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RESEARCH ON THE INFLUENCE OF FERTILIZATION ON YIELD AND ECONOMIC EFFICIENCY AT SOYA CULTURE

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Abstract: *The purpose of this paper is to evaluate the soybean yield obtained from the application of the additional fertilization and economic efficiency determination. Experimental factors: Factor A - the fertilization: $a_1-N_{20}P_{20}K_0$ (100 kg/ha), applied simultaneously with sowing, $a_2-N_{20}P_{20}K_0$ (100 kg/ha), applied simultaneously with the sowing + $N_{20}P_{20}K_0$ (100 kg/ha), applied in the 4-6 leaves phenophase, $a_3-N_{20}P_{20}K_0$ (100 kg/ha) applied simultaneously with sowing + N_{30} (100 kg/ha), applied in the 4-6 leaves phenophase and $a_4-N_{20}P_{20}K_0$ (100 kg/ha) applied simultaneously with sowing + N_{20} (100 kg/ha), applied in the 4-6 leaves phenophase; factor B - soybean varieties: b_1 -Mălina TD, b_2 -Darina TD, b_3 -Felix and b_4 -Onix; factor C - climatic conditions in the experimental years: c_1 -2015; c_2 -2016; c_3 -2017. By applying additional fertilization are obtained a very significant yields of over 120 kg/ha. The Mălina soybean variety achieved an average yield of 2706 kg/ha, in the period 2015-2017, with differences significantly higher than the other three varieties studied under the same conditions. The thermal and pluviometric regime is an important factor in determining the yield of a crop, in 2015 was obtained an average yield of 1912 kg/ha, and in the years 2016 and 2017 achieved the yield of 3447 kg/ha respectively 2329 kg/ha, with significantly higher differences than in 2015. The yield of the four varieties is in direct relationship with the level of fertilization.*

Keywords: *soybean, yield, fertilization, economic efficiency, climatic conditions*

Classification JEL: *Q 01, Q15, Q16*

INTRODUCTION

Daily, human activities affect the climate by using fossil fuels and chemical inputs in high quantities, producing a significant amount of CO₂, but in order to avoid irreversible damage to the environment, a number of alternatives have been found in agriculture, one of the main producers of greenhouse gases that increase temperature, the most important measures being taken in terms of fuel reduction through the use of conservative tillage systems.

Conservative tillage are alternative variants in soil processing to remove risk factors, the introduction of which is determined by the fact that the intense tillage has generated over time the degradation of soils in the arable and sub-arable layer.

The implementation of conservative tillage systems involves, besides knowing the level of soil suitability for different methods of processing, an information base on alternative technologies, a material basis specific to the minimum soil processing and their sustainability (Guș, 1997).

The principles on which conservative agriculture is based are the reduction of the number of agricultural tillage, the optimal rotation of crops, the preservation of at least 30% of the soil vegetal remains (Chețan et al., 2015), which have a role in soil protection against erosion (Șimon et al., 2016), increasing soil organic matter content (Malecka et al., 2012), biodiversity stimulation, soil water retention (Marin et al., 2015) and the introduction of a leguminous plant in rotation.

Soybean (*Glycine max* (L.) Merrill.) is an important and valuable field crop, used as a source of food for both man and animals (Conner et al., 2004), with high agrotechnical importance because it plays a special role in crop rotation, being a good precursor to most crop plants and symbiosis relationships with bacteria of the genus *Rhizobium*, contributes to a significant extent to improving soil attributes by raising fertility levels (David, 2005).

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MATERIAL AND METHOD

The experiment was conducted between 2015-2017 at Turda Agricultural Research and Development Station (ARDS Turda) on a faeozem verticus soil with neutral pH, clay loam texture, medium humus content, good supply of mobile phosphorus and potassium.

The soybean was sown at a distance of 18 cm, with the Gaspardo Directa 400 seed drill at 65 g.s./m². The tillage system used in the experiment is the conservative system (chisel variant at 30 cm depth) with the basic work done after the harvesting of the pre-culture and the preparation of the germinating bed with the rotary harrow before sowing. The soybean has been grown in a crop rotation system for 3 years, the pre-plant being corn.

Experimental factors are: factor A-fertilization levels: b₁-N₂₀P₂₀K₀ (100 kg/ha), applied simultaneously with sowing; b₂-N₂₀P₂₀K₀ (100 kg/ha), applied simultaneously with sowing + N₂₀P₂₀K₀ (100 kg/ha), applied in the 4-6 leaves pheno-phase; b₃-N₂₀P₂₀K₀ (100 kg/ha) applied at the same time as sowing + N₃₀ (100 kg/ha) applied to 4-6 leaves pheno-phase and b₄-N₂₀P₂₀K₀ (100 kg/ha) applied simultaneously with sowing + N₂₀ (100 kg/ha) applied in the 4-6 leaves pheno-phase; factor B - soybean varieties: b₁-Mălina TD, b₂-Darina TD, b₃-Felix and b₄-Onix; Factor C - climatic conditions in the experimental years: c₁-2015; c₂-2016; c₃-2017.

After sowing, a treatment was performed to control existing or emerging weeds with Tender (1.5 l/ha) and Sencor (0.35 l/ha). Control of monocotyledonous and dicotyledonous weeds was performed with Pulsar herbicides (1.0 l/ha) and Agil (1.0 l/ha) in weed rosette pheno-phase.

To protect the soybean culture against the red spider (*Tetranychus urticae*) a treatment with Omit 570 EW (0.8 l/ha) insecticide was performed, and the fungus disease (*Peronospora manshurica*) was treated with Ridomil Gold MZ 68 WG (2.5 kg/ha).

The obtained results were statistically processed by the variance analysis method and the lowest significant difference was determined - LSD - (5%, 1% and 0,1%) (ANOVA, 2015).

Climate conditions are a determinant of agricultural yield, and the analysis of the evolution of climatic factors is justified in the current context of climate change that is increasingly visible both globally and in our country.

The climatic conditions of the years 2015-2017 are presented according to the Turda Meteor Station located on the longitudinal coordinates: 23°47'; latitude 46°35'; altitude 427 m. During the last 60 years, the recorded multiannual average temperature was 9,1°C (Table 1) and the precipitation amount was 531 mm (Table 2).

The average temperatures recorded during the soybean crop growing months varied over the three years but were higher than the 60-year average with +1,5°C in 2015 being considered a warm year, with +0,9°C in year 2016, a year considered warm and +1,4°C in 2017, year considered hot.

The rainfall during the vegetation period and its uniformity is very important in achieving the yield, so that in 2016 from the emergence of soybean crop to harvest every month the amount of rainfall exceeded the multiannual average, the soybean crop benefiting from the entire amount reflected in significant yield, compared over the other two years, were periods when the lack of rainfall was felt by culture, especially in the fact that during the important times the amount of precipitation was low or lacking.

Table 1. Average air temperature (°C), Turda 2015-2017

Monthly average	2015												Annual average
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
	-0.7	0.0	5.5	9.6	15.8	19.4	22.3	21.9	17.3	9.7	6.1	0.7	10.6
Average 60 years	-3.4	-0.9	4.7	9.9	15.0	17.9	19.7	19.3	15.1	9.5	3.9	-1.4	9.1
Deviation	+2.7	+0.9	+1.2	-0.3	+0.8	+1.5	+2.6	+2.6	+2.2	+0.2	+2.2	+2.3	+1.5
Monthly average	2016												Annual average
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
	-2.8	4.6	5.9	12.4	14.3	19.8	20.5	19.6	17.1	8.3	2.9	-2.7	10.0
Average 60 years	-3.4	-0.9	4.7	9.9	15.0	17.9	19.7	19.3	15.1	9.5	3.9	-1.4	9.1
Deviation	+0.6	+5.5	+1.2	+2.5	-0.7	+1.9	+0.8	+0.3	+2.0	-1.2	-1.0	-1.3	+0.9
Monthly average	2017												Annual average
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
	-0.7	0.0	5.5	9.6	15.8	19.4	22.3	21.9	17.3	9.7	6.1	0.7	10.6
Average 60 years	-3.4	-0.9	4.7	9.9	15.0	17.9	19.7	19.3	15.1	9.5	3.9	-1.4	9.1
Deviation	+2.7	+0.9	+1.2	-0.3	+0.8	+1.5	+2.6	+2.6	+2.2	+0.2	+2.2	+2.3	+1.5

Monthly average	Ian.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
	-6.7	1.5	8.4	9.9	15.7	20.7	20.3	22.3	15.8	11.6	4.9	1.0	10.5
Average 60 years	-3.4	-0.9	4.7	9.9	15.0	17.9	19.7	19.3	15.1	9.5	3.9	-1.4	9.1
Deviation	-3.3	+2.4	+3.7	0.0	+0.7	+2.8	+0.6	+3.0	+0.7	+2.1	+1.0	+2.4	+1.4

Source: Turda Meteo Station, longitude: 23⁰47'; latitude 46⁰35'; altitude 427 m

Table 2. Recorded precipitation (mm), Turda 2015-2017

Month. amount	2015												Annual amount
	Ian.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov	Dec	
	12.3	20.9	12.8	32.2	66.0	115.7	52.2	72.2	172.6	45.4	32.0	6.9	641.2
Av. 60 years	21.8	18.8	23.6	45.9	68.7	84.8	77.1	56.5	42.5	35.6	28.5	27.1	531.0
Deviat.	-9.5	+2.1	-10.8	-13.7	-2.7	+30.9	-24.9	+15.7	+130.1	+9.8	+3.5	-20.2	+110.2
Month. amount	2016												Annual amount
	Ian.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov	Dec	
	25.0	23.8	47.0	62.2	90.4	123.2	124.9	91.0	24.6	152.2	45.3	7.2	816.8
Av. 60 years	21.8	18.8	23.6	45.9	68.7	84.8	77.1	56.5	42.5	35.6	28.5	27.1	531.0
Deviat.	+4.2	+5.0	+23.4	+16.3	+21.7	+38.4	+47.8	+34.5	-17.9	+116.6	+16.8	-19.9	+285.8
Month. amount	2017												Annual amount
	Ian.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov	Dec	
	2.6	19.2	46.1	65.2	65.4	30.6	110.2	36.1	56.2	49.2	30.8	20.7	532.3
Av. 60 years	21.8	18.8	23.6	45.9	68.7	84.8	77.1	56.5	42.5	35.6	28.5	27.1	531.0
Deviat.	-19.2	+0.4	+25.5	+19.3	-3.3	-54.2	+33.1	-20.5	+13.7	+13.6	+2.3	-6.4	+1.3

Source: Turda Meteo Station, longitude: 23⁰47'; latitude 46⁰35'; altitude 427 m

RESULTS AND DISCUSSIONS

Although soybean is a leguminous plant, it reacts very well to additional fertilization, bringing production yields of 245 kg/ha in the variant with 100 kg/ha of N₂₀P₂₀K₀, 160 kg/ha in the variant with 100 kg/ha of N₃₀ and 112 kg/ha in the version where 100 kg/ha of N₂₀ was applied, compared to the control variant where only basic fertilization was applied, these differences being statistically assured as very significant positive. From the data presented in Table 3, it can be seen that soybean is best harnessing the additional fertilization containing complex fertilizers.

Similar data was also obtained from the experiments performed by Chețan et al. (2017), suggesting that an additional fertilizer of N₄₀ kg/ha can bring a significant increase in production of more than 85 kg/ha of soybeans.

Table 3. Influence of fertilization factor on soybean production, Turda 2015-2017

Fertilization variant	Yield (kg)	Difference (kg)	Significance
N ₂₀ P ₂₀ K ₀ (100 kg/ha) (control variant)	2461	-	mt.
N ₂₀ P ₂₀ K ₀ (100 kg/ha) + N ₂₀ P ₂₀ K ₀ (100 kg/ha)	2703	242	***
N ₂₀ P ₂₀ K ₀ (100 kg/ha) + N ₃₀ (100 kg/ha)	2621	160	***
N ₂₀ P ₂₀ K ₀ (100 kg/ha) + N ₂₀ (100 kg/ha)	2573	112	***
LSD (p 5%) 13 LSD (p 1%) 29 LSD (p 0,1%) 57			

In the period 2015-2017 the soybean genotypes created at ARDS Turda recorded significant average yields, the highest being obtained by Mălina TD (2706 kg/ha), with a very significant increase in yield compared to the other three varieties studied during this period, the recorded yields of these varieties ranging from 2518 kg/ha to 2599 kg/ha, as can be seen from the data presented in Table 4.

The research done by Mureșanu et al. (2014) during the period 2007-2013 show that, following the yield results obtained by the four varieties created at SCDA Turda, the Felix and Onix varieties recorded slightly lower yields than Mălina TD, but Darina TD was noted for yield higher by about 42 kg/ha compared to Mălina TD.

Table 4. Influence of the variety factor on soybean yield, Turda 2015-2017

Variety	Yield (kg)	Difference (kg)	Significance
Mălina TD (control variant)	2706	-	mt.
Darina TD	2534	-172	000
Onix	2518	-188	000
Felix	2599	-107	000
LSD (p 5%) 6 LSD (p 1%) 18 LSD (p 0,1%) 36			

The climatic conditions of the growing season of an agricultural crop play an important role in achieving total production, the uniformity and the amount of rainfall correlated with the temperatures of the important vegetation pheno-phases being decisive in the formation of yield.

Drought is the main factor of abiotic stress that limits the productivity of culture worldwide, and the availability of water plays a major role in regulating the quantitative parameters of a culture. The water stress of the pods formation and the filling phase of the grain has the greatest negative effect on the number of pods per plant and the number of grain in the pod, being considered a major threat to soybean yield worldwide.

The significant amount of rainfall at each important moment in the soybean development period meant that in 2016 the yield was significantly higher than in the other two years studied and implicitly on the average of the three years considered as a control variant after as shown in Table 5.

Cheţan et al. (2013) conducted research on the influence of fertility level factors, soil cultivation system and climatic conditions on soybean yield, suggesting that in soybean crops, significant yields of up to 4047 kg/ha could be achieved.

Table 5. Influence of the year factor on soybean yield, Turda 2015-2017

Experimental year	Yield (kg)	Difference (kg)	Significance
Average years (control variant)	2589	-	mt.
2015	1912	-667	000
2016	3447	858	***
2017	2329	-260	000
DL (p 5%) 20 DL (p 1%) 45 DL (p 0,1%) 144			

The economic efficiency of an agricultural production activity is an essential aspect because it is important for the proper functioning of the recovery of the expenses and the obtaining of the profit. The bulk of the expenditure for the establishment of one hectare of soybean comes from the materials used, followed by fuel consumption expenditure required for all mechanical works and salary mechanized, as shown in Table 6.

Table 6. Total expenditures and economic efficiency

Fertilization variant	Hand works (lei)	Materials cost (lei)	Fuel cost + salary mechanized (lei)	Total costs (lei)	Economic efficiency (lei)
N ₂₀ P ₂₀ K ₀	93,62	1339,62	490,2	1923,44	-
N ₂₀ P ₂₀ K ₀ + N ₂₀ P ₂₀ K ₀	101,72	1482,62	507,35	2091,69	168,25
N ₂₀ P ₂₀ K ₀ + N ₃₀	101,72	1450,72	507,35	2059,79	136,35
N ₂₀ P ₂₀ K ₀ + N ₂₀	101,72	1413,65	507,35	2022,72	99,28

Soybean, besides being one of the most important plants in food and agro-technical use, it is also one of the most profitable agricultural crops, because even under unfavorable climatic conditions it produces profits. From the data presented in Table 7, it can be noticed that the resultant

sales result in an important profit, even a main yield of more than 1100 kg/ha can bring profit, without taking into account the secondary production obtained by baling the residues plant.

Table 7. Profit obtained on the basis of the level of fertilization and the average yield obtained during the period 2015-2017

Fertilization variant	Total costs (lei/ha)	Yield (kg/ha)	Price soybean (lei/kg)	Revenues selling soybean (lei/ha)	Profit (lei/ha)
N ₂₀ P ₂₀ K ₀	1923,44	2461	2	4922	2998,56
N ₂₀ P ₂₀ K ₀ + N ₂₀ P ₂₀ K ₀	2091,69	2703	2	5406	3314,31
N ₂₀ P ₂₀ K ₀ + N ₃₀	2059,79	2621	2	5242	3182,21
N ₂₀ P ₂₀ K ₀ + N ₂₀	2022,72	2573	2	5146	3123,28

CONCLUSIONS

The soybean culture responds positively to the application of additional fertilization, especially by the application of complex fertilizers, obtaining very significant yield increases as compared to the yields obtained from basic fertilization.

Soybean is an important crop in both human and animal nutrition as well in crops rotation, but it is also economically profitable, especially in years where yields exceed 2000 kg/ha.

Of the four varieties studied, the most profitable was the Mălina TD variety, which recorded the highest average production of 2015-2017 at 2706 kg/ha.

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