The use of mineral fertilizers in sunflower crops in the conditions of Ryazan region

D V Vinogradov\(^1\), M P Makarova\(^2\) and M M Kryuchkov\(^1\)

\(^1\)Ryazan State Agrotechnological University named after P. A. Kostychev, 1, Kostycheva str., Ryazan, 390044, Russia
\(^2\)Ministry of Agriculture and Food of Ryazan Region, 9, Yesenina str., Ryazan, 390006, Russia

E-mail: assistant_84@mail.ru

Abstract. The most important direction of increasing the production of sunflower oilseeds is improvement of technology elements that provide a fuller use of the productivity potential in soil and climatic conditions of a particular region. In this regard, the aim of the research was to identify the varieties and hybrids of sunflower most adapted to the natural and climatic conditions of Ryazan region, accounting for different levels of mineral nutrition. In order to identify biological features and economically valuable traits, a field experiment was conducted in 2017–2019. Agrotechnical measures for the cultivation of sunflower were carried out in accordance with zonal recommendations. As a result of the studies, it was found that variety Poseidon 625 was the most adapted to the climatic conditions of Ryazan region. Sunflower plants of Poseidon 625 variety were noted to have the smallest height (158–172 cm), the largest leaf surface area (11.61–16.53 thousand m\(^2\)/ha), the largest number of seeds formed in one basket (1,194–1,247 pcs), the largest mass of 1,000 seeds (49.9–59.8 g) and the highest yield (2.37–2.99 t/ha). On average, in 2017–2019, the introduction of full mineral nutrition in doses of N\(_{125}\)P\(_{60}\)K\(_{60}\) and N\(_{125}\)P\(_{120}\)K\(_{120}\) contributed to an increase in the yield of sunflower oilseeds by 0.06–0.45 and 0.07–0.62 t/ha, depending on the cultivated variety and hybrid.

1. Introduction
The oil and fat industry, where sunflower accounts for two-thirds of the total crop, faces the task to significantly increase production by 2024. The Ministry of Agriculture of Russia forecasts an increase in the gross yield of oilseeds to 29.3 million tons, including sunflower (up to 16.5 million tons), rapeseed (up to 3.9 million tons) and soybeans (up to 7.3 million tons).

The work has been actively carried out in Ryazan region for years to diversify the crop production industry. Oil crops have increased significantly in recent years [1–4]. Ryazan region is the northernmost region, where they are grown in significant quantities. In 2019, the area sown with oilseeds amounted to 150.6 thousand ha for the first time. In 2019, the gross yield of oilseeds reached 310.4 thousand tons, being the maximum result in the entire history of oilseed cultivation in the region.

The reserve for increasing crop yields is the fuller use of natural factors, the maximum realization of the biological potential of varieties and hybrids, the development of resource-saving and environmentally sound technologies [5–11].
In a diverse set of measures aimed at increasing the productivity of crops, an important role belongs to the introduction of highly productive varieties and hybrids and effective techniques for their growing [12, 13].

2. Problem statement
The study of morphological and biological characteristics of specific varieties and hybrids allows giving scientifically grounded recommendations for their cultivation in the region.

The purpose of the research is to identify the varieties and hybrids of sunflower most adapted to the climatic conditions of Ryazan region with accounts for different levels of mineral nutrition.

Research objectives include:
- carrying out phenological observations;
- determining the influence of nutritional conditions on the basic linear and photosynthetic parameters of sunflower plants;
- assessment of crop structure elements and quantitative indicators of productivity;
- generalization and mathematical processing of the results.

3. Materials and methods
The field experiment was laid in 2017–2019 on dark gray forest loamy soil of the experimental agrotechnological station of the Ryazan State Agrotechnological University in Ryazan district of Ryazan region. Agrochemical properties of the soil are as follows: the average humus content is 3.6–3.8 %, the availability of mobile forms of phosphorus is high (158–162 mg/kg of soil), potassium is increased (123–128 mg/kg of soil) and metabolic acidity is 5.7–5.8.

Objects of research are Russian variety of sunflower Poseidon 625, Hungarian hybrids Nova and Samantha.

The experimental design included the following options: \( \text{N}_{125}, \text{N}_{125}\text{P}_{60}\text{K}_{60} \) and \( \text{N}_{125}\text{P}_{120}\text{K}_{120} \) (predicted dose). Ammonium nitrate, nitrophosphate and superphosphate were used as fertilizers.

The predecessor was spring rape. The agricultural technology of sunflower in the experiment corresponded to recommendations generally accepted for this soil and climatic zone. Autumn plowing was carried out using PPO-7-35 plow. Early spring harrowing and pre-sowing cultivation using KPS-4.2 also took place. Sowing was carried out by the dotted method with SSNT-16 pneumatic seeder to a depth of 4–5 cm. The seeding rate was 45.0 million germinating seeds per 1 ha. The sowing date was the second decade of May. After sowing, the soil was rolled in with ring-spur roller ZKKSh-6. Harvest accounting was carried out manually in early September and mechanized from the entire accounting area of each plot. The area of the experimental plot was 120 m\(^2\), the accounting area was 100 m\(^2\), the plot arrangement was systematic and the replication was fourfold.

4. Results and discussion
The observations showed that a change in the level of mineral nutrition did not significantly affect the timing and duration of the phenological phases of the development of sunflower plants. Seedlings of all studied varieties and hybrids appeared 7–9 days after sowing. The period from seedlings to the beginning of blooming varied slightly and ranged from 49 to 54 days. The period from the beginning of blooming to physiological ripeness lasted 48–60 days. The shortest growing season of 97 days was observed in Poseidon 625 variety. Samantha hybrid was most late ripening and the duration of its growing season was 125 days.

On average, for 2017–2019, sunflower plants of Poseidon 625 variety were shortest (158–172 cm) and those of Samantha hybrid were the highest (183–205 cm). The height of Nova hybrid plants was 169–186 cm. There were no significant differences between the linear parameters of sunflower plants when different levels of mineral nutrition.

Despite the fact that the linear growth of plants is primarily due to a genetic factor, it varies significantly depending on the growing conditions of the crop [14]. So, in 2019, at the beginning of the
growing season, weather conditions were unfavorable for sunflower plants. There was moisture deficit (25–53 % of the norm). This unfavorable factor contributed to the formation of lower plants.

At the beginning of the growing season, the growth rate of the crop leaf apparatus was slow. After the emergence of seedlings about 4.5–5.2 % of the leaf surface was formed during a month. By the phase of the basket formation, the leaf area reached 42–45 % of the maximum one attained in the blooming period. Further, it decreased due to the death of leaves in the lower part of the stem.

On average, over the three years of research, it was found that the use of a high dose of fertilizer N250P120K120 for sunflower was similar to that of a dose of N125P60K60 by the effect on the formation of the leaf surface in the initial growing season. The leaf area of Poseidon 625 variety, Samantha and Nova hybrids in the phase of the basket formation was 11.61–16.53, 10.59–14.28 and 11.02–15.98 thousand m²/ha, respectively. During the flowering phase it was 22.48–25.18, 16.27–18.20 and 19.72–21.45 thousand m²/ha, respectively.

The research results showed that the photosynthetic potential of sunflower crops under the influence of weather conditions and the studied doses of mineral fertilizers changed relative to the assimilation surface area. The maximum photosynthetic potential in the experiments was achieved by Poseidon 625 variety with a dose of N250P120K120 (1,201.7 thousand m² × day/ha) in 2018.

One of the most important indicators of photosynthetic activity of plants is the value of the net productivity of photosynthesis (NPPh) [15]. On average over the years of research, this indicator in crops of Poseidon 625 variety was 4.71 g/m² per day and in crops of Samantha and Nova hybrids it was 4.35 g/m² per day and 4.22 g/m² per day.

The population density of sunflower plants at the beginning of the growing season, on average for 2017–2019, ranged from 43.1–44.7 thousand plants per 1 ha. By the end of the growing season, a decrease in the number of plants by 9.2–14.1 % was observed. At the same time, there was no clear dependence of the influence of the level of mineral nutrition on the safety of sunflower plants by the harvesting period (Table 1).

Mineral fertilizers used in the experiment positively influenced the indicators of the crop structure. On average, the diameter of the basket over the years of research was practically independent on the studied doses of fertilizers (Figure 1).

Table 1. Elements of the yield formula and the yield of sunflower, average for 2017-2019

| Hybrid (factor A) | Fertilizer dose (factor B) | Diameter of baskets, cm | Weight of seeds from the basket, g | Weight of 1000 seeds, g | The number of seeds in the basket, pcs | Yield, t/ha |
|------------------|----------------------------|------------------------|---------------------------------|----------------------|--------------------------------------|------------|
| Poseidon 625     | N125                       | 19.8                   | 61.9                            | 55.0                 | 1123                                 | 2.47       |
|                  | N125P60K60                 | 20.3                   | 80.2                            | 66.8                 | 1201                                 | 3.20       |
|                  | N250P120K120               | 21.8                   | 85.9                            | 67.2                 | 1278                                 | 3.44       |
| Samantha         | N125                       | 18.2                   | 42.8                            | 42.0                 | 1015                                 | 1.70       |
|                  | N125P60K60                 | 19.0                   | 44.0                            | 44.7                 | 1004                                 | 1.76       |
|                  | N250P120K120               | 20.7                   | 44.5                            | 46.1                 | 968                                  | 1.78       |
| Nova             | N125                       | 18.4                   | 42.3                            | 49.0                 | 863                                  | 1.70       |
|                  | N125P60K60                 | 19.6                   | 44.0                            | 51.1                 | 1058                                 | 1.75       |
|                  | N250P120K120               | 20.2                   | 50.5                            | 53.4                 | 946                                  | 2.00       |

LSD<sub>05</sub> AB interactions 2017 – 1.58 t/ha
2018 – 1.02 t/ha
2019 – 1.14 t/ha
The number of seeds formed in one basket, their mass, as well as the mass of 1000 seeds were determined by the level of plants’ supply with nutrients. As a result of the studies, it was found that these indicators were the highest in plants of variety Poseidon 625.

So, the average number of seeds from one basket was 1,194–1,247 pcs. It exceeded Hungarian hybrids Samantha and Nova by 12.2–19.9 and 14.4–25.7 %, respectively. The weight of 1000 seeds of Poseidon 625, on average over three years, ranged from 49.9 to 59.8 g, depending on the dose of mineral fertilizers. The smallest value of this indicator was observed in Samantha hybrid (43.0–47.0 g).

![Figure 1. Sunflower baskets, Fertilizer dose N<sub>125</sub>P<sub>60</sub>K<sub>60</sub>: 1 – Poseidon 625; 2 – Samantha; 3 – Nova](image)

The average for varieties and hybrids weight of 1000 seeds increased from the use of mineral fertilizers in a dose of N<sub>125</sub>P<sub>60</sub>K<sub>60</sub> by 1.9–8.1 g and by 3.8–9.9 g at a calculated dose of N<sub>250</sub>P<sub>120</sub>K<sub>120</sub>. Poseidon 625 was most responsive to the introduction of full mineral nutrition. This indicator increased by 21.5–22.1 % compared with the use of nitrogen fertilizers.

The final effect of all cumulative environmental factors is the yield. The largest crop of Poseidon 625 oilseeds was obtained in 2019 and that of Hungarian hybrids in 2018. On average, Poseidon 625 variety had the highest yield in 2017–2019. It was 2.37–2.99 t/ha and exceeded Samantha and Nova hybrids by 24.0–37.5 and 27.4–33.4 %, respectively.

To establish the mutual dependencies between the accompanying indicators of sunflower yield, for example variety Poseidon 625, correlation lattices were compiled for 2017, 2018 and 2019 (Table 2).

| Indicators                                      | 2017     | 2018     | 2019     |
|------------------------------------------------|----------|----------|----------|
| Maximum leaf area                               | 0.9739   | 0.9977   | 0.9216   |
| Photosynthetic potential                        | 0.1460   | 0.0430   | 0.2540   |
| Net productivity of photosynthesis              | 0.9972   | 0.9968   | 0.9407   |
| Population density before harvest               | 0.0480   | 0.0510   | 0.2200   |
| Diameter of baskets                             | 0.7977   | 0.9518   | 0.9997   |
| The mass of seeds from the basket               | 0.4120   | 0.1990   | 0.0160   |
| Mass of 1000 seeds                              | 0.6156   | 0.9338   | 0.6914   |
| The number of seeds in the basket               | 0.5780   | 0.2330   | 0.5140   |
| Population density before harvest               | 0.8932   | 0.9991   | 0.8447   |
| Diameter of baskets                             | 0.2970   | 0.0270   | 0.3600   |
| The mass of seeds from the basket               | 0.9996   | 1.0000   | 0.9999   |
| Mass of 1000 seeds                              | 0.0170   | 0.0010   | 0.0070   |
| The number of seeds in the basket               | 0.9862   | 0.9944   | 0.9778   |

Table 2. The relationship of the yield of sunflower variety Poseidon 625 with indicators (p)
This is due to the selection of more significant indicators in the management of the production process. For 2017, the dependency lattice shows that from the presented set of variables, a reliable (at \( p \) close to the threshold value of 0.05) positive dependence is manifested between the photosynthetic potential and the mass of seeds from the basket and between the photosynthetic potential and the mass of 1,000 seeds. Taking into account the presence of a positive yield response to the photosynthetic potential (\( p = 0.048 \)) and the mass of seeds from the basket (\( p = 0.017 \)), it can be concluded that agrotechnical measures (in our case, the application of mineral fertilizers) aimed at increasing the photosynthetic potential will increase the sunflower yield.

In 2018, the relationships between the indicators were more diverse than in 2017. Reliable relationships were established between the diameter of the baskets and the maximum leaf area, between the maximum leaf area and the mass of seeds from the basket, between the mass of seeds from the basket and the diameter of the baskets.

Among the biometric indicators of sunflower in 2018, its yield depended on the maximum leaf area (\( p = 0.043 \)), the diameter of baskets (\( p = 0.027 \)) and the weight of seeds from the basket (\( p = 0.01 \)).

Thus, as for variety Poseidon 625, it can be concluded that the mass of seeds from the basket in all years of observation determined the productivity of sunflower. Given that this indicator depends on other biometric indicators (positive, direct relationship), an improvement in the condition of the latter will contribute to an increase in the number of seeds.

5. Conclusion
The right choice of new, most productive varieties and hybrids of sunflower is an important condition for increasing the production of oilseeds in every region characterized by certain environmental conditions.

In 2017–2019, the maximum average photosynthetic indicators and productivity elements of sunflower plants were observed in Poseidon 625 variety, which could be characterized as the most adapted to the natural and climatic conditions of Ryazan region.

The creation of an optimal level of mineral nutrition of plants is important in the system of agricultural activities aimed at increasing the yield of sunflower.

In the studies aimed at studying biological characteristics and a comprehensive assessment of the productivity of new Russian and Hungarian varieties and hybrids when different levels of mineral nutrition, a high responsiveness of sunflower plants to the use of mineral fertilizers was established. On average, over three years, the highest yield of sunflower oilseeds was obtained by adding full mineral nutrition in doses of \( N_{125}P_{60}K_{60} \) and \( N_{250}P_{120}K_{120} \). The yield increase was 0.06–0.45 and 0.07–0.62 t/ha, respectively. Differences in yield data in the variants with the maximum dose of fertilizers and the dose of \( N_{125}P_{60}K_{60} \) were not significant.

Thus, the improvement of the elements of the technology of growing sunflower in the conditions of Ryazan region contributed to obtaining sufficiently high and stable yields of oilseeds.

References
[1] Vinogradov D V, Konkina V S, Kostin Y V, Kruchkov M M, Zaharova O A and Ushakov R N 2018 Developing the regional system of oil crops production management Res. J. of Pharmac., Biolog. and Chem. Sci. 9(5) 1276–1284
[2] Mantzioris E 1994 Dietary substitution with alpha-linolenic acid rich vegetable oil increases eicosapentaenoic acid concentrations in tissues Amer. J. of Clinical Nutrit. 59(6) 1304–1309
[3] Alpaslan M, Tepe S and Simsek O 2008 Effect of refining processes on the total and individual tocopherol content in sunflower oil Int. J. of Food Sci. & Technol. 36(7) 737–739
[4] Zubr J 1997 Oil-seed crop: Camelina sativa Indust. Crops and Products 6(2) 113–119
[5] Vinogradov D V, Vasileva V M, Makarova M P, Kochurov B I and Lupova E I 2019 Agroecological effect of sewage sludge and its mixtures with zeolite on the agrocenoses of oilseeds Theoret. and Appl. Ecol. 3 122–128
[6] Vakula S, Leontiev V, Koren L and Titok V 2009 Ecological variability of oil and protein content in flaxseed VAGOS. ЛŽб MOKSLO DARBAI 82(35) 77–81
[7] Canvin D T 1965 The effect of temperature on the oil content and fatty acid composition of the oils from several oil seed crops Canad. J. of Botany 43(1) 63–69
[8] Mustafaev M G 2007 Influence of salt quantity and type on productivity of agricultural plants in soil of the experimental area in Salyan Energy Ecol. Econ. Int. Congr. (Baku) pp 551–554
[9] Clegg S and Gobran G R 1997 Rhizospheric P and K in forest soil manipulated with ammonium sulfate and water Canad. J. of Soil Sci. 525–533
[10] Liu K and Wiatrak P 2012 Corn production response to tillage and nitrogen application in dryland environment Soil and Tillage Res. 124 138–143
[11] Olness A, Evans S D and Moncrief J F 1995 Maize Grain Yield Response to Tillage and Fertilizer Nitrogen Rates on a Tara Silt Loam J. of Agron. and Crop Sci. 174 273–285
[12] Liu X J, Mosier A R and Halvorson A D 2005 Tillage and nitrogen application effects on nitrous and nitric oxide emissions from irrigated corn fields Plant and Soil 276 235–249
[13] Koch M, Naumann M and Pawelzik E 2008 Cracking and fracture properties of potato (Solanum tuberosum L.) tubers and their relation to dry matter, starch, and mineral distribution J. of the Sci. of Food and Agricult. DOI: 10.1002/jsfa.9530
[14] Vasileva V 2015 Aboveground to root biomass ratios in pea and vetch after treatment with organic fertilizer Global J. of Environmental Sci. and Manag. 1(2) 71–74
[15] Malec P, Maleva M, Prasad M and Strzalka K 2010 Responses of Lemna trisulca L. exposed to low doses cadmium: thiols, metal bonding complexes and photosynthetic pigments as sensitive biomarkers of ecotoxicity Protoplasma 240(1-4) 69–74