Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 24, Issue 2, 2024
PRINT ISSN 2284-7995, E-ISSN 2285-3952

PROFITABILITY OF SUNFLOWER CULTURE ON A CAMBIC CHERNOZEM IN WESTERN ROMANIA

Adalbert OKROS[1*], Casiana MIHUȚ[1*], Alexandru RINOVETZ[1], Sorin CIULCA[1***], Alexander DEGIANSKI[2]**

[1]University of Life Sciences "King Mihai I" from Timișoara, Romania *Faculty of Agriculture, [**]Faculty of Food Engineering, [***]Faculty of Engineering and Applied Technologies, Timisoara, Romania, E-mails: adalbertokros@usvt.ro, casiana_mihut@usvt.ro, alexandruriovetz@usvt.ro, sorinciulca@usvt.ro
[2]Forest and Biomass Holding SA Company, Romania, 12, Ciprian Porumbescu Street, Timișoara 300236, Romania, Phone: +40256277001, Fax:+40256200296, E-mail: adegianski@yahoo.com

Corresponding author: casiana_mihut@usvt.ro, alexandruriovetz@usvt.ro

Abstract

The aim of this study consists in the optimization of some technological links of major importance for the sunflower culture to develop some technological recommendations, which allow obtaining high and efficient productions. The research was carried out over a period of 3 years, on a cambic chernozem. The methods refer to the effect of some technological factors on sunflower production and some of its morphological components in the pedoclimatic conditions of the outskirts of Timișoara, Romania. The effects of some technological factors on production were studied and analysed, obtaining useful information to optimize the technology of some hybrids in soil and climate conditions like those in Timișoara. Results showed that the 59,524 g.g./ha variant ($N_{50}P_{50}K_{50}$, scarification+ploughing) produced the most – 2,612 kg/ha in 2022 and 3,417 kg/ha in 2020. Also, the $N_{50}P_{50}K50$ variant at 24 cm per row ranked in the best 5 variants, recording productions of 2,507-3,145 kg/ha. The analysis of the economic efficiency of the production in different technological variants allows an adequate management of the costs to maximize the profit in accordance with market requirements. The researches related to this study fall under the concerns of obtaining useful information that will allow the achievement of superior, high-quality, and sustainable productions under the conditions of current climate changes.

Key words**:** *economic efficiency, cambic chernozem, density, fertilization, sunflower culture*

INTRODUCTION

Sunflower, originally from North America, is widespread in culture due to its adaptability to different soil and climate conditions. Sunflower seeds are an important source of nutrients, minerals, antioxidants, and vitamins, showing anti-oxidant, anti-microbial, anti-diabetic, anti-inflammatory, and wound healing effects [11, 16, 20, 22, 28, 29, 31].
Sunflower is also an important honey plant in the northern hemisphere [6], providing bees with both nectar and pollen [26]. In the climate conditions of Romania, in favourable years, even 100 kg of honey/ha can be produced. The reproductive system based on self-incompatibility and pollen structure prevents anemophilic pollination in sunflower. In the absence of pollinators, the percentage of seed formation is only 10-20% while, under the effect of pollination by insects, it increases up to 90%, producing high yields of seeds and oil [7, 30, 33, 36].
The sunflower inflorescence has a special aesthetic and ornamental value, presenting various sizes and colours, and there are numerous cultivars for this purpose [1].
Sunflower has a high allelopathic potential inhibiting the growth of many weed species [2, 15, 34]. The phytotoxic activity on weeds is due to some compounds called helianols – A, D, and E [16]. It also has a high phytoremediation potential, being one of the most studied plants in this sense [12; 20; 25; 27]. Numerous studies have shown that sunflower can contain, degrade, or eliminate heavy metals [3, 13, 14], polycyclic aromatic hydrocarbons [10], and polychlorinated biphenyls [9] from soil and water. Studies have shown that heavy metals such as lead, copper, zinc, cadmium, and cobalt accumulate

in high concentrations both in stems and roots, while in seeds the accumulation is much lower. As such, it can be used effectively and simultaneously for the phytoremediation of contaminated soils and as a renewable source of energy [17, 18, 20, 22, 32, 35].

Sunflower is considered a drought tolerant species and, as such, an opportunity for cultivation in regions where soil water resources are limited [10, 19, 21, 36, 38]. Due to temperature requirements, sunflower cultivation is currently limited to southern Europe and in parts of central and eastern Europe. In the conditions of the global temperature increase, the expansion of the culture towards the northern areas is also probable [23, 37]. Currently, it is extended in culture up to 62°N, in areas with a favourable climate in southern Finland; but, in the future, because of climate change, some very early hybrids could be cultivated up to 65°N [22, 23, 24].

With the current climate changes and their maintenance, it is estimated that, in 2030, the production of sunflower in Eastern European countries such as Romania, Hungary, and Bulgaria will decrease by 10-30% because of the increase in temperature, evapotranspiration, and the decreasing level of precipitations [5, 8, 34]. Sunflower is a much more environmentally friendly crop [5, 6], considering the greenhouse gas emissions which are 900 kg CO_2/ha, compared to rapeseed (2,700 kg CO_2/ha), wheat (2,800 kg CO_2/ha), maize (3,300 kg CO_2/ha), sugar beet (2,700 kg CO_2/ha).

The production per plant can be increased through selection of the cultivated genotypes or through technological measures that increase the height of the plants, the diameter of the calathidium, and the number of seeds, considering the high heritability of these production components [5, 39]. The production is affected by various foliar, stem, or calathidium diseases, which can reduce the harvest level by 20-50%. The greatest losses occur when infections occur before flowering [18] while, on the background of a late sowing, the infections are moderate [19].

In this context, the aim of this research is the optimization of some technological aspects in sunflower culture in order to establish some technological recommendations, which could result in high and efficient productions.

MATERIALS AND METHODS

A series of information from literature is systematized regarding the nutritional and therapeutic value of sunflower culture, respectively the effect of ecological and technological factors on production.

The particularities of the sunflower culture in the current context of climate change are also analysed.

The production potential of the NK Neoma hybrids was realized based on a trifactorial experiment of the 4 x 3 x 3 type, organized in three repetitions, with plots of 42 m^2 with six rows of 10 m, with density as the primary factor, with fertilization as the secondary factor, and with soil works as the tertiary factor.

Table 1. Characteristics of the trifactorial experiment

D. Density	F. Fertilisation	T. Soil Works
D_1 – 49.261g.g./ha, 70x29 cm D_2 – 53.908g.g./ha, 70x26.5 cm D_3 – 59.524g.g./ha, 70x24 cm D_4 – 66.756g.g./ha, 70x21.4 cm	F_1 – $N_0P_0K_0$ F_2 – $N_{50}P_{50}K_0$ F_3 – $N_{50}P_{50}K_{50}$	T_1 – Ploughing T_2 – Scarification T_3 – Scarification+Ploughing

Source: Own experiment.

The research took place in Timișoara during 2020-2022, on a moderately glazed, weakly decarbonated, loam-clayey cambic chernozem.

The soil has the following physico-chemical properties: humus 2.97%; nitrogen index 2.98; phosphorus 51 ppm; potassium 148 ppm; total porosity 53.55%; and aeration porosity 21.84%.

On each plot (replica), 10 plants were chosen and the following measurements were made: calathidium diameter (cm); the number of seeds in the calathidium; and the weight of the seeds in the calathidium (g). Based on the values obtained, descriptive statistical indices related to the different technological factors were calculated: arithmetic mean, error of the mean, and coefficient of variation.

To determine the significance of the differences between the different

combinations of technological factors, the data were processed statistically, through variance analysis and the t-test for bifactorial analyses organized in subdivided plots. The presentation of the meaning of the differences was done both by symbols (*; ^{0}) and by letters, considering the differences between the variants associated with different letters to be significant [4, 38].

The evaluation of the production and some of its morphological components in different technological variants was carried out by means of some parameters according to the linear regression analysis according to the Eberhart-Russell mathematical model [7]:

$$F_{ij} = \mu + g_i + b_i t_j + \delta_{ij} + e_{ij} \quad \text{.....(1)}$$

where:

F_{ij} – average of variant *i* in year j; μ – general average: g_i – the effect of variants *i*; t_j – the effect (index) of year *j*; b_i – linear regression coefficient between F_{ij} and t_j; δ_{ij} – F_{ij} deviations from the regression line; e_{ijk} – the error associated with variant *i* in year *j*.

- The regression coefficient b_i which indicates the value by which the average of a technological variant changes when the average of a certain year increases or decreases by one unit. For option *i* the regression coefficient is:

$$b_i = \sum F_{ij} t_j / \sum t_j^2 \quad \text{.....(2)}$$

- Variance of regression deviations:

$$s_\delta^2 = \frac{1}{n-2}\left[\left(\sum F_{ij}^2 - \frac{\left(\sum F_{ij}\right)^2}{n}\right) - \frac{\left(\sum F_{ij} t_j\right)^2}{\sum t_j^2}\right] - \frac{\sigma_E^2}{r}$$

.....(3)

where:

n – number of years; *r* – number of repetitions; σ_E^2 - error variance.

RESULTS AND DISCUSSIONS

Influence of some technological links on sunflower production in 2020

The technological links were established according to the type of soil, considering its texture. In this way, the three methods of tillage were established, respectively: ploughing, Scarification and Scarification + ploughing.

In 2020, as regards the combined effect of the three technological links (Table 2), it was found that only in the case of the density of 59,524 g.g./ha, soil works had a significant influence on production while, at the density of 49,261 g.g./ha, the effect was considerably lower. On the background of the density of 49,261 g.g./ha, it can be observed that fertilization with $N_{50}P_{50}K_0$ determined significant increases in production between 574 kg in the case of land preparation by Scarification and ploughing, respectively 983 kg/ha in the case of unilateral application of Scarification. Also, the $N_{50}P_{50}K_{50}$ variant had an important and significant effect on production, related to increases from 574 kg/ha for the association of Scarification with ploughing, up to 834 kg for the use of Scarification. Additional fertilization with potassium had small and insignificant effects on production.

Table 2. Influence of some technological links on sunflower production in 2020 (Density, in germinating grains/ha)

Density 49,261 g,g,/ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	1,714 b	1,615 b	1,816 b
$N_{50}P_{50}K_0$	2,476 a	2,598 a	2,390 a
$N_{50}P_{50}K_{50}$	2,393 a	2,449 a	2,420 a
Density 53,908 g,g,/ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	1,903 b	1,687 b	1,965 b
$N_{50}P_{50}K_0$	2,593 a	2,659 a	2,620 a
$N_{50}P_{50}K_{50}$	2,612 a	2,609 a	2,736 a
Density 59,524 g,g,/ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	x 2,228 b	xy 1,990 b	y 1,853 b
$N_{50}P_{50}K_0$	x 3,067 a	x 2,972 a	x 3,215 a
$N_{50}P_{50}K_{50}$	xy 3,145 a	y 3,012 a	x 3,417 a
Density 66,756 g,g,/ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	2,332 b	2,058 b	2,148 b
$N_{50}P_{50}K_0$	3,008 a	3,077 a	3,163 a
$N_{50}P_{50}K_{50}$	3,107 a	3,104 a	2,996 a

$DL_{5\%}$ =277 kg/ha $DL_{1\%}$=368 kg/ha $DL_{0.1\%}$=428 kg/ha (a.b). Soil works - $DL_{5\%}$=280 kg/ha $DL_{1\%}$=374 kg/ha $DL_{0.1\%}$=488 kg/ha (x. y). $DL_{5\%}$=290 kg/ha $DL_{1\%}$=385 kg/ha $DL_{0.1\%}$=500 kg/ha

Source: Own calculation.

In the case of a density of 53,908 g.g./ha, regardless of the method of soil preparation,

fertilization with nitrogen and phosphorus allowed obtaining significant increases in production, between 655 and 972 kg/ha. Against the background of NPK fertilization, production increases were 709-922 kg compared to the unfertilized version, associated with small and insignificant variations compared to NP-based fertilization.

At a density of 59,524 g.g./ha, on non-fertilized agricultural land, the preparation of the soil by ploughing allowed a significant increase in production by 375 kg/ha, while the $N_{50}P_{50}K_{50}$ variant, along with the combined application of ploughing and scarification, resulted in obtaining a significant increase in production of 405 kg compared to simple scarification. Regardless of the land preparation method, fertilization had a significant effect on production, associated with increases between 839-917 kg/ha in the case of ploughed soil and, respectively, 1,362-1,564 kg/ha for the combined option of scarification and ploughing.

At a density of 66,756 g.g./ha and fertilization with $N_{50}P_{50}K_{0}$, significant increases in production were obtained between 676 kg/ha in the case of land preparation by ploughing and, respectively, 1,015-1,019 kg/ha in the case of the other soil works. Also, the $N_{50}P_{50}K_{50}$ variant had an important and significant effect on production, from 775 kg/ha when ploughing, up to 1,046 kg/ha for combining scarification with ploughing. Meanwhile, additional fertilization with potassium had low and insignificant effects on production.

Influence of some technological links on sunflower production in 2021

In the year 2021, as seen from the data presented in Table 3, plant density, fertilization, and tillage had a real, distinctly significant influence on sunflower production, given the homogeneity of environmental conditions at the level of experience.

Fertilization resulted in a significantly higher increase of the production (77.69%), compared to the influence registered by density (4.30%) and, respectively, by soil works (3.34%). Likewise, single, or double interactions between the factors showed significant influences on production, with close, but considerably smaller, contributions than their separate effects.

Table 3. The influence of the variant on some technological links in the sunflower crop in 2021

Variation source	SP	GL	S^2	F test
Total	1,870,2297	107		
Replicas	50,198	2	25,099	0.98
Density	888,530	3	296,177	11.53**
Density error	154,064	6	25,677	
Fertilisation	13,445,581	2	6,722,791	208.59**
Density x Fertilisation	678,656	6	113,109	3.51*
Fertilisation error	515,673	16	32,230	
Soil work	412,380	2	206,190	8.96**
Density x Soil work	493,710	6	82,285	3.58**
Fertilisation x Soil work	365,596	4	91,399	3.97**
Density x Fertilisation x Soil work	593,231	12	49,436	2.15*
Work error	1,104,678	48	23,014	

Source: Own calculation.

Production results at the level of experience were influenced, to a degree of about 9.76%, by other sources of variation, uncontrollable by the experimental device.

Average production values under the effect of different densities (Table 4) show an amplitude of 232 kg, with limits from 2,016 kg/ha for a density of 49,261 g.g./ha to 2,248 kg/ha for the density of 66.756 g.g./ ha, against the background of low variability (4.95%). Changing the crop density by reducing the area of a plant from 0.203 to 0.186 m^2 determined a significant increase in production of 6.60% equivalent to 133 kg/ha; in exchange, the intensification of the crop by reducing the distance between plants from 29 to 24 cm had a high efficiency being associated with an increase in production of 11.51%.

Increasing the crop density by reducing the distance between plants from 24 to 21.4 cm had a negative effect on production, causing a significant decrease of 198 kg/ha.

Table 4. Effect of density on sunflower production in 2021

53,908 – 49,261	2,149	2,016	106.60	133*
59,524 – 49,261	2,248	2,016	111.51	232**
66,756 – 49,261	2,050	2,016	101.69	34
59,524 – 53,908	2,248	2,149	104.61	99
66,756 – 53,908	2,050	2,149	95.39	-99
66,756 – 59,524	2,050	2,248	91.19	-198^{00}

Source: Own calculation.

Considering the cumulative effect of fertilization (Table 5), average production values were found with limits from 1,653

kg/ha in the unfertilized variant to 2,508 kg/ha in the case of the $N_{50}P_{50}K_{50}$ variant.

Table 5. Effect of fertilization on sunflower production in 2021

Fertilisation	Means (kg/ha)		Relative values (%)	Difference/Significance
$N_{50}P_{50}K_0 - N_0P_0K_0$	2,186	1,653	132.24	533***
$N_{50}P_{50}K_{50} - N_0P_0K_0$	2,508	1,653	151.72	855***
$N_{50}P_{50}K_{50} - N_{50}P_{50}K_0$	2,508	2,186	114.73	322***

$DL_{5\%}$=90 kg/ha $DL_{1\%}$=124 kg/ha $DL_{0.1\%}$=170 kg/ha
Source: Own calculation.

In general, fertilization with nitrogen and phosphorus determined a very significant increase in production by 533 kg/ha, equivalent to an increase of about 32%. Also, NPK-based fertilization positively influenced production, generating an increase of about 52%, respectively, 855 kg/ha. Additional fertilization with potassium allowed an increase in production of about 15%, equivalent to 322 kg/ha.
Regarding the unilateral effect of tillage (Table 6), the production in 2021 showed an amplitude of variation of 150 kg/ha, with average values between 2,047 kg/ha in the case of ploughing and 2,197 kg/ha in the case of scarification, under the conditions of a reduced variability of 3.58% between the three basic works.

Table 6. Effect of tillage on sunflower yield in 2021

Soil work	Means (kg/ha)		Relative values (%)	Difference/ Significance
Scarification – Ploughing	2,197	2,047	107.33	150***
(Scarification+ Ploughing) – Ploughing	2,104	2,047	102.78	57
(Scarification+ Ploughing) – Scarification	2,104	2,197	95.77	-93^0

$DL_{5\%}$=72 kg/ha $DL_{1\%}$=96 kg/ha $DL_{0.1\%}$=125 kg/ha
Source: Own calculation.

Overall, in 2021 (Table 6), based on the use of scarification, a very significantly higher production was recorded compared to ploughing, associated with an increase of 7.33%. Against the background of the reduced level of water in the soil in the spring of 2021, the combination of scarification and ploughing had a negative effect on production causing a significant reduction of about 4.3%.
Regarding the interaction between densities and fertilizations (Table 7), it was found that, on unfertilized agricultural land, the increase in crop density from 49,261 to 53,908 g.g./ha had a small and insignificant effect on production, but by changing the density from 53,908 to 59,524 g.g./ha, there was a significant increase in production of 237 kg/ha. Later, the increase in the thickness to the level of 66,756 g.g./ha was associated with a reduction in production by 150 kg/ha.

Table 7. Effect of density and fertilization on sunflower production in 2021

(g.g./ha)	Fertilisation				
	$N_0P_0K_0$	$N_{50}P_{50}K_0$	$N_{50}P_{50}K_{50}$	$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
49,261	x 1,561 b	y 2,111 ab	x 2,375 b	2,016±71	18.26
53,908	z 1,575 b	y 2,264 a	x 2,608 a	2,149±88	21.28
59,524	z 1,812 a	y 2,285 a	x 2,647 a	2,248±72	16.59
66,756	z 1,662 ab	y 2,085 b	x 2,403 b	2,050±65	16.44
$\bar{x} \pm s_{\bar{x}}$	1,653±27	2,186±28	2,508±30	2,116±38	
$S_{\%}$	9.85	7.47	7.10	18.51	

Densities - $DL_{5\%}$=179 kg/ha $DL_{1\%}$=247 kg/ha $DL_{0.1\%}$=340 kg/ha (a,b). Fertilisations - $DL_{5\%}$=170 kg/ha $DL_{1\%}$=230 kg/ha $DL_{0.1\%}$=310 kg/ha (x, y, z)
Source: Own calculation.

Under the effect of fertilization with $N_{50}P_{50}K_0$, a variation in yields is observed from 2,085 kg/ha for the density of 66,756 g.g./ha to 2,285 kg/ha for the density of 58,524 g.g./ha. For this agrofund, the use of plant nutrition areas of 0.168-0.186 m^2 allowed significant increases in production compared to the density related to an individual area of 0.15 m^2.
With $N_{50}P_{50}K_{50}$ application, the production recorded an amplitude of 272 kg, with the limits between 2,375 at the density of 49,261 g.g./ha and, respectively, 2,647 for the density of 59,524 g.g./ha. And, in the case of this agricultural fund, it was found that the use of densities related to distances between plants in a row of 26.5 and 24 cm showed high efficiency, materialized by significant increases in production of 8.5-11.5% compared to densities related to some spaces between plants of 21.4 and 29 cm.
Fertilization showed a lower effect on the production of plants grown at densities of 49,261 g.g./ha, where fertilization with NP and, respectively, NPK generated increases in production of 35-52% compared to the control variant, when the additional fertilization with potassium allowed a 12.5% increase in production. And, in the case of other densities, a significant increase in production is observed due to fertilization with nitrogen + phosphorus or nitrogen + phosphorus + potassium, associated with increases between 26.10-46.08% for the density of 59,524

g.g./ha and 43.74-65.58% for the one of 53,908 g.g./ha. Also, for the three densities, a significant effect of additional fertilization with potassium can be found, realized through increases of 318-344 kg/ha.

Table 8. Effect of density and tillage on sunflower production in 2021

Density (g.g./ha)	Soil work			$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
	Ploughing	**Scarification**	**Scarification+ Ploughing**		
49261	y 1,896 b	x 2,121 b	xy 2,030 bc	2,016±71	18.26
53908	x 2,108 a	x 2,190 ab	x 2,148 ab	2,149±88	21.28
59524	y 2,154 a	x 2,304 a	xy 2,286 a	2,248±72	16.59
66756	xy 2,029 ab	x 2,171 ab	y 1,951 c	2,050±65	16.44
$\bar{x} \pm s_{\bar{x}}$	2,047±58	2,197±+64	2,104±73	2,116±38	
$S_{\%}$	17.01	17.36	20.76	18.51	

Densities - $DL_{5\%}$=148 kg/ha $DL_{1\%}$=199 kg/ha $DL_{0.1\%}$=263 kg/ha (a,b,c). Soil works - $DL_{5\%}$=144 kg/ha $DL_{1\%}$=1926 kg/ha $DL_{0.1\%}$=251 kg/ha (x, y)
Source: Own calculation.

Regarding the effect of the interaction between densities and tillage on production (Table 8), it follows that, in the variant where it was ploughed, increasing the crop density by reducing the distance between plants from 29 to 26.5 and 24 cm, respectively, was associated with significant increases of production between 11.18 and 13.61%. Subsequently, reducing the distance between plants from 24 to 21.4 cm determined a small and insignificant variation in production by 6%.

When using scarification, a progressive increase in production was noted against the background of the increase in crop density from 49,261 to 59,524 g.g./ha, associated with a significant increase of 8.62%. The reduction of plant nutrition area from 0.168 to 0.15 m^2 determined an insignificant decrease in production by about 133 kg/ha.

The plants cultivated at the density of 59,524 g.g./ha more efficiently capitalized on the agrofund represented by the association of scarification with ploughing, registering significant increases in production between 12.61% compared to the density of 49,261 g.g./ha and 17.17% compared to the density of 66,756 g.g./ha ha. At the same time, against the background of these basic soil works, it was observed that changing the distance between plants in a row from 21.4 to 26.5 cm allowed a significant increase in production by 10.1%.

Tillage had a low and insignificant effect on the production of plants grown at the density of 53,908 g.g./ha and, respectively, a significantly higher effect on the productivity of plants grown at the density of 49,261 g.g./ha. The plants grown at distances of 29 and 24 cm more effectively capitalized on the arable land prepared by scarification, achieving significant increases in production of 6.97-11.87% compared to the plants grown on the arable land prepared by ploughing. In the case of the plot of 66,756 g.g./ha, against the background of a lower reserve of water in the soil, it was found that the preparation of the land by scarification favoured a significant increase in production by 11.27% compared to the use of scarification in association with ploughing.

Table 9. Effect of fertilization and tillage on sunflower yield in 2021

Fertilisation	Soil work			$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
	Ploughing	**Scarification**	**Scarification+ Ploughing**		
$N_0P_0K_0$	x 1,641 c	x 1,714 c	x 1,603 c	1,653±27	9.85
$N_{50}P_{50}K_0$	y 2,102 b	x 2,308 b	y 2,149 b	2,186±28	7.47
$N_{50}P_{50}K_{50}$	y 2,397 a	x 2,568 a	x 2,560 a	2,508±30	7.10
$\bar{x} \pm s_{\bar{x}}$	2,047±58	2,197±+64	2,104±73	2,116±38	
$S_{\%}$	17.01	17.36	20.76	18.51	

Fertilisations - $DL_{5\%}$=132 kg/ha $DL_{1\%}$=176 kg/ha $DL_{0.1\%}$=229kg/ha (a,b,c). Soil works - $DL_{5\%}$=125 kg/ha $DL_{1\%}$=166 kg/ha $DL_{0.1\%}$=217 kg/ha (x, y)
Source: Own calculation.

Considering the combined effect of fertilization and tillage on production in 2021 (Table 9) in the case of the unfertilized agrofund, basic tillage had the lowest influence on the level of production, against the background of small and insignificant variations. Thus, in the case of the treatment with $N_{50}P_{50}K_0$, it can be observed that scarification showed a significantly superior effect, against the background of production increases of 7.39-9.80% compared to the other two basic soil works. Land preparation by applying simple scarification or in combination with ploughing favoured a more efficient utilization of $N_{50}P_{50}K_{50}$ fertilization, materialized by significant increases in production of about 6.8%.

Regardless of the basic soil works, fertilization showed a significant effect on production producing increases of 28.09-34.65% for the $N_{50}P_{50}K_0$ variant and 46.07-

59.70%, respectively, for $N_{50}P_{50}K_{50}$. Against the background of fertilization with nitrogen and phosphorus, additional fertilization with potassium generated a significant increase in production between 11.26% for the agricultural land prepared by scarification and, respectively, 19.12% when scarification was applied in association with ploughing.

Considering the combined influence of density, fertilization, and tillage on production (Table 10), for a density of 49,261 g.g./ha, a reduced and insignificant effect of tillage was observed both in the case of the unfertilized agrofund and in the case of applying the treatment with $N_{50}P_{50}K_{50}$. On the land prepared by scarification, the plants used the nitrogen and phosphorus treatment more effectively compared to the plants grown on the land prepared by ploughing.

Table 10. Influence of some technological links on production in 2021

Densities 49,261 g.g./ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	x 1,452 b	x 1,631 b	x 1,600 c
$N_{50}P_{50}K_0$	y 1,990 a	x 2,240 a	xy 2,103 b
$N_{50}P_{50}K_{50}$	x 2,246 a	x 2,492 a	x 2,387 a
Densities 53,908 g.g./ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	x 1,697 c	xy 1,590 c	y 1,437 c
$N_{50}P_{50}K_0$	x 2,170 b	x 2,348 b	x 2,275 b
$N_{50}P_{50}K_{50}$	y 2,458 a	xy 2,633 a	x 2,732 a
Densities de 59,524 g.g./ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	x 1,702 c	x 1,875 b	x 1,860 c
$N_{50}P_{50}K_0$	x 2,184 b	x 2,405 a	x 2,266 b
$N_{50}P_{50}K_{50}$	x 2,575 a	x 2,633 a	x 2,732 a
Density	**66,756 g.g./ha**		
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	x 1,712 b	x 1,761 c	x 1,514 c
$N_{50}P_{50}K_0$	xy 2,065 a	x 2,237 b	y 1,952 b
$N_{50}P_{50}K_{50}$	x 2,309 a	x 2,514 a	x 2,387 a

Fertilisations - $DL_{5\%}$=264 kg/ha $DL_{1\%}$=352 kg/ha $DL_{0.1\%}$=458 kg/ha (a,b,c). Soil works - $DL_{5\%}$=249 kg/ha $DL_{1\%}$=332 kg/ha $DL_{0.1\%}$=434 kg/ha (x, y, z). $DL_{5\%}$=260 kg/ha $DL_{1\%}$=345 kg/ha $DL_{0.1\%}$=447 kg/ha
Source: Own calculation.

Fertilization showed a lower influence on production on the land prepared by ploughing and a higher influence in the case of plants grown on the land where scarification was applied in association with ploughing. In the case of agrofunds where ploughing or scarification was used, fertilization determined production increases of about 37-55%, when potassium had a positive effect on production but not statistically guaranteed. The plants grown on the land where scarification was applied in combination with ploughing made more efficient use of both nitrogen and phosphorus fertilization and additional potassium fertilization, recording increases of 31.43-49.19%, under the conditions of a significant effect of potassium of 13.50%.

Against the background of plant cultivation at the density of 53,908 g.g./ha, soil works did not significantly influence the efficiency of the treatment with $N_{50}P_{50}K_{50}$ while, on the non-fertilized agrofund, the use of ploughing favoured a significant increase in production by 18.09%. The plants utilized the fertilization with $N_{50}P_{50}K_{50}$ more effectively on the land prepared by scarification and ploughing compared to the land where only ploughing was used. The influence of fertilization on production was higher than at the previous density, with significant production differences between the three variants. Thus, the treatment with nitrogen and phosphorus determined increases of 27.87-47.67%, and fertilization with NPK was associated with increases of 44.84-90.11%, compared to the non-fertilized version. Also, the positive effect of additional fertilization with potassium was materialized by significant increases of 8.76-20.08%.

Under the conditions of a density of 59,524 g.g./ha, the basic tillage had little influence on the level of production, against the background of insignificant variations between 173 kg on the unfertilized agrofund and 221 kg on the $N_{50}P_{50}K_{50}$ agrofund. Fertilization had a significant effect on production, more pronounced in the variants where ploughing was practiced or its association with scarification, causing increases of 406-482 kg/ha for the $N_{50}P_{50}K_{50}$ variant and about 875 kg for $N_{50}P_{50}K_{50}$. Against the background of the treatment with nitrogen and phosphorus, the additional fertilization with potassium generated a significant increase in production between 391 for the agricultural land prepared by ploughing and, respectively, 466 kg/ha in the case of the agricultural land where scarification was applied in association with ploughing. In the case of land preparation by scarification, fertilization had positive effects

on production, associated with increases of 530-758 kg/ha, against the background of an insignificant influence of potassium.

In the case of the density of 66,756 g.g./ha, a reduced and insignificant effect of the soil works was observed both in the case of the unfertilized agrofund and in the case of the application of $N_{50}P_{50}K_{50}$. On the soil prepared by scarification, the plants used the fertilization with nitrogen and phosphorus more efficiently compared to the plants grown on a scarified soil in association with ploughing. Fertilization showed a lower influence on production on the land prepared by ploughing and a higher influence in the case of plants grown on the land where scarification was applied in association with ploughing. In the case of the agrofund where ploughing was used, fertilization determined increases in production of about 353-597 kg/ha, in the conditions where potassium had a positive effect on production, but not statistically ensured. The plants grown on the lands where scarification was applied made more efficient use of both nitrogen and phosphorus fertilization as well as the additional potassium fertilization, recording gains of 438-873 kg/ha, under the conditions of a significant effect of potassium of 435 kg/ha.

Influence of some technological links on sunflower production in 2022

In the year 2022, the analysis of the variance components (Table 11) shows that only density and fertilization had a real and statistically assured influence on the production, against the background of a reduced and insignificant influence of both soil works and environmental conditions at the level of replicas. Fertilization showed a significantly higher influence (58.33%) than tillage (19.93%) and soil work (0.28%). The simple interactions between the three factors showed significant influences on production achievement, associated with contributions of 1-2%.

The results obtained under the effect of the three factors were influenced to an extent of about 15.44% by other uncontrollable sources through the experimental device.

Table 11. The influence of the variant on some technological links in the sunflower crop in 2022

Variation source	SP	GL	S^2	F test
Total	10,532,387	107		
Replicas	49,461	2	24,731	1.30
Density	1,965,868	3	655,289	34.35**
Density error	114,469	6	19,078	
Fertilisation	5,321,178	2	2,660,589	100.52**
Density x Fertilisation	510,182	6	85,030	3.21*
Fertilisation error	423,495	16	26,468	
Soil work	21,084	2	10,542	0.49
Density x Soil work	343,918	6	57,320	2.65*
Fertilisation x Soil work	214,114	4	53,529	2.47*
Density x Fertilisation x Soil work	529,568	12	44,131	2.04*
Work error	1,039,050	48	21,647	**84.56**

Source: Own calculation.

Regarding the cumulative effect of density, in 2022 (Table 12) average production values were found with the limits of 2,016 kg/ha in the case of the 49,261 g.g./ha variant and 2,336 kg/ha in the case of the 59,524 g.g./ha variant, against the background of low variability (7.12%). The increase in crop density from 49,261 to 53,908 g.g./ha had a small and insignificant effect on production, associated with an increase of about 4.5%.

By changing the density from 53,908 to 59,524 g.g./ha, a significant increase in production of about 11% was recorded, equivalent to 229 kg/ha. Later, the intensification of the culture up to the level of 66,756 g.g./ha was associated with an insignificant variation of the production.

Table 12. Effect of density on sunflower production in 2022

Density (g.g./ha)	Means (kg/ha)		Relative values (%)	Difference/Significance
53,908 – 49,261	2,107	2,016	104.51	91
59,524 – 49,261	2,336	2,016	115.87	320***
66,756 – 49,261	2,311	2,016	114.63	295***
59,524 – 53,908	2,336	2,107	110.87	229***
66,756 – 53,908	2,311	2,107	109.68	204**
66,756 – 59,524	2,311	2,336	98.93	-25

Source: Own calculation. $DL_{5\%}$=92 kg/ha $DL_{1\%}$=139 kg/ha $DL_{0.1\%}$=224 kg/ha

Considering the unilateral effect of fertilization, it was observed that the production (Table 13) recorded an amplitude of 505 kg/ha with values ranging between 1,882 kg/ha in the case of the unfertilized variant and 2,387 kg/ha in the case of the use of $N_{50}P_{50}K_{50}$, under the conditions a variability of 12.4% between treatments.

Fertilization with NP and, respectively, NPK, generated production increases of 22.7-26.8% compared to the untreated variant, while additional potassium fertilization allowed an insignificant variation in production by 3.4%.

Table 13. Effect of fertilization on sunflower yield in 2022

Fertilisation	Means (kg/ha)		Relative values (%)	Difference/ Significance
$N_{50}P_{50}K_0 - N_0P_0K_0$	2,309	1,882	122.69	427***
$N_{50}P_{50}K_{50} - N_0P_0K_0$	2,387	1,882	126.83	505***
$N_{50}P_{50}K_{50} - N_{50}P_{50}K_0$	2,387	2,309	103.38	78

$DL_{5\%}$=81 kg/ha $DL_{1\%}$=112 kg/ha $DL_{0.1\%}$=154 kg/ha
Source: Own calculation.

Under the effect of different soil works, the production showed a very small range of variation of 3-8 kg/ha, with values ranging between 2,188 kg/ha on the agricultural land where ploughing was applied and 2,196 kg/ha in the case of land preparation by scarification and ploughing, under conditions of extremely low variability between the three basic works (Table 14). The application of different soil works had very close, respectively, significantly equal effects, on production, not statistically differentiated.

Table 14. Effect of tillage on sunflower yield in 2022

Soil work	Means (kg/ha)		Relative values (%)	Difference/Significance
Scarification – Ploughing	2,193	2,188	100.23	5
(Scarification+ Ploughing) – Ploughing	2,196	2,188	100.37	8
(Scarification+ Ploughing) - Scarification	2,196	2,193	100.14	3

Source: Own calculation.

The combined effect of density and fertilization on production (Table 15) shows that, in the case of agrofund fertilized with nitrogen and phosphorus, only the reduction of the distance between plants from 29 to 26.5 cm generated significant production variations of 7.7%, while changes in the distance between plants from 26.5 to 21.4 cm had small and insignificant influences.

Table 15. Effect of density and fertilization on sunflower yield in 2022

Density (g.g./ha)	Fertilisation				
	$N_0P_0K_0$	**$N_{50}P_{50}K_0$**	**$N_{50}P_{50}K_{50}$**	$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
49,261	y 1,665 b	x 2,120 b	x 2,264 b	2,016±54	13.94
53,908	y 1,774 b	x 2,283 a	x 2,265 b	2,107±50	12.32
59,524	z 2,036 a	y 2,400 a	x 2,572 a	2,336±48	10.60
66,756	y 2,053 a	x 2,433 a	x 2,446 a	2,311±42	9.41
$\bar{x} \pm s_{\bar{x}}$	1,882±33	2,309±27	2,387±28	2,193±27	
$S_{\%}$	10.52	6.99	7.05	12.93	

Densities - $DL_{5\%}$=152 kg/ha $DL_{1\%}$=206 kg/ha $DL_{0.1\%}$=277 kg/ha (a,b). Fertilisations - $DL_{5\%}$=163 kg/ha $DL_{1\%}$=224 kg/ha $DL_{0.1\%}$=308 kg/ha (x, y, z)
Source: Own calculation.

On the unfertilized farmland and in the case of $N_{50}P_{50}K_{50}$ application, it was found that the densities of 59,524 and 66,756 g.g./m^2 favoured the highest productions, associated with significant increases compared to the other two densities, not statistically differentiated.

The plants cultivated at the density of 59,524 g.g./ha used fertilization at a higher level, thus registering significant increases of 364-536 kg/ha, against the background of a significant effect of 172 kg/ha of potassium. Under the conditions of the other crop densities, fertilization with $N_{50}P_{50}K_0$ determined significant increases in production between 380 kg/ha in the case of the density of 66,756 g.g./m^2, respectively 509 kg/ha for the density of 53,908 g.g./m^2. Also, the $N_{50}P_{50}K_{50}$ variant had an important and significant effect on production, related to increases from 393 kg/ha for the density of 66,756 g.g./ha up to 599 kg for the use of the density of 49,261 g.g./ha. Potassium fertilization had small and insignificant effects on the production of plants grown at distances of 21.4, 26.5 and 29 cm per row.

Regarding the effect of density on production in different fertilization conditions (Table 15) in the case of unfertilized agrofund, the amplitude (388 kg/ha) and variability (10.52%) between plots were higher, recording production increases of 14.77-23.3% by cultivating plants at densities of 59,524-66,756 g.g./ha. Against the background of fertilization with $N_{50}P_{50}K_0$ and $N_{50}P_{50}K_{50}$, the effect of crop density was less but significant, recording, at densities of 59,524-66,756 g.g./ha, an increase in production of 5.12-14.76% compared to the first two densities.

Table 16. Influence of some technological links on sunflower production in 2022

Density (g.g./ha)	Soil work				
	Ploughing	**Scarification**	**Scarification+ Ploughing**	$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
49,261	x 2,010 b	x 2,017 b	x 2,023 c	2,016±54	13.94
53,908	x 2,069 b	x 2,081 b	x 2,173 b	2,107±50	12.32
59,524	x 2,303 a	x 2,382 a	x 2,322 a	2,336±48	10.60
66,756	x 2,372 a	x 2,294 a	x 2,266 ab	2,311±42	9.41
$\bar{x} \pm s_{\bar{x}}$	2,188±50	2,193±45	2,196±48	2,193±27	
$S_{\%}$	13.78	12.25	13.08	12.93	

Densities - $DL_{5\%}$=138 kg/ha $DL_{1\%}$=184 kg/ha $DL_{0.1\%}$=242 kg/ha (a,b,c,d). Soil works - $DL_{5\%}$=140 kg/ha $DL_{1\%}$=186 kg/ha $DL_{0.1\%}$=243 kg/ha (x, y, z)
Source: Own calculation.

About the influence of the soil works, it was found that, no matter the space between the plants, the method of land preparation had a small and insignificant contribution to the achievement of production against the

background of a lower level of precipitation at the beginning of the vegetation period.

Based on the preparation of the land by ploughing, the establishment of the crop at 21.4-24 cm between plants allowed obtaining production increases of 11.3-18% compared to the other two plots, respectively increases of 277-365 kg/ha for the agrofund where scarification was applied. In the case of land preparation by scarification and ploughing, the effect of density on production is higher. Thus, it was found that the plot of 59,524 g.g./ha favoured significant production increases of 6.85-14.78% compared to the plots of 49,261-53,908 g.g./ha. Also, reducing the space between plants from 29 to 26.5 cm was associated with an increase in production of 7.42%.

Considering the combined effect of fertilization and tillage on production in 2022 (Table 17) in the case of unfertilized agrofund, basic tillage had the lowest influence on the level of production against the background of small and insignificant variations. Thus, in the case of the treatment with $N_{50}P_{50}K_0$, it can be observed that scarification showed a significantly superior effect against the background of production increases of 7.39-9.80% compared to the other two basic soil works. The preparation of the land by simple scarification alone or in association with ploughing favoured a more efficient use of fertilization with $N_{50}P_{50}K_{50}$, materialized by significant increases in production of about 6.8%.

Considering the interaction between tillage and fertilization (Table 16), it follows that, on the unfertilized agrofund, tillage had the highest influence on production, against the background of an amplitude of 206 kg/ha. Thus, under these conditions, soil preparation by ploughing allowed a significant increase in production by 11.20% compared to the variant where only scarification was applied. The association of scarification with ploughing did not determine significant production variations compared to the unilateral application of the two works. Against the background of the application of $N_{50}P_{50}K_0$ and $N_{50}P_{50}K_{50}$, the soil works did not significantly influence the production, which presented very small and irregular amplitudes of variation.

Table 17. Effect of fertilization and tillage on sunflower yield in 2022

Fertilisation	Soil work				
	Ploughing	**Scarification**	**Scarification+Ploughing**	$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
$N_0P_0K_0$	x 1,853 b	x 1,920 b	x 1,872 b	1,882±33	10.52
$N_{50}P_{50}K_0$	x 2,329 a	x 2,282 a	x 2,316 a	2,309±27	6.99
$N_{50}P_{50}K_{50}$	x 2,382 a	x 2,378 a	x 2,399 a	2,387±28	7.05
$\bar{x} \pm s_{\bar{x}}$	2,188±50	2,193±45	2,196±48	2,193±27	
$S_{\%}$	13.78	12.25	13.08	12.93	

Fertilisations - $DL_{5\%}$=125 kg/ha $DL_{1\%}$=166 kg/ha $DL_{0.1\%}$=216 kg/ha (a,b,c). Soil works - $DL_{5\%}$=121 kg/ha $DL_{1\%}$=161 kg/ha $DL_{0.1\%}$=211 kg/ha (x, y, z)
Source: Own calculation.

As for the effect of tillage on production for each fertilization agrofund (Table 17), it can be observed that, in the case of the three fertilization options, the amplitudes of variation between tillage were small and insignificant, between 21 kg for the treatment with $N_{50}P_{50}K_{50}$ and 67 kg for the non-fertilized agrofund.

Under the conditions of land preparation by ploughing, fertilization generated an amplitude with limits from 1,853 kg/ha for the control variant to 2,382 kg/ha for the $N_{50}P_{50}K_{50}$ variant. As such, fertilization allowed obtaining significantly higher productions by over 25.69%. Against the background of land preparation by scarification, the variability between treatments was between 1,920 and 2,378 kg/ha, with significant increases of 18.85-23.85% because of fertilization with two and, respectively, three macroelements. In the case of using scarification in combination with ploughing, fertilization treatments determined a variation in production of 527 kg/ha. Nitrogen and phosphorus fertilization caused a significant increase in production by 23.72%, while nitrogen, phosphorus and potassium fertilization allowed a 28.15% increase in production.

Considering the effect of the interaction between densities, fertilizations, and tillage on production in 2022 (Table 18), it was found that no matter the space between plants or the fertilization treatment applied, tillage had a low and insignificant influence on plant growth and development of sunflower, respectively, their productivity. The amplitude between soil works was 58-203 kg/ha for the

density of 49,261 g.g./m^2, 107-171 kg/ha for the density of 53,908 g.g./m^2, 61-165 kg/ha in the case of the density of 59,524 g.g./m^2 and, respectively, 103-188 kg/ha for the density of 66,756 g.g./ha.

Under the conditions of the density of 49,261 g.g./ha, it can be observed that fertilization with nitrogen and phosphorus determined significant increases in production from 311 kg/ha in the case of land preparation by scarification up to 572 kg/ha, in the case of application of scarification in association with ploughing. Also, fertilization with NPK had an important and significant effect on production, generating increases between 390 and 756 kg/ha. Additional potassium fertilization had low (79-184 kg/ha) and insignificant effects on production. Against the background of the density of 53,908 g.g./ha, fertilization showed a significant effect on production causing increases of 27.46-29.3165% for $N_{50}P_{50}K_0$ and, respectively, 24.08-33.35% for $N_{50}P_{50}K_{50}$.

Table 18. Influence of some technological links on production in 2022

Density 49,261 g.g./ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	x 1,631 b	x 1,783 b	x 1,580 b
$N_{50}P_{50}K_0$	x 2,114 a	x 2,094 a	x 2,152 a
$N_{50}P_{50}K_{50}$	x 2,284 a	x 2,173 a	x 2,336 a
Density 53,908 g.g./ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	x 1,747 b	x 1,730 b	x 1,844 b
$N_{50}P_{50}K_0$	x 2,259 a	x 2,205 a	x 2,386 a
$N_{50}P_{50}K_{50}$	x 2,200 a	x 2,307 a	x 2,288 a
Density 59,524 g.g./ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	x 1,996 b	x 2,055 b	x 2,057 c
$N_{50}P_{50}K_0$	x 2,405 a	x 2,480 a	x 2,315 b
$N_{50}P_{50}K_{50}$	x 2,507 a	x 2,612 a	x 2,595 a
Density 66,756 g.g./ha			
Fertilisation	Soil work		
	Ploughing	**Scarification**	**Scarification+Ploughing**
$N_0P_0K_0$	x 2,040 b	x 2,111 b	x 2,008 b
$N_{50}P_{50}K_0$	x 2,538 a	x 2,350 a	x 2,412 a
$N_{50}P_{50}K_{50}$	x 2,539 a	x 2,420 a	x 2,378 a

Fertilisations - $DL_{5\%}$=249 kg/ha $DL_{1\%}$=332 kg/ha $DL_{0.1\%}$=431 kg/ha (a,b,c). Soil works - $DL_{5\%}$=242 kg/ha $DL_{1\%}$=322 kg/ha $DL_{0.1\%}$=421 kg/ha (x, y, z). $DL_{5\%}$=244 kg/ha $DL_{1\%}$=324 kg/ha $DL_{0.1\%}$=420 kg/ha
Source: Own calculation.

Against the background of fertilization with nitrogen and phosphorus, additional fertilization with potassium generated a differentiated and insignificant variation in production associated with an increase of 4.63% for the agrofund prepared by scarification and, respectively, a reduction of production by 2.6-4.1% for the other two basic soil works.

In the case of growing plants at the density of 59,524 g.g./ha, fertilization showed a lower influence on the production on the land prepared by ploughing and scarified and a higher influence in the case of scarified in association with ploughing. In the case of agrofunds where ploughing or scarification was used, fertilization determined increases in production of 409-557 kg/ha, while potassium had a positive effect (102-132 kg/ha) on production but not statistically ensured. The plants grown on the land where scarification was applied in combination with ploughing made more efficient use of both nitrogen and phosphorus fertilization and additional potassium fertilization, recording increases of 258-538 kg/ha, under the conditions of a significant effect of potassium of 280 kg/ha.

Under the conditions of the density of 66,756 g.g./ha, it was found that, regardless of the method of land preparation, fertilization with $N_{50}P_{50}K_0$ had a significant effect on the production associated with increases between 11.32 when using scarification and, respectively, 24.41% when using ploughing. Also, it was observed that the plants more efficiently capitalized on the fertilization with $N_{50}P_{50}K_{50}$ on the arable land where ploughing was applied, obtaining a significant increase of 24.46%, compared to the arable land related to scarification, where the production increase was 14.64%. The individual effect of potassium was reduced, generating insignificant production variations of + 1.5-3%.

CONCLUSIONS

During the study carried out in the period 2020-2022 on a cambic chernozem from Timișoara, Romania, the following were found:

- Fertilization had the highest contribution to production variability, being between 58.33% in 2022 and 78.55% in 2020.

- The density of the culture showed an influence on production between 4.30% in 2021 and 19.93% in 2022.
- Soil works recorded the lowest contribution to production, with values from 0.06% in 2020 to 3.34% in 2021.
- Reducing the distance between plants in a row from 29 to 26.5 cm determined significant increases in production in the period 2020-2021 associated with increases of 133-168 kg/ha. Under the conditions of 2022, the increase in density from 49,261 to 53,908 g.g./ha had a small and insignificant effect on production, associated with a 4.5% increase.
- By changing the density from 53,908 to 59,524 g.g./ha, a significant production increase of 10.87-16.46% was recorded in 2020 and 2022, equivalent to 229-391 kg/ha. The increase of the distance between plants in a row from 26.5 to 24 cm under the conditions of 2021, was associated with an insignificant variation in production of 99 kg/ha.
- The increase in crop density from 59,524 to 66,756 g.g./ha had, in 2020 and 2022, a small and insignificant effect on production, causing a variation of 10-25 kg/ha. Under the conditions of 2021, reducing the distance between plants from 24 to 21.4 cm had a negative effect on production, causing a significant decrease of 198 kg/ha.
- Fertilization with nitrogen and phosphorus determined a significant increase in production, with increases of 22.7% in 2022 and 45.21% in 2020, equivalent to increases of 427-828 kg/ha;
- Fertilization with $N_{50}P_{50}K_{50}$ generated significant increases in production from 26.8% in 2022 to 51.72% in 2021, associated with increases of 505-891 kg/ha.
- The application of potassium in a dose of 50 kg/ha against the background of fertilization with $N_{50}P_{50}$ had a small and insignificant effect on production in 2020 and 2022. In the less favourable conditions of 2021, the additional fertilization with potassium allowed an increase in production of about 15% equivalent to 322 kg/ha; at the level of the entire experiment, it was found that, against the background of climate conditions in 2020 and 2022, the type of soil preparation did not significantly influence sunflower production. In the conditions of 2020, amid the use of scarification, there was a higher production in line with ploughing, associated with an increase of 7.33% and 150 kg/ha, respectively.
- Regarding the average productions for the various technological links, it was observed that the variant 59,524 g.g./ha – $N_{50}P_{50}K_{50}$ – scarification+ploughing recorded the highest productions (2,612 kg/ha in 2022 and 3,417 kg/ha in 2020). Also, the $N_{50}P_{50}K_{50}$ variant, in the case of plants grown at 24 cm per row, ranked in the best 5 variants, recording productions of 2,507-3,145 kg/ha.
- The $N_{50}P_{50}K_0$ variant of the plants grown at a density of 59,524 g.g./ha on the land prepared by scarification and ploughing achieved superior productions in the favourable conditions of 2020 associated with significantly lower productions in the less favourable conditions of 2021-2022. Against the background of the absence of mineral fertilization with macroelements, the production recorded variations between 1,437 and 1,875 kg/ha in 2021 and, respectively, 1,806-2,523 kg/ha in 2020.

Considering the averages for different technological variants over the entire period of the study, it is found that the highest productions of 2,742-2,915 kg/ha were obtained under the effect of the density of 59,524 g.g./ha and fertilization with $N_{50}P_{50}K_{50}$ in association with different soil works, the respective productions being significantly superior to 57% of the technological links.

ACKNOWLEDGEMENTS

This paper is published from the project 6PFE of the University of Life Sciences "King Mihai I" from Timisoara and Research Institute for Biosecurity and Bioengineering from Timisoara.

REFERENCES

[1]Adeleke, B.S., Babalola, O.O., 2020, Oilseed crop sunflower (*Helianthus annuus*) as a source of food: Nutritional and health benefits. Food Sci Nutr. 2020. 8: 4666–4684.
[2]Chantal, K., Basil, T., Ong'or, I, 2018, Bandushubwenge D, Soter N, Shabani F. Research

Effects of Different Nitrogen Fertilizer Levels on Sunflower Growth and Yield Attributes. Pak J. of Nutrition. 2018. 17, 557-562.
[3]Chen, K. F., Yeh, T. Y., Hsu, Y. H., Chen, C. W., 2012, The phytoattenuation of the soil metal contamination: the effects of plant growth regulators (GA3 and IAA) by employing wetland macrophyte vetiver and energy plant sunflower. Desalin Water Treat. 2012. 45(1-3): 144-152.
[4]Ciulca, S., 2006, Metodologies for experiments in agricultura and biology (Metodologii pentru experimentare în agricultură şi biologie). Agroprint Publishing House, pp.7-12.
[5]Debaeke, P., Casadebaig, P., Flenet, F., Langlade, N., 2017, Sunflower and climate change in Europe: crop vulnerability, adaptation, and mitigation potential. Oilseeds Fats Crops Lipids. 2017. 24: D102 10.1051/ocl/2016052.
[6]Degianski, A., Pîrşan, P., 2018, Study regarding the effect of density, fertilization and tillage on sunflower yield under the conditions from Timişoara. Research Journal of Agricultural Science, 59(2), 28-33.
[7]Delaplane, K.S., Mayer, D.F., 2000, Crop pollination by bees. New York: CABI, 2000, pp. 43.
[8]Eberhart, S.A., Russell, W.A., 1966, Stability parameters for comparing varieties. Crop. Sci. pp. 6-11.
[9]Fiebig, R., Schulze, D., Chung, J.C., Lee, S.-T., 1997, Biodegradation of polychlorinated biphenyls (PCBs) in the presence of a bioemulsifier produced on sunflower oil. Biodegradation. 1997. 8(2): 67-75.
[10]Gan, S., Lau, E.V., Ng, H.K., 2009, Remediation of soils contaminated with polycyclic aromatic hydrocarbons (PAHs). J Hazard Mater. 2009. 172(2-3): 532-549.
[11]Guo, S., Ge, Y., Na Jom, K., 2017, A review of phytochemistry, metabolite changes, and medicinal uses of the common sunflower seed and sprouts (*Helianthus annuus* L.) Chemistry Central Journal. 2017. 11: 95.
[12]Kara, Y., Koca, S., Vaizogullar, H.E., Kuru, A., 2013, Studying phytoremediation capacity of jojoba (*Simmondsia chinensis*) and sunflower (*Helianthus annuus*) in hydroponic systems. Curr Opin Biotech. 2013. 24(1): S34.
[13]Ker, K., Charest, C., 2010, Nickel remediation by AM-colonized sunflower. Mycorrhiza. 2010. 20(6): 399-406.
[14]Li, W.P., Shi, H.B., Zhu, K., Zheng, Q., Xu, Z., 1998, The quality of sunflower seed oil changes in response to nitrogen fertilizer. Agron. J. 2017. 109: 2499–2507.
[15]Macías, F.A., Varela, R.M., Torres, A., Oliva, R.M., Molinillo J., 1998, Bioactive norsesquiterpenes from *Helianthus annuus* with potential allelopathic activity. Phytochemistry. 1998. 48: 631-636.
[16]Macías, F.A., Varela, R.M., Torres, A, Molinillo, J.M.G., 1999, New bioactive plant heliannuols from cultivar sunflower leaves. J Nat Prod. 1999. 62(12): 1636-1639.
[17]Madejon, P., Murillo, J., Maranon, T., Cabrera, F., Soriano, M., 2003, Trace element and nutrient accumulation in sunflower plants two years after the Aznalcollar mine spill. Sci Total Environ. 2003. 307(1-3): 239-257.
[18]Marques, A.P.G.C., Moreira, H., Franco, A.R., Rangel, A.O.S.S., Castro, P.M.L., 2013, Inoculating *Helianthus annuus* (sunflower) grown in zinc and cadmium contaminated soils with plant growth promoting bacteria - Effects on phytoremediation strategies. Chemosphere. 2013. 92(1): 74-83.
[19]Miklic, V., Mrda, J., Modi, R., Jocic, S., Dusanic, N., Hladni, N., Miladinovic, D., 2012, Effect of location and harvesting date on yield and 1,000-seed weight of different sunflower genotypes. Rom Agric Res. 2012. 29: 219-225.
[20]Mihuț, C., Niță L., 2018, Atmospheric Factors used to characterize soil resources https://www.rjas.ro/issue_detail/44, Timișoara, pp. 114-120.
[21]Mihuț, C., Duma-Copcea, A., Mihuț, A., 2018, Evaluation of the production capacity of agricultural land from the perimetre of the Periam locality, Timis County for its sustainable use. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 18(1), 253-256.
[22]Mircov, V. D., Okros, A, Mihuț, C., Jercimovici, S., Dudas, M., Ciulca, S., 2021, Interpretation And Analysis Of The Rainfall Regime In The Western Part Of The Country For Timis And Caras Severin In 2015-2019, Research Journal of Agricultural Science, 53, 142.
[23]Niemelä, T.A., Tulisalo, U.E., 2000, Sunflower hybrids adapted to the finnish growing conditions. In: Proceedings of the 15th International Sunflower Conference, Toulouse (France), N, pp. 22–26.
[24]Peltonen-Sainio, P., Jauhiainien, L., Hakala, K., Ojanen, H., 2009, Climate change and prolongation of growing season: changes in regional potential for field production in Finland. Agric Food Sci. 2009. 18: 171–190.
[25]Seth, C., Misra, V., Singh, R.R., Zolla, L., 2011, EDTA-enhanced lead phytoremediation in sunflower (*Helianthus annuus* L.) hydroponic culture. Plant Soil. 2011. 347(1-2): 231-242.
[26]Skarpa, P., Losak, T., 2008, Changes in selected production parameters and fatty acid composition of sunflower in response to nitrogen and phosphorus applications. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 2008. 56: 203–210.
[27]Szabó, A., Pepó, P., 2005, Effect of agrotechnical and meteorological factors on yield formation in sunflower production. Cereal Research Communications. 2005. 33: 49–52.
[28]Tariq, M., Mott, C.L.B., 2007, The significance of boron in plant nutrition and environment. A review. Journal of Agronomy. 2007. 6(1): 1-10.
[29]Tejeda-Agredano, M.C., Gallego, S., Vila, J., Grifoll, M., Ortega-Calvo, J.J., Cantos, M., 2013, Influence of the sunflower rhizosphere on the biodegradation of PAHs in soil. Soil Biol Biochem. 2013. 57: 830-840.

[30]Thavaprakash, N., Senthilkumar, G., Sivakumar, S.D., Raju, M., 2003, Photosynthetic attributes and seed yield of sunflower (*Helianthus annuus* L.) as influenced by different levels and ratios of nitrogen and phosphorus fertilizers. Acta Agronomica Hungarica. 2003. 51: 149–155.
[31]Toth, V.R., Meszkaros Veres, S., Nagy, J., 2002, Effects of the available nitrogen on the photosynthesis activity and xanthophylls cycle pool of maize in filed. Journal of Plant Physiology. 2002. 159: 627- 634.
[32]Vanaja, M., Yadav, S.K., Archana, G., Jyothi Lakshmi, N., Vagheera, P., Abdul Razak, S.K., Maheswar, M., Venkateswarlu, B., 2011, Response of C4 (maize) and C3 (sunflower) crop plants to drought stress and enhanced carbon dioxide concentration. Plant Soil Environ. 2011. 57: 207–215.
[33]Yasin, M., Mahmood, A., Iqbal, Z., 2011, Growth and yield response of autumn sunflower (*Helianthus annuus*L.) to varying planting densities under subtropical conditions. Int. J. Agric. Appl. Sci. 2011. 3(2): 86-88.
[34]Wang, D.X., Cui, L.J., Song, D.X., Sun, E.Y., Liu, J.G., 2012, Effects of nitrogen, phosphorus and potassium fertilizers on yield and quality of oil sunflower. Liaoning Agricultural Sciences. 2012. 1: 4–9.
[35]Zahoor, A., Riaz, M., Ahmad, S., Ali, H., Khan, M.B., Javed, K., Anjum, M.A., Zia-ul-Haq, M., Khan, M.A., 2010, Ontogeny growth and radiation use efficiency of *Helianthus Annuus* L., as affected by hybrids, nitrogenous regimes and planting geometry under irrigated arid conditions. Pak. J.Bot. 2010. 42(5): 3197-3207.
[36]Zhang, J.B., Yang, J.S., Yao, R.J., Yu, S.P., Li, F.R., Hou, X.J., 2014, The effects of farmyard manure and mulch on soil physical properties in a reclaimed coastal tidal flat salt-affected soil. J. Integr. Agric. 2014. 13: 1782–1790.
[37]Zoumpoulakis, P., Sinanoglou, V., Siapi, E., Heropoulos, G., Proestos, C., 2017, Evaluating modern techniques for the extraction and characterisation of sunflower (*Hellianthus annus* L.) seeds phenolics. Antioxidants. 2017 6(3): 46.
[38]Zubillaga, M.M., Aristi, J.P., Lavado, R.S., 2002, Effect of phosphorus and nitrogen fertilization on sunflower (Helianthus annuusL.) nitrogen uptake and yield. J. Agron. Crop Sci. 2002. 188: 267-274.
[39]http://www.fao.org/faostat - Accessed in 2020, 2021, 2022.