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SUNFLOWER YIELD AND QUALITY UNDER THE INFLUENCE OF SOWING DATE, PLANT POPULATION AND THE HYBRID

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ABSTRACT

Sunflower yield and quality can be significantly increased by optimizing agricultural practices and in corroboration with plant characteristics and environment. Sowing time and plant population are two important factors which affects vegetation and sunflower production. The paper focuses on the influence of these factors in conjunction with other technological elements and the climatic evolution on the final production and its quality in the southern part of the country. The researches were performed during the 2019-2021, in the experimental field of NARDI Fundulea and the aim of this study was to evaluate the effect of sowing date, plant population and climatic conditions on the yield and quality of sunflower. Experimental treatment comprised three different sowing dates (I - April 1, II - April 15 and III - May 1), using three sunflower hybrids (FD15E27, FD19E42 and Performer) and three plant populations (30,000, 50,000 and 70,000 plants/hectare). Rainfall was uneven during the growing season, from year to year, and maximum sunflower production and quality was maximized from medium plant density and earlier sowing dates, depending on hybrid and technology.

The oil content varied widely between 44.2-50.0% depending on the hybrid and plant density and sowing date. The early sowing date led to increase of oil content, which was depending on climatic conditions and plant populations. The primary source of variation was the sowing date, the difference between oil content in early and late sowing dates was influenced by plant population, hybrid and year varying from 0.7% to 5.8%.

The seeds yield and quality of the sunflower were significantly influenced by the climatic conditions of the agricultural year, the sowing date, the plant population and used hybrids, as well as the interaction between these factors.

Keywords: sunflower hybrids, sowing dates, plant density, yield and quality.

INTRODUCTION

The sunflower (*Helianthus annuus* L.) is one of the most important crops and occupies the fourth position among vegetable oilseeds after soybean, oil palm and canola in the world (Rodriguez et al., 2002; Ahmad et al., 2011), grown on 26 million ha in the world and producing about 51.9 million tons of sunflower seeds around the world in 2018 (http://data.un.org - FAO STAT 2018). In Romania sunflower was cultivated on 1.2 million ha in 2020 (www.madr.ro). Sunflower productivity in terms of seed yield and oil production varies significantly depending on technological and environmental factors, such as temperature evolution (Kaleem et al., 2009, 2011; Paraschivu et al., 2021a), uneven distribution of precipitation (Lawal et al., 2011; Olowe et al., 2013), technological links such as sowing time (Lawal et al., 2011; Anjum et al., 2012), plant density and nitrogen nutrition (Ali et al., 2012), varied planting pattern (Yasin et al., 2013) and sowing of genetically enhanced hybrids (Ali et al., 2011; Paraschivu et al., 2021b). The results of different research shows the role of sowing time and plant density on increased the sunflower production of seeds and oil under different climatic conditions (Vrânceanu, 2000; Barros et al., 2004; Ekin et al., 2005).

Differences between hybrids are determined, on the one hand, by genetic characteristics and environmental conditions (Lauretti et al., 2000; Ekin at al., 2005) and on the other hand, by nutrition space, soil fertility and soil processing (Joksimovic et al., 1999; Vega and Hall, 2002).

Given these considerations, in this paper we present the results obtained in recent years, on a soil of cambic chernozem, on the

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evaluation of the influence of sowing time, plant density and climatic conditions on sunflower production and its quality.

MATERIAL AND METHODS

The tests took place on the experimental platform of the National Agricultural Research and Development Institute (NARDI) - Fundulea during 2019/2020/2021, on a soil specific to the experimental area (cambic chernozem). Regarding the physical characteristics of the soil, the humus content is higher in the first 15 cm due to the former bedding and gradually decreases to depth. The soil consists of several horizons:

- Water + Aph - 0-30 cm, clay-clay-dust with 36.5% clay and permeability 492, pH 5.9.
- Am - 30-45 cm, clay-clay with 37.3% clay, compacted, DA 1.41 g/cm³, pH 5.9.
- A/B (45-62 cm), Bv1 (62-80 cm), Bv2 (82-112 cm), Cnk1 (149-170 cm), Cnk2 (170-200 cm).

Depending on the agricultural year, the water supply of the soil is favourable for field crops, groundwater at 10-12 meters.

The experimental material included three sunflower hybrids (FD15E27, FD19E42 and Performer), developed at the NARDI Fundulea. Hybrids were sown at three different dates (I - 01 April, II - 15 April, III - 01 May) and three plant populations (30,000, 50,000 and 70,000 plants/ha^{-1}). The size of the plot was 56 m^2 (20 m long, 4 rows, 70 cm distance between rows). The cultivation of sunflower followed in the rotation of wheat. Harvesting was performed with a combine harvester. Meteorological data were recorded at the NARDI Fundulea weather station. The data were statistically evaluated using analysis of variance procedure - ANOVA.

The method of determination of seed oil content and fatty acid composition

The seeds were oven dried ventilated at 40°C for 4 hours up to a moisture content of about 5%, and were then ground with Waring blender. Four grams of dried seeds were extracted with petroleum ether for 4 hours in a Soxhlet system (Buchi B-811, Germany) according to the SR-EN_ISO 659/2003 method. The oil extract was evaporated by distillation at a reduced pressure in a rotary evaporator at 40°C until the solvent was totally removed. The oil was extracted for two times from a 2 g air dried seed sample by homogenization with the same solvent. Oil content was calculated with formula: $W0=(m1/m_0)$ x100, were m1 is the weight in grams of total seed sample and m_0 is the weight in grams of the air dried seed sample. The oil sample – 10 mg - was converted to its fatty acid methyl esters (FAME) by dissolving with 1 ml heptane and adding 100 μL sodium methoxide in methanol. The methyl esters of the fatty acids (0.5 μL) were analysed in a Hewlett-Pakard 6890 series gas chromatograph (Perkin Elmer Clarus 500) equipped with a flame ionizing detector (FID) and a fused silica capillary column (WAX 52 CB, Varian). Conditions: oven temperature program, 120°C for 1 min raised to 155°C at a rate of 15°C min^{-1}; carrier gas, helium at constant pressure 250 kPa. Peak identification was made by comparing the relative retention times with those of a commercial standard mixture of FAME. The area of each fatty acid peak was expressed as a percentage of the total area.

RESULTS AND DISCUSSION

Climatic aspects

In 2019, was a dry year, the months with the lowest amounts of precipitation were September with 6.2 mm, compared to 50.9 mm multiannual average and August with 12.6 mm compared to 51.5 mm multiannual average. The highest amounts of precipitation were recorded in July with 87.4 mm, about 14.7 mm above the multiannual average. Regarding the thermal regime, in the period June - September, the registered values show that the average monthly temperatures were higher than the multiannual average, in June by 3°C above the multiannual average (Table 1).

The year 2020 was a very dry one, with accentuated water deficit and high temperatures, compared to the multiannual average. The months with the lowest rainfall were 14 mm compared to 44.6 mm on average, August with 5.4 mm compared to

49.7 mm on average and July with 34.2 mm compared to 71.4 mm on average. In May and June there were precipitation amounts close to normal, 57.8 mm and 68.4 mm, respectively. The precipitation deficit affected the installation and development of crop plants in the first phases after emergence, which had a negative impact on the final production.

Higher than average annual temperatures have exacerbated the drought. In July and August, due to the severe drought, the development of maize crop was affected. The average temperatures recorded in the agricultural year 2020 were 20.6°C, compared to the multiannual average of 18.5°C and an increase was 2.1°C.

In 2021, it was a year characterized as normal in terms of water quantities recorded, but with uneven distribution of rainfall, especially in July, August and September. Temperatures recorded an annual average of 19.1°C and a difference of 0.6°C compared to the multiannual average.

In order to establish the influence of the climatic elements, on the evolution of the sunflower culture, the values of the final production were analysed and corroborated, from a quantitative and qualitative point of view, depending on the studied factors.

Table 1. The meteorological parameters in the experimental period (2019-2021)

	Years/Months	April	May	June	July	August	September	Total/Average
Precipitations (mm)	2019	51.4	124.2	74.6	87.4	12.6	6.2	356.4
	2020	14.0	57.8	68.4	34.2	5.4	68.6	248.4
	2021	31.0	57.6	135.0	21.2	24.2	4.0	273.0
	50 years average	**44.0**	**60.0**	**73.0**	**72.7**	**51.5**	**50.9**	**352.1***
Temperatures (°C)	2019	11.2	17.2	23.6	22.9	24.7	19.3	19.8
	2020	12.4	16.8	21.8	25.1	25.5	20.8	20.6
	2021	9.7	17.2	21.1	25.3	24.2	17.3	19.1
	50 years average	**11.1**	**16.9**	**20.7**	**22.7**	**22.1**	**17.3**	**18.5****

Source of dates: NARDI Fundulea weather station; *sum; **mean.

Production and Quality

The yields registered significantly different values from one year to another, depending on the sowing dates, the plants density, the characteristics of the hybrid and the evolution of precipitations and temperatures.

In the agricultural year 2019, the experimental average was 2.5 to/ha. Climatic conditions and the combination of technology links led to minimum yields of between 1.8 to/ha (Performer, late sowing time III, plant density 70,000 pl/ha) and a maximum of 3.9 to/ha (FD19E42, early sowing time I, average plant density 50,000 pl/ha) (Figure 1).

In 2020, the deficit of soil moisture associated with very high temperatures, from May to August, led to an average value of experience of 1.5 to/ha. The lowest yields of 1.0 to/ha (Performer, sowing date III and high plant density 70,000 pl/ha), and the highest of 2.0 to/ha (FD19E42, sowing date I and average plant density 50,000 pl/ha).

The climatic conditions in 2021, corroborated with the following factors, registered an average production of experience of 2.86 to/ha. Harvest ranged from at least 2.1 to/ha (Performer, sowing date III, high density 70,000 pl/ha) and the same value of 3.8 to/ha (FD19E42 and FD15E27, early sowing date I, plant density 50,000 pl/ha).

In the case of differences between hybrids, they may be associated with other influencing factors, such as applied technology, pedoclimatic favourable and genotypic traits. Previous research has shown that the value range of production can be 2.6 to 3.3 tons in Pakistan (Ali et al., 2012), 1.34 to 3.96 tons in Turkey (Ekin et al., 2005) or 1.10 to 3.98 tonnes in Italy (Lauretti et al., 2000) in varying pedoclimatic conditions and different years.

The quantitative differences in production between the agricultural years are influenced by the climatic conditions and the technological links applied. The data obtained by us are in line with the results of European research.

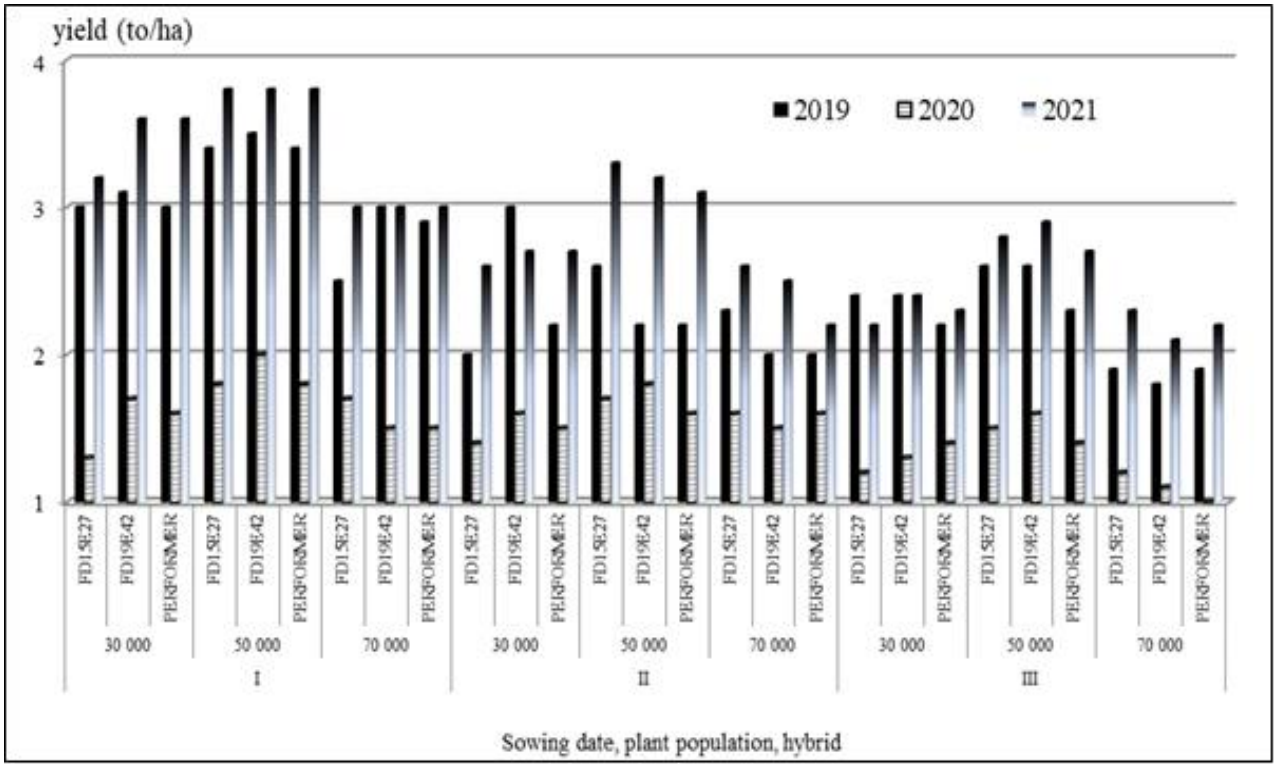

Figure 1. Yields for sunflower hybrids under experimental conditions (2019-2021)

Directly in the field, measurements were performed and data were collected on various parameters of crop growth and yield.

Seed yields (pl/ha) - the data presented in Table 2 showed that seed production was significantly and very significantly influenced by technological factors. It registered maximum values at the conditions of 2021 for the variant with a plant population of 50,000 pl/ha and the sowing dates I, with 3.8 to/ha, followed by the variant with a plant population of 50,000 pl/ha and the sowing dates II, with 3.2 to/ha. The minimum production was registered in the conditions of the year 2020 for the variant with a plant population of 70,000 pl/ha and the sowing dates III, with 1.1 to/ha, due to the installation of the pedological and atmospheric drought corroborated with the very high density of crop plants.

Seed humidity (%) - from the data obtained and presented in Table 2 it is clear that the average experience was 12%. In 2021, the highest value of seed moisture was recorded, as an average of experience, of 12.7%.

The lowest value (10.5%) was registered for the variant with sowing date II, plant population of 50,000 pl/ha in the conditions of 2020, and the highest value (13.6) was registered in the variant with sowing date III, plant population of 70,000 pl/ha in the conditions of 2019.

Plant height (m) - the interactive effects of all technological factors on plant height proved to be very significant in 2021, and the average experience was 2.13 m. The maximum plant height (2.33 m) was recorded in the variant with a plant population of 50,000 pl/ha and sowing dates II. This could be explained by the competition between crop plants, secondly, by the genetic characteristics of the taller hybrids.

Table 2. ANOVA for seeds yield, seeds humidity, emergence days and plant height (average the years 2019-2021)

Year/ Sowing Date (SD)	Plant population (PD)	Seeds Yield	Seeds Humidity	Emergence	Plant Height
		(to/ha)	(%)	(days)	(m)
2019	PD 1	3.0	12.2	10	2.20
	PD 2	3.4	12.2	10	2.09
	PD 3	2.8	12.4	11	2.12
2020	PD 1	1.5	10.1	12	2.12
	PD 2	1.9	10.4	11	2.15
	PD 3	1.6	10.1	12	2.11
2021	PD 1	3.5	11.8	9	2.30
	PD 2	3.8	11.8	10	2.28
	PD 3	3.0	11.9	10	2.00
Average SD I		**2.7**	**11.4**	**10.5**	**2.14**
2019	PD 1	2.4	12,6	10	2.30
	PD 2	2.3	12.6	11	2.20
	PD 3	2.1	12.9	11	2.21
2020	PD 1	1.5	10.6	13	2.11
	PD 2	1.7	10.5	15	2.02
	PD 3	1.6	10.9	15	1.90
2021	PD 1	2.7	12.5	9	2.32
	PD 2	3.2	12.6	10	2.33
	PD 3	2.4	12.6	10	2.19
Average SD II		**2.2**	**11.9**	**11.5**	**2.17**
2019	PD 1	2.3	13.5	10	2.30
	PD 2	2.5	13.4	10	2.28
	PD 3	1.9	13.6	11	2.19
2020	PD 1	1.3	11.4	14	1.80
	PD 2	1.5	11.4	15	1.80
	PD 3	1.1	11.8	15	1.62
2021	PD 1	2.3	13,0	9	2.20
	PD 2	2.8	13.1	10	2.30
	PD 3	2.2	13.1	10	2.22
Average SD III		**1.9**	**12.7**	**11.5**	**2.08**
ANOVA / Semnifications					
Year (Y)		**	**	**	**
Plant density (PD)		**	**	ns	**
PD*Y		**	*	*	*
Sowing date (SD)		**	*	**	*
SD*Y		**	*	**	*
PD*SD		*	ns	*	*
Y*PD*SD		**	*	*	**

*: significant at P-value <0.05; **: significant at P-value <0.01; ns: not significant.

In the laboratory were determined and recorded data on the quality of sunflower seeds. In the experiment, the mass and weight in hectolitres of 1000 seeds decreased significantly with increasing plant density.

Hectolitre weight (HW - kg/hl) recorded an average of experience about 35.8 kg/hl. The highest value had the variant with the hybrid FD19E42, the sowing date I with 39.7 kg/hl.

Weight thousands grains (WTS - g) determined an average for experience of 50.0 g, with a maximum value of 56.7 g for the variant with FD19E42 hybrid associated with sowing date I and plant density 30,000 pl/ha.

Oil content (%) - as an average value of experience recorded 47.3%. The variant with sowing date I, plant density 70,000 pl/ha for the hybrid FD19E42, with 50.0%, obtained maximum results.

Protein content (%) - average experience value of 17.6% and did not have a significant influence from the hybrid used. The highest value was recorded by the variant with the hybrid FD19E42 associated with the plant density of 70,000 pl/ha and sowing date II, with 21.0%.

The oil and protein content registered higher values with the increase of the plant density, due to the competition manifested by the large number of plants per unit area.

Table 3. ANOVA for hectolitre weight (HW), weight thousands grain (WTS), oil and protein content (average 2019-2021)

Plant density (PD) (pl/ha)	Hybrid	HW	WTG	Oil content	Protein
		(kg/hl)	(g)	(%)	(%)
30,000	FD15E27	39.7	56.7	48.0	17.1
	FD19E42	39.7	56.7	48.0	17.9
	Performer	38.0	53.5	46.2	16.5
50,000	FD15E27	32.1	41.0	44.6	15.0
	FD19E42	32.8	43.5	45.0	16.0
	Performer	31.6	41.0	44.0	15.5
70,000	FD15E27	37.2	55.5	48.9	20.1
	FD19E42	37.6	56.1	50.0	20.2
	Performer	36.8	53.2	48.0	18.2
Average SD I		**36.2**	**50.8**	**47.0**	**17.4**
30,000	FD15E27	39.1	53.1	48.4	17.6
	FD19E42	39.0	53.6	48.9	18.6
	Performer	37.2	52.6	46.9	16.4
50,000	FD15E27	31.6	40.8	45.4	15.9
	FD19E42	32.4	42.5	46.2	15.9
	Performer	30.5	40.2	44.2	15.5
70,000	FD15E27	36.9	56.1	50.2	20.3
	FD19E42	37.4	56.1	50.3	21.0
	Performer	35.1	52.0	48.5	20.0
Average SD II		**35.5**	**49.7**	**47.7**	**17.9**
30,000	FD15E27	39.3	55.2	48.0	17.5
	FD19E42	39.4	55.9	49.5	17.6
	Performer	36.2	54.0	47.3	17.0
50,000	FD15E27	32.0	40.8	44.4	15.0
	FD19E42	32.6	41.2	45.6	15.6
	Performer	32.0	39.3	43.3	15.0
70,000	FD15E27	36.4	53.8	49.0	20.1
	FD19E42	36.5	53.7	49.9	20.1
	Performer	37.6	52.3	47.3	19.2
Average SD III		**35.8**	**49.6**	**47.1**	**17.5**
ANOVA / Semnifications					
Plant density (PD)		**	**	ns	*
Sowing date (SD)		*	*	*	*
SD*PD		*	ns	*	**
Hybrid (H)		*	*	*	ns
PD*H		*	*	*	*
SD*H		ns	ns	**	*
PD*SD*H		*	*	*	*

*: significant at P-value <0.05; **: significant at P-value <0.01; ns: not significant.

The oil with high oleic acid content is mainly used in the chemical and cosmetic industry. Due to its very good resistance and stability to high temperatures and oxidation, it is particularly suitable for human consumption.

For the three sunflower hybrids, the delay of sowing decreased the content of oleic acid and increased linoleic acid, more visible in low humidity conditions than in normal condition of the year (Figure 2). Regarding oleic acid, the best results were found for the hybrid FD19E42 in 2021, followed by the hybrid FD15E27, at the same grading of factors: sowing in early or normal times, plant density of 50 thousand plants/hectare, with a content of 37.2%.

The largest decrease in oleic acid caused by the date of sowing was found in the hybrid Performer in 2008, with a difference of 7.69% between the date of early sowing and the date of late sowing. The results are consistent with the research of Sin and Partal (2012), the explanation being the negative effect of drought on the low oleic acid content.

Regarding the linoleic acid content, it registered values between 51-54.9% in 2019, between 45-49.8% in 2020 and between 53-57.8% in 2021. The differences were generated by the graduation of factors and climatic conditions of the agricultural year.

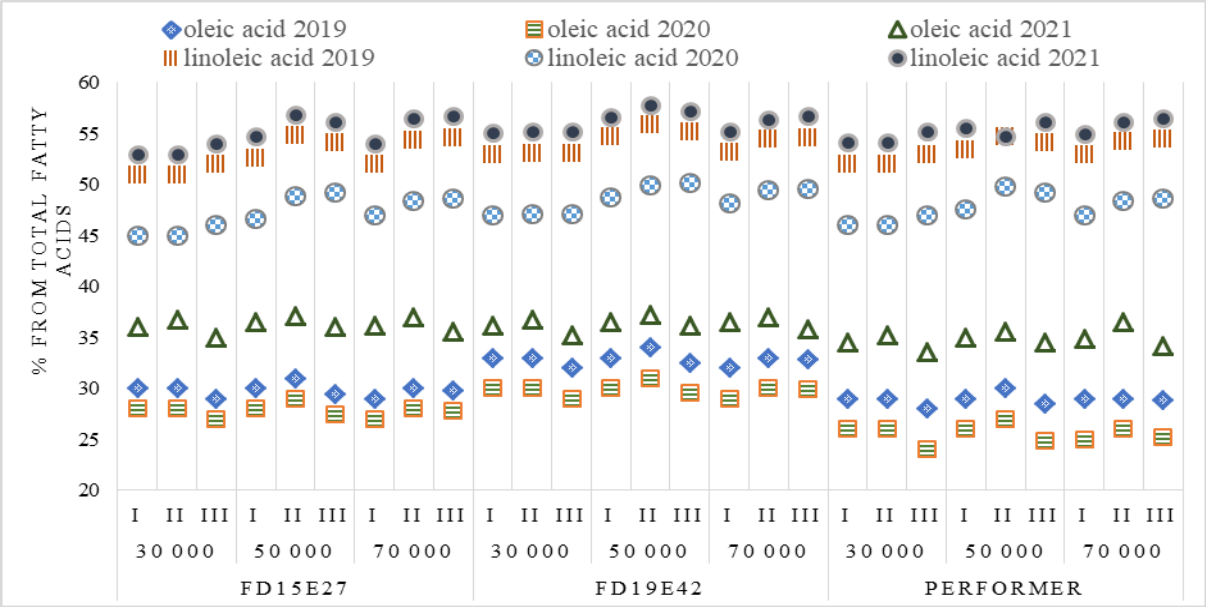

Figure 7. Oleic and linoleic acid content (% from total fatty acids) from sunflower seeds 2019-2020-2021

For both analysed components - oleic acid and linoleic acid - the hybrid FD19E42 recorded the best results, the agricultural year 2021 being the one with linear results, regardless of the technological variant, due to the favourable climatic conditions for sunflower cultivation.

CONCLUSIONS

Sunflower is significantly influenced by the date of sowing and the plant population. Both are technological links implemented to maximize and stabilize crop yield and quality.

Sunflower yields decreases significantly, up to 45-51% when the sowing period was delayed by 15 days - season III, depending on the climatic conditions of the year. The production of maximum quantity and quality is obtained at a population of 50,000 pl/ha.

The hectolitre mass and weight of 1000 seeds decreased with the increase of plant population.

Oil and protein content registered higher values with the increase of plant population, due to the influence of the population.

For the oleic acid, the best option is the hybrid FD19E42 or the hybrid FD15E27, at the same gradation of factors: sowing date I

or sowing date II, plant population of 50,000 pl/ha, with a content of 37.2%.

Regarding the linoleic acid content, the recommended option is association the FD19E42 hybrid with early or normal sowing and a plant population of 50,000 pl/ha.

The hybrid FD19E42 can be recommended in culture for high seed production and oil content, in the soil and climatic conditions of the study area or in other areas with similar conditions.

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