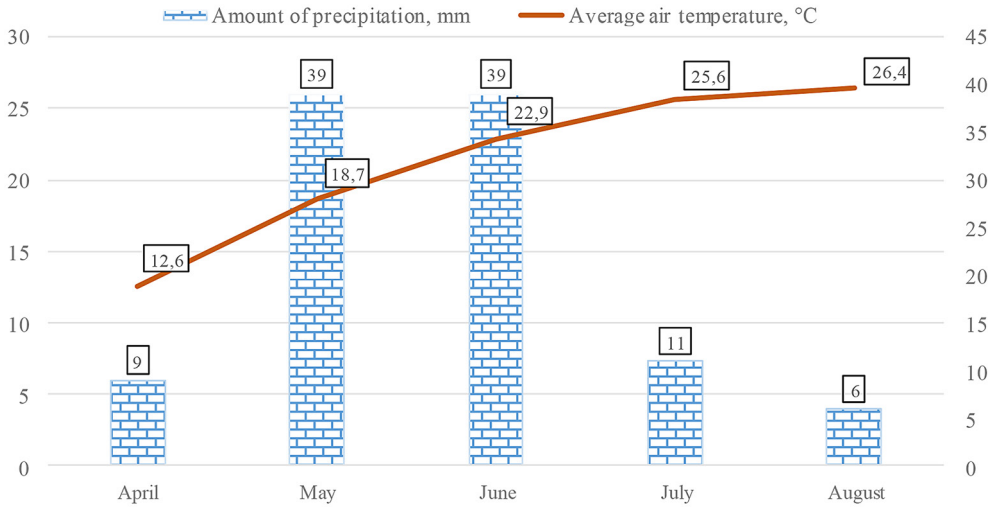

Figure 1. Meteorological conditions during the Sunflower growing season in 2020

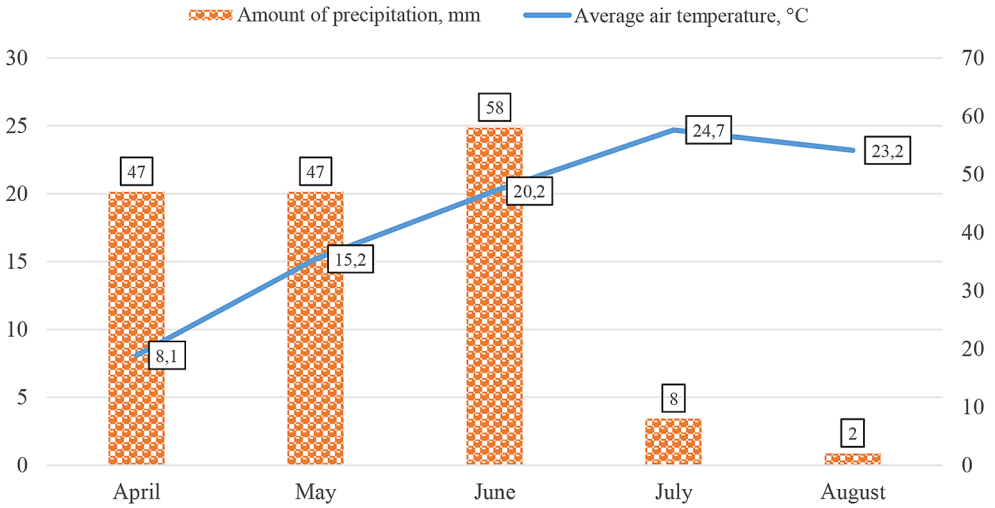

Figure 2. Meteorological conditions during the sunflower growing season in 2021

growing in the steppe zone. Foliar top dressing was carried out in the phase of 6–8 leaves using a working solution of 300 l/ha. In a field experiment, the effect of microfertilizers on the growth, development and productivity of sunflower hybrids was studied. Records and observations, plant height, and seed yield were determined according to the method of state variety testing. Soil moisture was determined at the beginning and end of the growing season of winter rapeseed by the thermostatic-weight method, followed by drying the samples to the mass of absolutely dry soil. Mathematical and statistical processing of research results was performed using variance analysis using the STATISTICA 10.0 program (Ushkarenko et al., 2020).

RESULTS AND DISCUSSION

By studies (Mazur et al., 2021) it was determined that the duration of vegetation phases and interphase periods of plants were significantly influenced by the ecological and biological characteristics of sunflower hybrids. This was also confirmed by our research. On average, for 2020–2021, it was determined that the duration of the main interphase periods of growth and development of sunflower plants was significantly influenced by the studied factors. Thus, the interphase period of "full shoots – basket formation" was shorter in plants of the Darius hybrid as 33 days, which was 3 days less than in hybrids of NK Kamen and Tutti (Table 1).

The interphase period of "flowering – basket formation" of sunflower plants lasted 20–23 days, depending on the factors studied. It was shorter in the Darius hybrid (20–21 days), depending on factor B, and it was slightly longer in the NK Kamen and Tutti hybrids (21–23 days).

The duration of the interphase period "flowering – full ripeness" significantly depended on the biological characteristics of hybrids and not significantly it depended on foliar top dressing with microfertilizers. Thus, the reporting period for the Darius hybrid was 55–56 days and it almost did not depend on foliar top dressing with microfertilizers (factor B), while the duration of the interphase period for the NK Kamen and Tutti hybrids was by 4–5 days longer (59–61 days). Thus, the growing season of the studied sunflower hybrids

Table 1. Duration of interphase periods of growth and development of sunflower hybrid plants (days) depending on foliar top dressing with microfertilizers (average for 2020–2021)

Hybrids (factor A)	Microfertilizers (factor B)	Interphase periods of plant growth and development			
		Full shoots – basket formation	Basket formation – flowering	Flowering – full ripeness	Full shoots – full ripeness
Darius (St.)	Control	33	20	55	108
	Quantum	33	21	56	110
	Rostok	33	21	55	109
	Reakom	33	21	56	110
	Nanomix	33	21	55	109
	Average	33	21	55	109
NK Kamen	Control	36	21	59	116
	Quantum	36	23	61	120
	Rostok	36	23	59	118
	Reakom	36	22	61	119
	Nanomix	36	23	59	118
	Average	36	22	60	118
Tutti	Control	36	21	59	116
	Quantum	36	22	61	119
	Rostok	36	23	59	118
	Reakom	36	23	60	119
	Nanomix	36	23	59	118
	Average	36	22	60	118
LSD_{05}	Factor A	2,5	1.4	3.8	8.1
	Factor B	0,5	1.1	0.5	1.9

lasted from 108 days in the Darius hybrid in the control variant of foliar top dressing it lasted up to 120 days in the NK Kamen hybrid with foliar top dressing with Quantum.

In addition, it should be noted that all the studied variants of factor B (microfertilizers) positively affected the duration of the growing season of sunflower plants, which exceeded the control variant by 1–4 days, depending on the hybrid. The total water consumption of sunflower plants significantly depended on the studied factors. Sunflower plants of the NK Kamen hybrid consumed more water (2191–2259 m^3/ha) during the entire growing season, which is 129–146 m^3/ha higher than the total water consumption of Darius hybrid plants and 3–21 m^3/ha more than the consumption of Tutti hybrid plants (Fig. 3).

Studies conducted during 2019–2021 in the Southern steppe of Ukraine determined that foliar top dressing of sunflower plants with a biological product with microelements Chelafit Combi contributed to an increase in their total water consumption from 3410 m^3/ha up to 3425 m^3/ha, depending on the hybrid, which was 370–391 m^3/ha higher than the control variant (without microfertilizers) (Domaratsky et al., 2022).

Our studies showed that factor B (microfertilizers) had a smaller effect on the total water consumption of sunflower plants, which ranged from 2089–2222 m^3/ha in the variant with Nanomix up to 2113–2259 m^3/ha in the variant with foliar top dressing Quantum, which was by 27–31 m^3/ha and 51–68 m^3/ha, respectively, more than the control. It was determined that the total water consumption of sunflower plants (2259 m^3/ha) was recorded in the NK Kamen hybrid with foliar top dressing with Quantum microfertilizer, while the lowest consumption was 2062 m^3/ha in the Darius hybrid in the control variant (without microfertilizers).

Studies of Ukrainian scientists in 2019–2020 determined a significant effect of foliar top dressing with Novalon foliar microfertilizer in the 5–6 leaf phase at a rate of 1 kg/ha on increasing the height of sunflower plants by 4–9 cm depending on the hybrid under study (Totsky et al., 2021). Other researchers proved that microfertilizers could increase the height of sunflower plants by 8.7–16.1 cm or 4.6–8.1% (Nesterchuk, 2019). As a result of our research, a significant influence of factor B (microfertilizers) on the formation of plant height of the studied hybrids was established. Thus, foliar top dressing with complex microfertilizer Quantum increased the height of sunflower plants of the studied hybrids by 4.6–5.2 cm, or by 3.0–3.1%, compared to the control (water treatment), while the height of Rostok increased by 1.1–1.2 cm (0.7–0.8%); the height of Reakom increased by 2.8–3.7 cm (1.7–2.4%) and the height of Nanomix increased by 1.9–2.3 cm or by (1.2–1.4%) (Fig. 4).

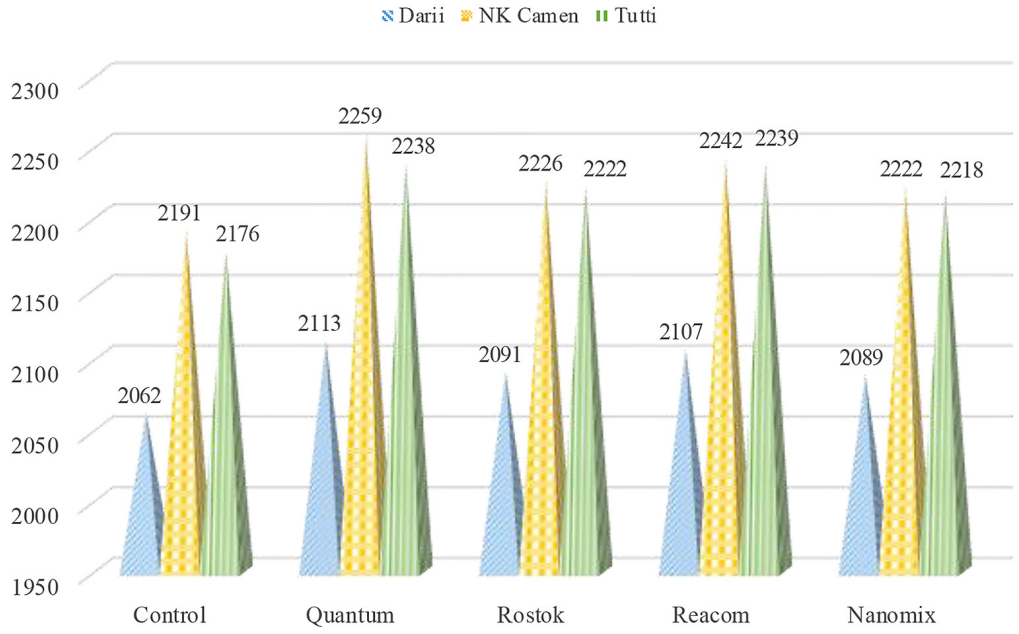

Figure 3. Total water consumption (m^3/ha) of sunflower hybrid plants depending on foliar top dressing with microfertilizers, average for 2020–2021. LSD_{05} factor A (variety) – 110 m^3/ha. factor B (microfertilizers) – 35 m^3/ha

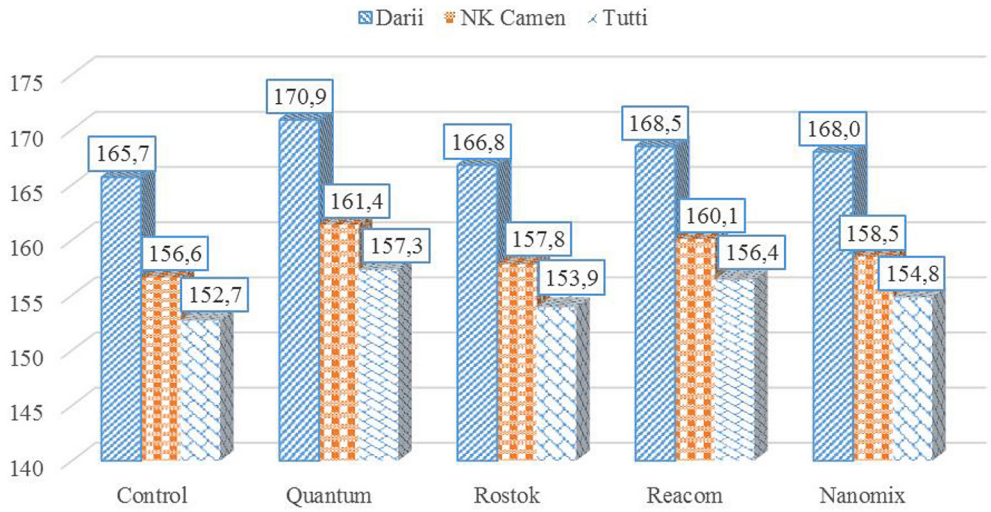

Figure 4. Height of sunflower hybrid plants depending on foliar top dressing with microfertilizers (average for 2020-2021), cm, LSD $_{05}$ factor A (variety) 8.5 cm, factor B (microfertilizers) – 1.8 cm

Morpho-biological features of hybrids also had a significant influence on the formation of plant heights of Darius, NK Kamen, and Tutti hybrids. Thus, a large plant height (165.7–174.8 cm) was formed in the Darius hybrid, a slightly smaller one was formed 156.6–161.4 cm in the NK Kamen hybrid, and the smallest one was 152.7–156.4 cm in the Tutti hybrid. So, on average for 2020–2021,

Table 2. Yield of sunflower hybrid seeds depending on foliar top dressing with microfertilizers, (average for 2020–2021)

Hybrids (factor A)	Microfertilizers (factor B)	Years		Average for 2020–2021
		2020	2021	
Darius (St.)	Control	1.71	2.04	1.88
	Quantum	2.09	2.43	2.26
	Rostok	1.96	2.27	2.12
	Reakom	2.01	2.36	2.19
	Nanomix	1.99	2.32	2.16
	Average	1.95	2.28	2.12
NK Kamen	Control	2.01	2.29	2.15
	Quantum	2.38	2.71	2.55
	Rostok	2.23	2.57	2.40
	Reakom	2.30	2.64	2.47
	Nanomix	2.29	2.61	2.45
	Average	2.24	2.56	2.40
Tutti	Control	1.84	2.17	2.01
	Quantum	2.24	2.58	2.41
	Rostok	2.15	2.42	2.29
	Reakom	2.21	2.51	2.36
	Nanomix	2.19	2.46	2.33
	Average	2.13	2.43	2.28
	Average for factor A	2.11	2.43	2.27
LSD_{05}	Factor A	0.17	0.26	0.21
	Factor B	0.22	0.34	0.28
	Interaction of factors (AB)	0.38	0.59	0.48

the Darius hybrid in the variant with foliar top dressing with Quantum microfertilizer had a higher height of sunflower plants (170.9 cm).

In world science and practice, it was found the positive effect of foliar top dressing with microfertilizers on the yield of sunflower seeds (Škarpa et. al., 2013; Klymchuk et al., 2021). Our research confirmed it. Thus, on average for 2020–2021, the yield of all the studied hybrids was higher in all variants of foliar top dressing with microfertilizers and it ranged from 2.12 t/ha for the hybrid Darius in the variant with Microfertilizer Rostok up to 2.55 t/ha for the hybrid NK Kamen in the variant with microfertilizer Quantum, which was by 0.24–0.40 t/ha more than the control (without microfertilizers) (Table 2).

The highest seed yield (2.40 t/ha) on average for two years (2020–2021) was obtained in the hybrid NK Kamen, and the lowest it was 2.12 t/ha in the hybrid Darius. Years of the research varied in weather conditions, which affected the formation of sunflower seed yields. Thus, the average yield for all the studied factors in 2020 was 2.11 t/ha, which was by 0.32 t/ha, or 13.2% less than in 2021. It was determined that all the studied sunflower hybrids reacted positively to foliar top dressing with microfertilizers. So, on average for 2020–2021, the yield of sunflower seeds of the hybrid Darius in the variant with microfertilizer Quantum was 2.26 t/ha, the yield of Rostok was 2.12 t/ha, the yield of Reakom was 2.47 t/ha, the yield of Nanomix was 2.16 t/ha, which was by 20.2; 12.8; 31.4 and 14.9%, respectively, more than the control (without fertilizers). A large increase in the yield of sunflower seeds among the studied microfertilizers was obtained in the variant with Quantum top dressing, which is 0.37–0.38 t/ha more than the control variant.

According to the results of the variance analysis, the smallest significant difference in factor A was 0.17–0.26 t/ha, in factor B it was 0.22–0.34 t/ha, and the interaction of factors AB it was 0.38–0.59 t/ha. By research by scientists (Kokovikhin et al., 2015; Milev, 2015) it was determined that the treatment of sunflower crops with complex fertilizers increased the oil content in seeds. Our research also confirmed it. Thus, the introduction of microfertilizer Quantum increased the fat content in seeds by 0.7–0.9%, depending on the hybrid, microfertilizer Rostok increased

Table 3. Seed quality of sunflower hybrids depending on foliar top dressing with microfertilizers, (average for 2020–2021)

Hybrids (factor A)	Microfertilizers (factor B)	Fat content, %	Conditional oil yield, c/ha
Darius (St.)	Control	49.2	9.3
	Quantum	50.1	11.3
	Rostok	49.4	10.5
	Reakom	49.9	10.9
	Nanomix	49.7	10.7
	Average	49.7	10.5
NK Kamen	Control	51.9	11.2
	Quantum	52.7	13.4
	Rostok	52.1	12.5
	Reakom	52.5	13.0
	Nanomix	52.4	12.8
	Average	52.3	12.6
Tutti	Control	51.6	10.4
	Quantum	52.3	12.6
	Rostok	51.9	11.9
	Reakom	52.0	12.3
	Nanomix	51.8	12.1
	Average	51.9	11.9
LSD_{05}	Factor A	0.17	0.26
	Factor B	0.22	0.34
	Interaction of factors (AB)	0.38	0.59

by 0.2–0.3%, Reakom increased by 0.4–0.6%, Nanomix increased by 0.2–0.5% (Table 3). A higher fat content in sunflower seeds was formed in the NK Kamen hybrid as 52.3% on average for factor B, slightly less it was 51.9% in the Tutti hybrid, which was by 2.6 and 2.2%, respectively, more than in the Darius hybrid.

The conditional yield of oil from seeds also depended on the factors studied. A large (1.34 t/ha) indicator was recorded in the hybrid NK Kamen in the variant with foliar top dressing with microfertilizer Quantum, which was 0.22 t/ha, or by 13.8% higher than the control. The lowest conditional oil yield from 1 ha (9.3 °C) was recorded in the Darius hybrid in the control variant. It was determined that foliar top dressing of sunflower plants with microfertilizers increased the yield of oil from seeds by 0.12–0.20 t/ha in the Darius hybrid; it increased by 0.13–0.22 t/ha in the NK Kamen hybrid and also increased by 0.15–0.22 t/ha in the Tutti hybrid.

Thus, nutrition of plants with Quantum microfertilizer contributed to an increase in the conditional oil yield in sunflower seeds to the maximum values as 1.13 t/ha for the Darius hybrid; it was 1.26 t/ha for the Tutti hybrid and also it was 1.34 t/ha for the NK Kamen hybrid.

CONCLUSION

In the Southern steppe of Ukraine, foliar top dressing of sunflower plants with microfertilizers in the 5-6-leaf phase promoted their better growth and development, it increased the yield and quality of seeds. It was determined that the introduction of microfertilizers increased the duration of the growing season from 1 up to 4 days, depending on the hybrid. A higher total water consumption of sunflower plants (2259 m^3/ha) was obtained in the hybrid NK Kamen in the variant with foliar top dressing with microfertilizer Quantum. Foliar top dressing with microfertilizers increased the height of sunflower hybrid plants by 3.1–3.8% (Quantum); it increased by 0.7–0.8% (Rostok); it increased by 1.7–2.4% (Reakom); also it increased by 1.2–1.4% (Nanomix). The use of Quantum microfertilizer increased the yield by 18.6–20.2% and the fat content in sunflower seeds increased by 1.4–1.5%. A higher conditional oil yield (1.34 t/ha) was obtained from seeds of the NK Kamen hybrid in the variant with foliar top dressing with Quantum microfertilizer.

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