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THE INFLUENCE OF GREEN MANURES ON PRODUCTION AND QUALITY OF FLAX SEEDS

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ABSTRACT

To cope with the new conditions generated by climate change, a key objective of today's agriculture would be to promote the use of natural fertilization systems for both organic matter restoration, agro-ecosystem stability, biodiversity conservation, pollution limitation, sustainable use of natural resources, increasing productivity and the quality of agricultural products intended for human consumption.

In this context, the main objective of this study was to evaluate the influence of natural fertilization with green fertilizers on the productivity and quality of flax seeds, as an alternative to replacing or reducing the amounts of mineral fertilizers used. The study was conducted during 2017-2019 at the Sibiu Variety Testing Center, on 6 flax varieties for oil in 4 fertilization variants.

The results obtained in the experiment showed a different behavior of the flax varieties analyzed, depending on the genotype and environmental conditions both in terms of quantitative and qualitative characteristics.

The most productive genotype was the Cristina variety, with superior yield compared to control Lirina, for three experimental years and fertilization variants. The seed production was influenced by the type of fertilization, the non-fertilized variant registering a deficit of 300-400 kg/ha compared to mineral fertilized variants. The fertilization with green fertilizers determined the realization of similar productions to those obtained after applying mineral fertilization. Also in terms of the amount of oil/ha again the Cristina variety had an increase of over 5% compared to the control Lirina, in all fertilization variants.

All six flax genotypes analyzed respond quite favorably to the application of green manures and can certainly be integrated into a system of sustainable agriculture, ecological, organic.

Keywords: flax seeds, health, green manure, flaxseed oil, fatty acids.

INTRODUCTION

Flax (*Linum usitatissimum* L.) is considered to be one of the oldest cultivated plants known and used before our era.

Due to their physico-chemical composition flax seeds make up a multi-component system of bio-active plant substances: fats, proteins, lignans, soluble and insoluble dietary fiber, phenolic compounds, minerals (Mg, K, P, Fe, Na, Cu, Zn, Mn) and vitamins (A, E, C, F) (Bhatty, 1995).

Since 2000, the therapeutic strategy with nutritional interventions containing flax seeds has been the subject of much medical research, the results highlighting three important potential health benefits: fatty acid content (omega 3), soluble and insoluble fiber, and phytoestrogens (Gogus and Smith, 2010) which confers to the flax, functional food and nutraceutical attributions.

For the varnishes, paints, and linoleum industry, flax is the most valuable natural source of siccative oil. In some countries, it's manifests interest in obtaining some varieties of linseed oil for food use, through interventions on in linolenic acid and even linoleic acid level (Ionescu, 2006). The same

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author also mentions that the use of flax fibers in the textile industry is due to their characteristics, namely: gloss, fineness, and strength.

Increasing agricultural production through the rational use of productive resources and the technical and social modernization of agriculture directly contribute to solving the world food problem (Oancea, 2003). There are many signals which point out that increasing agricultural production without considering the application of sustainable measures can have undesirable effects over time. Berca et al. (2012) define the sustainability of the environment as well as its property of maintaining its functions, quantity, and quality of resources at the same level similar to the initial one. The same authors mention some of the factors that lead to degradation of sustainability, among which are the very intensive cultivation of land, which causes a decrease in crop yields, reduction of humus and nutrients in the soil. In this regard, the non-discriminatory use of chemicals in agriculture, excessive and deep soil works and abundant irrigation have led to soil degradation, surface, and deep water pollution and air pollution in semi-arid Mediterranean areas (Lal, 2008). The soil is considered an essential non-renewable resource, with potentially rapid degradation rates, in contrast to the extremely slow formation and regeneration processes (Van-Camp et al., 2004). Numerous researchers, including Komatsuzaki and Ohta (2007), state that there is a strong link between soil degradation and desertification processes on the one hand, and the risks of accelerating greenhouse effects and climate change, on the other. The same two authors also mention that by continuous cultivation and unbalanced fertilization that does not provide a rational replacement of nutrients in the soil, removed by harvest or lost by various processes (erosion, leaching, and gaseous emissions), physical, chemical, and biological soil properties are degraded, intensifying global warming.

The use of natural organic fertilizers can be a lever to minimize the negative effects, due to the intensive exploitation of the soil, through their content in macroelements and organic matter, improving the physical structure of the soil. These fertilizers are also economically efficient and are an important measure for sustainably increasing soil fertility.

The aim of this paper is to find new technological variants to limit or replace the mineral fertilization of flax for oil with organic fertilization with green manures.

MATERIAL AND METHODS

The biological material used in this study was represented by six varieties of flax for oil: Alexin, Lirina, Cristina, Fluin, Geria and Elan FD, all being creations of NARDI Fundulea. Also, for the establishment of the vegetal carpet destined for green fertilizers, the species were used, Phacelia (*Phacelia tanacetifolia*) the Balo variety and the black mustard (*Brassica nigra*) the ITC 21 variety, both species being singularly sown. The experiment took place over three experimental years, 2017, 2018 and 2019 and in this regard for the establishment of crops for green manure, phacelia, and mustard was sown since 2016 ensuring fertilization for the following year (2017). In order to obtain a maximum amount of green mass and to prevent the lignification of the stems, the mowing and chopping of the phacelia and mustard crops was done when at least 50% of the plants reached flowering until full flowering. After mowing, the plants debris was chopped and incorporated into the soil through a milling work, followed by plowing in autumn. We also, it was done weighed the green mass obtained per m^2 and manually moved, the mustard over a plot of phacelia to obtain a larger amount of biomass. The amount of flaxseed was calculated to provide 800 germinating grains/m^2. The experiment was placed according to the method of completely randomized blocks with three repetitions, the experimental plot being 12 m^2. Mineral fertilization was carried out simultaneously with sowing, the dose being 250 kg commercial substance/ha, complex fertilizer type N.P.K. (20-20-0).

The experimental fields are located in Sibiu County, 3 km from the city of Sibiu, on the lands under the administration of the State Institute for Variety Testing and Registration with the working point - Sibiu Variety Testing Center. The dominant soils in the area of the experiments are represented by the faeoziom and an alluvial soil strip along a stream probably formed by alluvial deposits over time and by the clearings made. The physicochemical characteristics of the soil are between the following values: pH - 6.9-7.5 (tendency to reaction slightly acidic to weakly alkaline), nitrogen - 0.190-0.220% (moderate to good supply), phosphorus - 350-450 ppm (very good to excessive supply), potassium - 300-500 ppm (very good to excessive supply) and humus - 2.3-3.3% (medium content).

RESULTS AND DISCUSSION

The evolution of temperatures and precipitation (Figures 1 and 2) recorded in the experimental field during 2017-2019 with deviations from the average of the last 55 years highlight the importance of environmental factors and their interaction with genotype and fertilization. The requirements of linseed oil for temperature are higher than necessary for the entire vegetation period being between 1800-2000 degrees and for rainfall are moderate, about 150-200 mm (with high consumption during intense growth until flowering). The year 2018 was an atypical one with drought in April-May and excess rainfall in June-July, with negative effects both on the production of green manure needed in 2019 and on the production of flax seeds and its quality.

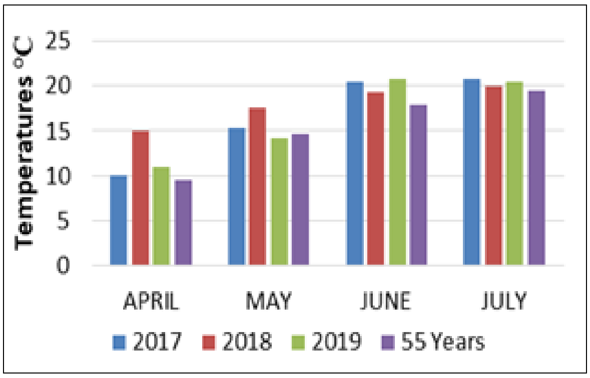

Figure 1. Evolution of temperatures (°C) 2017-2019 compared to the average of the last 55 years

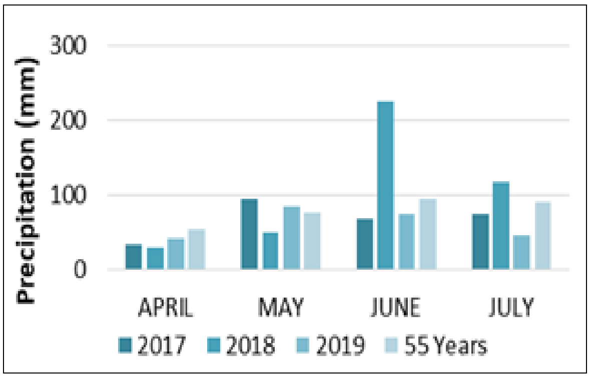

Figure 2. Evolution of precipitation (mm) 2017-2019 compared to the average of the last 55 years

Regarding soil fertility, in 2017 at the establishment of the experiment a set of chemical analyzes of the soil was performed, the samples being taken from the non-fertilized and fertilized with mustard biomass. The analyzes performed at the Office for Pedological Studies Cluj show that the soil has a weakly alkaline pH, very good to excessive supply of phosphorus, very good to excessive supply of potassium, moderate supply of nitrogen and medium humus content (Table 1).

Table 1. Soil analysis from the research field, Sibiu 2017

No	Identification	Depth (cm)	pH	N (%)	P (ppm)	K (ppm)	Humus (%)
1	Unfertilized	0-20	7.72	0.196	360	344	2.66
2	Unfertilized	20-40	7.82	0.183	350	308	2.29
3	Fertilization phacelia + mustard	0-20	7.59	0.202	416	472	3.20
4	Fertilization phacelia + mustard	20-40	7.70	0.174	400	456	2.37

The analysis of the variance for seeds production obtained for the 6 flax varieties, in the 3 experimental years, for different fertilization variants (Table 2), indicates that all the factors studied, but also the interactions between them have a very significant influence on of this character.

Table 2. Analysis of variance for seed production of flax

Source of variation	SP	DOF	S^2	F
A (year)	21332980	2	10666490	94424.66***
B (fertilizer type)	3836639	3	1278880	1382.34***
A x B	105225	6	17537.5	18.956***
C (variety)	6596099	5	1319220	940.682***
A x C	267393.5	10	26739.35	19.067***
B x C	95216.64	15	6347.77	4.526***
A x B x C	95269.47	30	3175.64	2.264***
Other types of interactions	198799.98	144	13697.38	
Error A	451.8518	4	112.96	
Error B	16652.77	18	925.154	
Error C	168288.9	120	1402.40	

Productivity heredity is very complex being the result of all productivity elements, polygenically controlled quantitative characters. Regarding the influence of the experimental conditions on the grain production in the three experimental years (Table 2), it was found that the first year was clearly differentiated from the other ones. This year's climatic conditions allowed a higher production than the other two years, with a very significant positive difference from the experience average, ensuring a production increase of 20%.

As expected, seeds production was strongly influenced by the type of fertilizer applied. In the case of mineral fertilization, the highest yield was obtained (2255 kg/ha). Our results shown that flax also reacts positively to the application of organic fertilizers, the yields obtained in this case being statistically assured as very significant positive than the variant without fertilization. There was a positive yield response to green fertilization (whit phacelia and phacelia combined with mustard) with an increase of production of 215, respectivly 316 kg/ha compared to the control.

Of the 6 flax varieties studied, with a upper seed production per unit area, compared to the Lirina variety, the Cristina variety was noted (2413 kg/ha), the difference of 107 kg/ha recorded compared to the control being very significant positive (Table 3).

Table 3. Influence of experimental conditions on seed production (kg/ha) for studied flax varieties (2017-2019)

Source of variance	Yield (kg/ha)	Difference (%)	Difference (kg/ha)	Significance
Year (A)				
Years average	2148	100	0	Control
A_1 - 2017	2568	120	420	***
A_2 - 2018	1812	84	-336	000
A_3 - 2019	2064	96	-84	000
LSD 5%: 4.92 LSD 1%: 8.15 LSD 0.1%: 15.25				
Fertilization (B)				
B_1 - unfertilized	1923	100	0	Mt.
B_2 - fertilization with phacelia	2175	113	252	***
B_3 - fertilization with phacelia + mustard	2239	116	316	***
B_4 - mineral fertilization	2255	117	330	***
LSD 5%: 12.13 LSD 1%: 16.64 LSD 0.1%: 22.65				
Variety (C)				
Lirina	2306	100	0	Mt.
Alexin	2155	94	-151	000
Geria	2062	89	-244	000
Cristina	2413	105	107	***
Fluin	2078	90	-228	000
Elan FD	1873	81	-433	000
LSD 5%: 17.48 LSD 1%: 23.13 LSD 0.1%: 29.75				

By analyzing the interaction between variety and type of fertilization influence on the oil content, it is observed that the analyzed biological material reacted differently to applied fertilizers. Without fertilization, the Lirina variety used as control, had the highest oil content compared to 4 of the other 5 analyzed varieties (Table 4). Mineral and organic fertilization led to an increase in oil for Cristina variety with very significant positive difference in the case of organic fertilization respectively significant positive difference following the application of mineral fertilization.

Table 4. The influence of the variety x type of fertilization interaction on the oil content (%) for the 6 flax varieties studied

No	Genotype	Oil (%)	%	Diff.	Oil (%)	%	Diff.	Oil (%)	%	Diff.	Oil (%)	%	Diff.
		B1			**B2**			**B3**			**B4**		
1	Lirina	46.3	100	Mt.	46.37	100	Mt.	46.71	100	Mt.	46.89	100	Mt.
2	Alexin	45.57	98.3	000	46.39	100	-	46.68	99.9	-	46.9	100	-
3	Geria	46.17	99.6	-	46.52	100.3	-	46.72	100	-	46.6	99.4	00
4	Cristina	46.01	99.3	000	46.99	101.3	***	47.27	101.2	***	47.2	100.7	**
5	Fluin	45.7	98.6	000	46.39	100	-	46.31	99.1	000	46.21	98.6	000
6	Elan FD	45.79	98.8	000	46.48	100.2	-	46.67	99.9	-	46.68	99.5	0
LSD 5%: 0.18; LSD 1%: 0.24; LSD 0.1%: 0.31													

Genotype and environment interaction was analyzed using linear regression techniques. There was considerable variation for grain yield among both genotypes and environments. Stability was estimated using the Eberhart and Russell method (Figure 3). According to the stability analysis variety Cristina was the most stable for grain yield in all three experimental years. If in the climatic conditions of 2018 all 6 studied varieties obtained grain yield under 2200 kg/ha, the highest productions were obtained in 2017 year. If Cristina variety reached the highest yield in all 3 experimental years, Elan TD variety was the most sensitive to environmental changes and can be recommended for cultivation under favorable conditions.

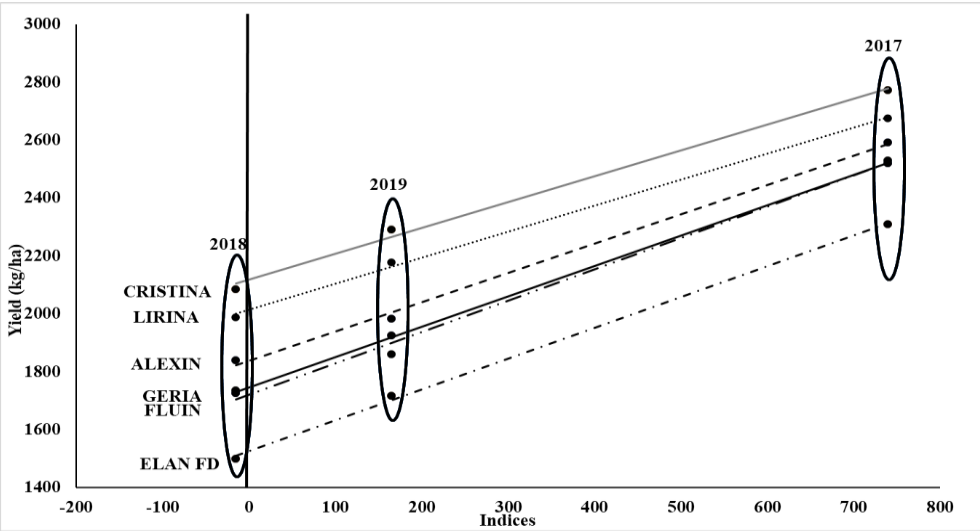

Figure 3. Yield stability analysis for 6 flax varieties, using Eberhart and Russell method

From the analysis of the influence of the interaction of the varieties with the types of fertilization studied on the seed production (Figure 4), a different reaction of the material to the four types of fertilizer was highlighted. The Cristina variety had a positive response to all fertilization options, with very significant positive differences compared to the control Lirina. Most varieties achieved the highest yields following the application of mineral fertilization, with the exception of Alexin and Elan FD varieties which reached maximum yields of 2147 kg/ha, respectively 1968 kg/ha in the fertilized version with green manure (phacelia + mustard).

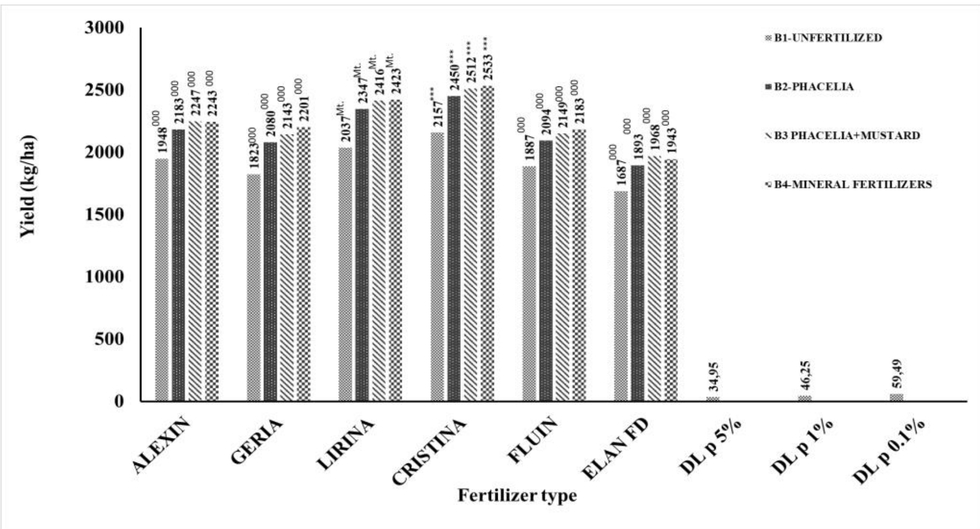

Figure 4. Influence of variety x fertilization interaction, on seed production (kg/ha) (2017-2019)

The calculation of the correlation coefficients helps to identify the degree of association between the studied agronomic properties. Table 5 shows the correlation coefficients analyzed in the experiment, highlighting the existence of significant correlations between the studied characters. There is a significant positive relationship between the production obtained and the number of capsules per plant (r = 0.88*). Similar results were obtained by Rajesh (2011) who studied the correlations between seed production and different agronomic indices at 10 flax genotypes.

Table 5. Correlation coefficients (r) between the analyzed productivity elements and the main quality indices for the flax genotypes studied (2017-2019)

	Plant height (cm)	TKW (g)	No. of capsule/ plant (no)	Yield (kg/ha)	Oil content (%)
Plant height (cm)	1				
TKW (g)	0.32	1			
No. of capsule/ plant (no)	-0.68	-0.10	1		
Yield (kg/ha)	-0.49	0.23	0.88*	1	
Oil content (%)	-0.75	-0.55	0.58	0.45	1

The involvement of environmental factors in the formation of productions is obvious, so at the level of 2018 the yields obtained were below the threshold of 1800 kg/ha (Figure 5). In the other 2 experimental years, the 6 varieties compared achieved higher yields in 2018, especially the year 2017, a year favorable for flax cultivation with yields of over 2400 kg/ha.

The rather pronounced upward trend of regression lines and the high values of the determination and correlation coefficients calculated for each year, suggest the close link between the number of capsules/plant and seed production.

An important element that contributes to the realization of the production is the mass of 1000 kernals (TKW). Figure 6 shows the grain size recorded for the 6 varieties of flax studied. It can be seen that this character is closely related to the biological factor, being less influenced by the type of fertilizer applied. The Lirina variety, used as a control, recorded the lowest values of this parameter, at the opposite pole being the Alexin variety with TKW values of 9 g.

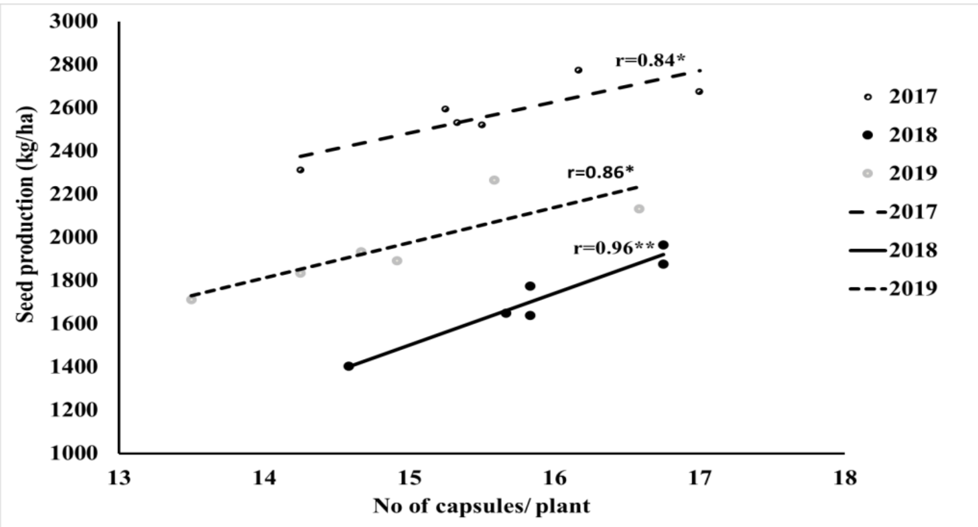

Figure 5. Relationship between the number of capsules/plant and flaxseed production (2017-2019)

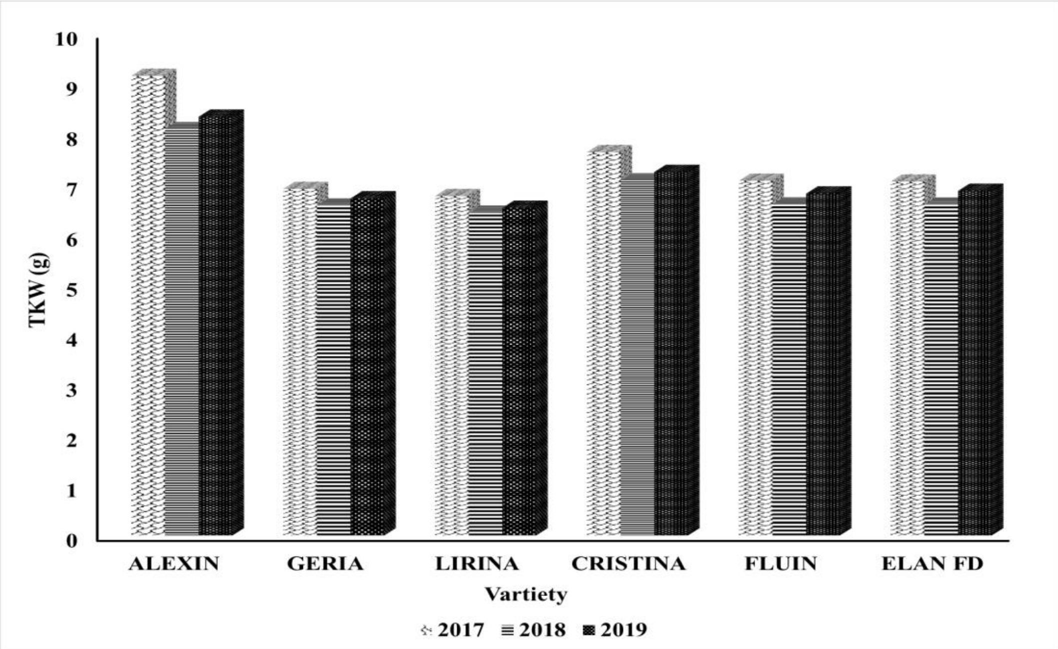

Figure 6. Mass of 1000 kernels in the 6 varieties of flax studied (2017-2019)

Flax seeds have a special importance in the human diet being one of the most important sources of polyunsaturated fatty acids (Popa, 2012). The amount of oil per hectare for the analyzed flax varieties varied depending on the genotype and was also influenced by the type of fertilizer applied. It is observed that the mineral fertilization determined the accumulation of the largest amount of oil in the seeds in the case of the entire biological material analyzed, again noting the Cristina flax variety in which it was obtained, in this fertilization variant, on average over the 3 experimental years, an amount of oil of 1083 kg/unit area (Figure 7). The Lirina flax variety, used as a control of the experiment, had a good behavior in terms of oil content/ha, Cristina being the only variety that, compared to the witness, accumulated a larger amount of oil in all the fertilizer variants experienced.

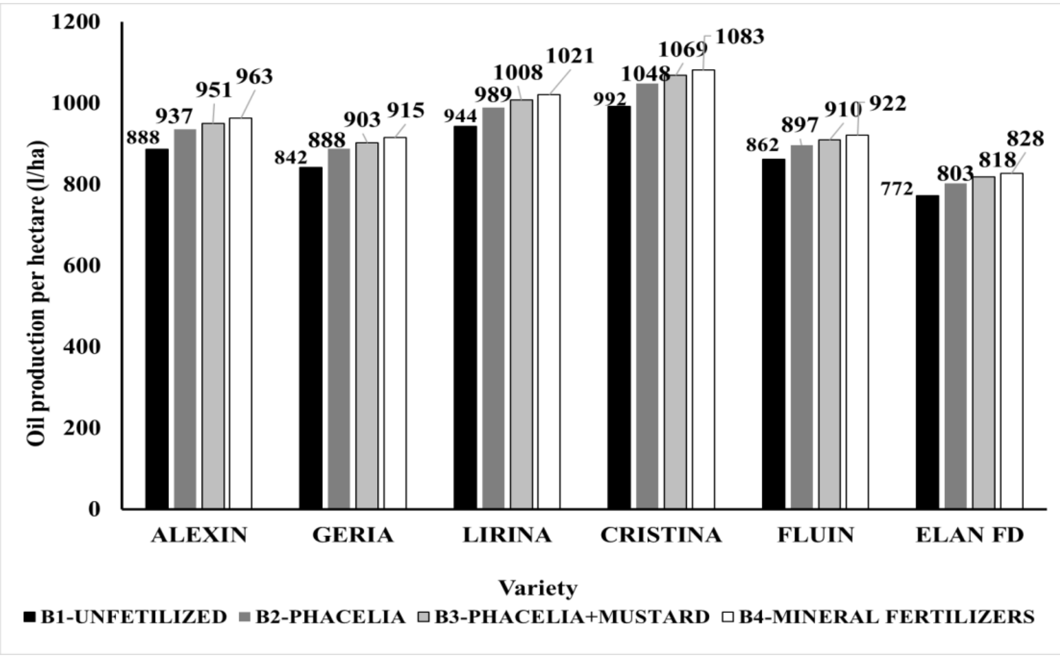

Figure 7. The amount of oil per ha for the 6 flax varieties studied (2017-2019)

CONCLUSIONS

The results obtained in the experiment showed a different behavior of the analyzed flax varieties, depending on the environmental conditions and the experimental conditions.

The most productive genotype was the Cristina variety, which obtained superior yields to the control Lirina in the three experimental years for all fertilization variants. The year 2017 offered the analyzed cultivars to achieve high yields, of over 2300 kg/ha, the maximum production being reached by the Cristina variety (2850 kg/ha for mineral fertilization).

The seed production was strongly influenced by the type of fertilization applied, in the non-fertilized variant the production losses being, on average, 332 kg/ha compared to the control variant (mineral fertilization).

The green fertilizers determined the realization of some productions similar to those obtained after the application of the mineral fertilization, the differences compared to the control being insignificant.

Flaxseed quality was also influenced by environmental factors, fertilizer type and genotype. The highest values of the amount of oil/ha were obtained, again, for the Cristina variety, which in all experimental variants had an increase of over 5% compared to the control Lirina.

Therefore, it could be stated that all six flax genotypes analyzed respond quite favorably to the application of green manures and can certainly be integrated into a system of ecological, organic farming which to leads to the production of nutraceuticals products.

Included in the daily diet of consumers or nutraceuticals, flax seeds open the gates of the 21st century by their contribution to improving the availability of healthy food choices, increasing the nutritional profile of foods, reducing the consumption of salt, sugar and saturated fats, by improving the content of fatty acids ω-3 and bioactive compounds (Goyal et al., 2014).

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