# SUNFLOWER PRODUCTIVITY DEPENDING OF THE FERTILIZATION LEVEL ON THE CHERNOZEM LEACHED IN THE CENTRAL AREA OF MOLDOVA

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***Abstract.*** *The evaluation results on the sunflower productivity in long-term experiences cultivated on the leached (cambic) chernozem according to the fertilization level and agrometeorological conditions of the 2011-2019 years are presented. The humus content in the arable layer of chernozem constitutes 3.4%;* $pH_{H_2O}$ = 6.8; *∑(Ca,Mg) = 37.4 meq ·100g* $^{-1}$ *of soil; clayey-loamy texture. Administration of the mineral fertilizers on the natural background on average for 6 years led to the increase of the sunflower yields from 1.49 t·ha*$^{-1}$ *to 2.55 t·ha*$^{-1}$*, the production increase by 18-71%. On the phosphorus levels the crop yield increased from 18% containing 1.5 mg to 52% - 3.0-3.5 mg 100 g*$^{-1}$ *of mobile phosphorus in soil versus the background level* $N_{45}K_{29-30\,mg\,100\,g^{-1}\,of\,soil}$ *On the* $N_{3.5}K_{29-30\,mg\,100\,g^{-1}\,of\,soil}$ *(PK) variant, the increase in yield versus the control variant was 38%. In nitrogen-based versions of PK at doses of 30-90 kg·ha*$^{-1}$ *the increase in sunflower production was 53-70% compared to the control variant (the natural background) and 15-32% relative to PK variant. The optimal soil phosphorus level for leached chernozem in the sunflower cultivation was 3.0-3.5 mg·100 g*$^{-1}$ *of soil (Machigin method), and optimal nitrogen level - 45-60 kg·ha*$^{-1}$*.*

***Key words****: Chernozem leached, Fertilization, Nutrition level, Productivity, Sunflower.*

## INTRODUCTION

Sunflower is the main oil plant grown in the south-eastern part of Europe. In the Republic of Moldova, sunflower covers an area of over 350 thousand ha. Over the last ten years, thanks to new hybrids and performance technologies, the average sunflower seed harvest in Moldova has increased from 1.0-1.6 to 2.1-2.3 tonnes per hectare (AGRICULTURA, 2019). The productivity of agricultural crops largely depends on the weather conditions (precipitations) and soil fertility level. Research has shown that the average multiannual amount of rainfall ensures 2.7 t·ha$^{-1}$ of sunflower seed. From the natural fertility of the soil the 1.4 t·ha$^{-1}$ of sunflower seeds can be obtained (ANDRIEȘ, 2007; LEAH, 2018; ЛУНЕВА *et al.*,1986; LEAH & LEAH, 2012). The unvalued quantity of seed production in the humidity conditions of Moldova is 1.3 t·ha$^{-1}$. This quantity of sunflower seed production can be returned by applying mineral fertilizers and improving their use doses.

Sunflower culture reacts positively to fertilization, it has been established that the rational use of fertilizers ensures a harvest increase by 25-40 percent. The application of fertilizers on the chernozems leached (cambic) contributed to the increase of the crop with 0.67-0.74 t·ha$^{-1}$ of sunflower seeds compared to the non-fertilized variant (control). Increasing the content of mobile phosphorus in soil from 1.0 mg to 3.0-3.5 mg ·100 g$^{-1}$ on the background (fund) of $N_{60}K_{60}$ resulted in the harvest increase by 38-41% (ANDRIEȘ, 2007; LEAH *et al.*, 2010; LUNGU *et al.*, 2013).

The chernozems of Moldova are relatively rich in humus, the weighted average content constituting 3.1%. In the process of organic matter mineralization in the soil, annually, about of 74 kg·ha$^{-1}$ of nitrogen is produced, which is not enough to obtain profitable productions of sunflower seed. According to the phosphorus content the soils of Moldova are poor. According to the results of the last agrochemical mapping cycle of soils about 60% of the investigated area have a degree of assurance under the optimum content of mobile phosphorus in the soils. Up to 90% of the soils are relatively optimally insured with potassium accessible to plants. The main reserve of accessible potassium has a changeable form, which is largely restored by disaggregating potassium minerals from the soil (ANDRIEȘ S., 2011; BURLACU, 2000; TOMA, 2008; PROGRAM, 2004; LEAH, *et al*., 2019).

From the nutritive regimes of the Moldovan soils, in the first minimum are nitrogen and phosphorus. In order to improve the fertilization system of the leached (cambic) chernozem from the Central area, the productivity and quality of the sunflower seed were evaluated according to the fertilization level and agrometeorological conditions of the 2011-2019 years.

## MATERIAL AND METHODS

The field research was carried out on the long-term Experimental Station "Ivancea" (Orhei rayon) of the Institute of Pedology, Agrochemistry and Soil Protection "Nicolae Dimo", founded in 1964 on the clayey-loamy leached chernozem. The humus content in the arable layer of soil constitutes 3.4%; $p\mathrm{H}_{\mathrm{H_2O}}$=6.8; ∑(Ca, Mg) = 37.4 mg·100g$^{-1}$ of soil. Since 2000 year the station has been registered in the European network EUROSOMNET. In the crop rotation was cultivated: winter wheat, corn for grains, sunflower, winter barley, rapeseed and legumes (alfalfa, peas, beans, soy). The preceding culture for sunflower, from six years, for four years was winter wheat, and in 2013 and 2019 years - maize for grains. The experiments were performed in four repetitions. Surface of the experimental plot was 200 m$^2$ (ANDRIES, *et al.,* 2014).

The investigations were undertaken on the following levels of mineral nutrition: mobile phosphorus ($P_2O_5$) in soil was 1.0-1.2 mg·100g$^{-1}$ (natural background); 1.5; 2.0; 2.5; 3.0; 3.5; 4.0 and 4.5 mg·100g$^{-1}$; exchangeable potassium ($K_2O$) in soil was 29-32 mg·100g$^{-1}$ (natural background). The content of the phosphorus and potassium in the soil was determined by the Machigin method (extracted in 1% ammonium carbonate solution in a ratio of 1:20, pH=9). According to the classification of soils regarding the degree of insurance with mobile phosphorus and exchangeable potassium in the Republic of Moldova, the scale has 6 degrees, from less - than 1 mg to more - than 7 mg·100 g$^{-1}$ of soil for mobile phosphorus and from less - than 5 mg up to more - than 40 mg·100g$^{-1}$ of exchangeable potassium in soil (RECOMANDĂRI, 2012; ANDRIEȘ *et.al.*, 2008).

The levels of mobile phosphorus in the soil were maintained by export compensation of phosphorus from the preceding culture with the application of phosphorus fertilizers at the soil basic tillage. Potassium fertilizers in experiments since 2010 and so far do not applied. Nitrogen (N) doses were applied annually 0, 30, 45, 60, 75 and 90 kg·ha$^{-1}$ in active substance. The oil content in sunflower seeds was determined by the Soxhlet method. The seed sample was repeatedly degreased with ethyl ether solvent, then dried in an oven at temperature 105 °C and then was weighed.

## RESULTS AND DISCUSSIONS

The amount of rainfall, as well as their distribution during the vegetation period of the plants, conditioned the sunflower productivity. During the agricultural investigation years, the agrometeorological conditions were different. From six years of research at "Ivancea" Station two years have been relatively dry (2012 and 2015), with a humidity deficit of 17-21% compared to the multiannual average, less drought was the year 2019. Nearly the norm was the year 2011 with 563 mm, making up 102%, over the norm or so-called "wet years" were - 2013 and 2017, respectively 115% and 108%. The average of atmospheric deposition over 6 years was 19 mm, lower than the multiannual average, constituting 533 mm.

Precipitation during the cold period of the year (September-March) created favourable humidity conditions at the early spring, which at the first stage of sunflower development ensured the normal growth and development of the plants. The amount of precipitation in the cold period at the station in four years was close to the norm, constituting 92-114% compared to the multiannual average, except for 2012 with the precipitation amount of only 60% and 2015 - 127% above the norm (Table 1).

A decisive role regarding the level of yield crops has the quantity as well as the distribution of the precipitates during the vegetation of sunflower. Atmospheric deposition for the active period of sunflower development (April-August) in six years of research decreased on average by 4% compared to the multiannual average, and in 2015 they were 55% less, constituting 134 mm. The drought effect was most pronounced in June, July and August, where the monthly precipitation decreased from 39% to 75% compared to the multiannual average, and air temperatures exceeded the norm by 2.0 - 3.9$^0$C (Table 1).

*Table 1*

The atmospheric deposition at the "Ivancea" station in 2011-2019 years

| Year | Month IX-III | | IV | | V | | VI | | VII | | VIII | | IV-VIII | | Agricultural year* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | % | mm | % | mm | % | mm | % | mm | % | mm | % | mm | % | mm | % |
| 2011 | 245 | 95 | 49 | 117 | 26 | 49 | 195 | 247 | 31 | 51 | 17 | 28 | 318 | 108 | 563 | 102 |
| 2012 | 153 | 60 | 38 | 90 | 114 | 215 | 48 | 61 | 59 | 97 | 22 | 37 | 281 | 95 | 434 | 79 |
| 2013 | 293 | 114 | 20 | 47 | 64 | 121 | 84 | 106 | 126 | 206 | 46 | 77 | 340 | 115 | 633 | 115 |
| 2015 | 325 | 127 | 39 | 93 | 10 | 19 | 33 | 42 | 37 | 61 | 15 | 25 | 134 | 45 | 459 | 83 |
| 2017 | 251 | 97 | 99 | 236 | 46 | 87 | 60 | 76 | 91 | 149 | 49 | 82 | 345 | 117 | 596 | 108 |
| 2019 | 237 | 92 | 37 | 88 | 78 | 147 | 90 | 114 | 36 | 59 | 35 | 58 | 276 | 93 | 513 | 93 |
| Average for 6 years | 251 | 97 | 47 | 112 | 56 | 106 | 85 | 108 | 63 | 104 | 31 | 51 | 282 | 96 | 533 | 96 |
| Average multi-annual | 257 | 100 | 42 | 100 | 53 | 100 | 79 | 100 | 61 | 100 | 60 | 100 | 295 | 100 | 552 | 100 |

**Note. The period of the agricultural years is considered 01.09.2010 - 31.08.2019*

Periodic droughts during sunflower vegetation have reduced seed production. Fertilizers diminished the effects of drought, they positively influenced the growth and development of plants. Their application led to the improvement of the soil nutritive regime, consequently to the increase of the sunflower seed production compared to the unfertilized version. The sunflower production increased on average, from 1.49 t·ha$^{-1}$ on the control variant (natural fund) to 2.55 t·ha$^{-1}$ on the fertilized variants (Table 2).

The increase in seed harvest for fertilized variants increased by 18.4-71.1% compared to the natural fund. On phosphorus fertilization levels, production increased from 18.5% against the background of 1.5 mg mobile phosphorus, to 50.7-52.1%, 3.0-3.5 mg·100g$^{-1}$ of soil compared to the $N_{45}K_{29-32}$ background. In the variant with the fund of $P_{3.5}K_{29-32}$ the increase in harvest compared to the control constituted 38.2%. For nitrogen variants in doses of 30-90 kg·ha$^{-1}$ against the background $P_{3.0}K_{29-32}$ (PK) the seed production increase was 0.79 - 1.05 t·ha$^{-1}$ or 53.0-70.5% compared to the control variant and 14.8-32.3% compared to PK background.

In the drought years, fertilizers have contributed significantly to the formation of sunflower crops. Although, the global harvest decreased in these years, the productivity compared to the unfertilized variant in 2012 increased by 11-60%, and in 2015 it doubled (from 0.85 t·ha$^{-1}$ to 1.7-1, 85 t·ha$^{-1}$). The role of phosphorus fertilizers in the drought years was decisive in formation of the sunflower production. The optimum level of mobile phosphorus in the arable layer of the leached chernozem was 3.5 mg·100g$^{-1}$, and in the wet years the optimum level of phosphorus decreased to 3.0 mg·100g$^{-1}$. The nitrogen fertilizer was quite revealing in the formation of sunflower yields, during these two years the seed production increase constituted 4-26% (Table 2).

*Table 2*

The sunflower yield obtained on the chernozem leached according to the level of fertilization, t · ha$^{-1}$

| Variant* | | Year of cultivation | | | | | | Average yield, t·ha$^{-1}$ | Yield increase, % |
|---|---|---|---|---|---|---|---|---|---|
| Nitrogen, kg ·ha$^{-1}$ | $P_2O_5$ mg ·100g$^{-1}$ | 2011 | 2012 | 2013 | 2015 | 2017 | 2019 | | |
| Control | 1.0 | 1.90 | 1.42 | 1.93 | 0.85 | 1.31 | 1.52 | 1.49 | - |
| 45 | 1.0 | 2.21 | 1.57 | 2.21 | 1.43 | 1.45 | 2.14 | 1.84 | 18.4 |
| 45 | 1.5 | 2.30 | 1.65 | 2.36 | 1.49 | 1.77 | 2.68 | 2.04 | 36.9 |
| 45 | 2.0 | 2.36 | 1.71 | 2.79 | 1.56 | 2.20 | 2.86 | 2.25 | 51.0 |
| 45 | 2.5 | 2.40 | 1.90 | 3.14 | 1.69 | 2.55 | 2.86 | 2.42 | 62.4 |
| 45 | 3.0 | 2.50 | 2.15 | 3.21 | 1.71 | 2.60 | 2.92 | 2.52 | 69.1 |
| 45 | 3.5 | 2.54 | 2.27 | 3.19 | 1.78 | 2.59 | 2.89 | 2.54 | 70.5 |
| 45 | 4.0 | 2.57 | 2.13 | 3.18 | 1.83 | 2.51 | 2.88 | 2.52 | 69.1 |
| 45 | 4.5 | 2.51 | 2.23 | 3.21 | 1.85 | 2.53 | 2.96 | 2.55 | 71.1 |
| 0 | 3.5 | 2.32 | 1.78 | 2.64 | 1.64 | 1.89 | 2.11 | 2.06 | 38.2 |
| 30 | 3.5 | 2.40 | 1.90 | 3.00 | 1.70 | 2.22 | 2.48 | 2.28 | 53.0 |
| 45 | 3.5 | 2.49 | 2.25 | 3.21 | 1.72 | 2.50 | 2.90 | 2.51 | 68.4 |
| 60 | 3.5 | 2.55 | 2.22 | 3.26 | 1.81 | 2.49 | 2.89 | 2.54 | 70.5 |
| 75 | 3.5 | 2.50 | 2.17 | 3.27 | 1.82 | 2.57 | 2.80 | 2.52 | 69.1 |
| 90 | 3.5 | 2.34 | 2.20 | 3.22 | 1.84 | 2.49 | 2.73 | 2.47 | 65.8 |

**Note. The exchangeable potassium content in the soil is 29-32 mg ·100g$^{-1}$ of soil*

The application of fertilizers into the leached chernozem slightly influenced the synthesis of oil formation in sunflower seeds (LEAH & LEAH, 2018). Seed oil content in the research years ranged from 38.2% to 55.4%, the five-year average was 45.9-47.9%. In the control variant, the oil quantity was 0.2-2.0% higher than on the fertilized variants, the average constituting 0.7% (Table 3).

*Table 3*

The oil content of sunflower seeds cultured on the leached chernozem, %

| Variant | Year of cultivation | | | | | | Average, % |
|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2015 | 2017 | 2019 | |
| Control | 48.0 | 50.5 | 43.6 | 48.6 | 45.5 | 51.6 | 47.9 |
| $N_{45}P_{1.0}K$* | 46.5 | 50.8 | 39,8 | 47.3 | 46.7 | 52.0 | 47.2 |
| $N_{45}P_{1.5}K$ | 46.0 | 50.2 | 42.7 | 49.6 | 45.5 | 53.8 | 47.9 |
| $N_{45}P_{2.5}K$ | 46.8 | 49.3 | 39.2 | 48.1 | 45.8 | 55.1 | 47.4 |
| $N_{45}P_{3.5}K$ | 47.6 | 48.3 | 40.4 | 48.6 | 46.2 | 55.4 | 47.7 |
| $N_{45}P_{4.5}K$ | 46.5 | 50.0 | 41.7 | 47.9 | 47.2 | 54.3 | 47.9 |
| $P_{3.5}K$ | 45.5 | 48.3 | 38.2 | 46.2 | 47.2 | 50.0 | 45.9 |
| $N_{45}P_{3.5}K$ | 48.7 | 46.9 | 42.8 | 47.8 | 45.7 | 55.0 | 47.8 |
| $N_{60}P_{3.5}K$ | 46.1 | 49.4 | 39.1 | 45.2 | 46.9 | 53.0 | 46.6 |
| $N_{75}P_{3.5}K$ | 46.0 | 50.8 | 40.1 | 46.3 | 45.2 | 52.0 | 46.7 |
| $N_{90}P_{3.5}K$ | 45.9 | 51.1 | 41.1 | 46.4 | 45.5 | 52.0 | 47.0 |

**K – background, the exchangeable potassium content in the soil is 29-32 mg ·100g$^{-1}$*

In the fertilized and higher-yielding variants, the seed oil content did not increase. When forming the sunflower seed production, the so-called "dilution effect" was produced. The quantity of oil obtained from a surface unit is a comprehensive indicator for crop productivity evaluation. This indicator gives the possibility to determine the agronomic efficiency or fertilizer efficiency in order to obtain the sunflower seed production. The administration of mineral fertilizers in some years of research practically doubled the content of oil obtained at 1 ha compared to the natural fund (Table 4).

*Table 4*

The quantity of sunflower oil obtained according to the level of fertilization, kg·ha$^{-1}$

| Variant | Year of cultivation | | | | | | Average, kg·ha$^{-1}$ | Yield increase, % |
|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2015 | 2017 | 2019 | | |
| Control | 912 | 717 | 841 | 413 | 596 | 784 | 710 | - |
| $N_{45}P_{1.0}K$* | 1027 | 797 | 879 | 676 | 677 | 1113 | 861 | 21.0 |
| $N_{45}P_{1.5}K$ | 1058 | 828 | 1008 | 739 | 805 | 1442 | 980 | 38.0 |
| $N_{45}P_{2.5}K$ | 1123 | 937 | 1231 | 813 | 805 | 1576 | 1081 | 52.3 |
| $N_{45}P_{3.5}K$ | 1209 | 1096 | 1289 | 865 | 1196 | 1601 | 1209 | 70.3 |
| $N_{45}P_{4.5}K$ | 1167 | 1115 | 1338 | 886 | 1194 | 1607 | 1218 | 71.5 |
| $P_{3.5}K$ | 1055 | 860 | 1008 | 757 | 892 | 1055 | 938 | 32.1 |
| $N_{45}P_{3.5}K$ | 1212 | 1055 | 1374 | 822 | 1142 | 1595 | 1200 | 69.0 |
| $N_{60}P_{3.5}K$ | 1175 | 1097 | 1275 | 818 | 1168 | 1532 | 1177 | 65.8 |
| $N_{75}P_{3.5}K$ | 1150 | 1102 | 1311 | 842 | 1161 | 1456 | 1170 | 64.8 |
| $N_{90}P_{3.5}K$ | 1074 | 1124 | 1323 | 854 | 1133 | 1420 | 1154 | 62.5 |

**K – background, the exchangeable potassium content in the soil is 29-32 mg ·100g$^{-1}$*

On average, during research years, the levels of phosphorus fertilization increased from 710 kg to 1218 kg·ha$^{-1}$. The role of nitrogen fertilizers was very significant. The application of nitrogen fertilizers in doses of 30-45 kg·ha$^{-1}$ on the PK background has led to an increase in the amount of oil from 938 kg to 1200 kg·ha$^{-1}$. Increasing nitrogen doses from 60 kg to 90 kg·ha$^{-1}$ did not lead to an increase in oil seed production per hectare (Table 4).

The yield of oil production in sunflower cultivation from the application of mineral fertilizers increased from 21.0 to 71.5% compared to the control variant. On phosphorus levels ($N_{45}P_{1.0}K_{29\text{-}32}$) the yield increased according to the level, from 21.0% to 50.5%. When applying nitrogen fertilizers in doses of 30-90 kg·ha$^{-1}$ against the background of $P_{3.5}K_{29\text{-}32}$, the oil yield decreased compared to the administered doses and constituted 36.9-30.4%. The maximum yield of sunflower oil production was obtained on the variant $N_{45}P_{3.5}K_{29\text{-}32}$.

Production efficiency (output) of sunflower oil production from the application of mineral fertilizers increased from 21.0% to 71.5% compared to the control variant. On the phosphorus levels ($N_{45}P_{1.0}K_{29\text{-}32}$) the yield increased according to the level, from 21.0% to 50.5%. When applying nitrogen fertilizers in doses of 30-90 kg·ha$^{-1}$ against the background of $P_{3,5}K_{29\text{-}32}$, the oil yield decreased compared to the administered doses and constituted 36.9-30.4%. The maximum yield of oil production was obtained on the variant $N_{45}P_{3.5}K_{29\text{-}32}$.

## CONCLUSIONS

The application of mineral fertilizers on the natural background (fund) of the leached chernozem led to the increase of sunflower seed production from 1.49 kg·ha$^{-1}$ to 2.55 kg·ha$^{-1}$, obtaining an increase of 18-71%.

Fertilization levels with phosphorus from 1.5 mg to 4.5 mg · 100 g$^{-1}$ of mobile phosphorus led to an increase in sunflower harvest by 18-52%, the levels with nitrogen fertilizers in doses of 30-60 kg·ha$^{-1}$ on the optimal background $P_{3,5}K_{29\text{-}32\ mg/100g\ sol}$ - 15-32% of seed increase.

Production efficiency (output) of sunflower oil production on phosphorus levels increased as a function of mobile phosphorus content in the soil. The application of nitrogen fertilizers in doses higher than 60 kg·ha$^{-1}$ on the background of $P_{3,5}K_{29\text{-}32}$ led to the decrease of the yield production. The maximum yield of oil production was obtained on the variant $N_{45}P_{3.5}K_{29\text{-}32\ mg/100}$.

It has been established that for obtaining the 2.5-3.0 kg·ha$^{-1}$ of sunflower seeds production on leached chernozem, the optimum level of mobile phosphorus in soil is 3.0-3.5 mg ·100 g$^{-1}$ of soil (Machigin method) and optimal doses of nitrogen are 45-60 kg·ha$^{-1}$.

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