SOIL PROTECTION STUDY THROUGH THE APPLICATION OF COMPLEX METHODS FOR SUSTAINABLE MANAGEMENT OF THE SOYBEAN AGROSYSTEM

Felicia Cheţan[1], Loredana Suciu[1,2], Cornel Cheţan[1], Adina Tărău[1], Ioana Crişan[1], Felicia Mureşanu[1]*
[1]Agricultural Research and Development Station Turda, Romania
[2]University of Agricultural Sciences and Veterinary Medicine, Faculty of Agriculture, Cluj-Napoca, Romania

*Corresponding author:
Agricultural Research and Development Station Turda
27 Agriculturii Street, 401100, Turda, Cluj, Romania
Tel: + 40264311680(1)
Fax: + 40264311792
E-mail:felice_fely@yahoo.com

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Abstract: The degradation of natural soil fertility is caused by practicing the classic tillage system (ploughing with the furrow return) and using high doses of chemical fertilizers. It is necessary to adopt soil tillage techniques that aim to preserve and improve soil fertility without decrease production. In Romania, soybean crop, could be an economic boost for the agriculture sector because it reduces the costs required for the procurement of vegetable protein needed for the livestock and food sector, soybeans being a plant that fixes nitrogen from various sources (precipitation, activity of *Bradyrhizobium japonicum* bacteria, humus mineralization and residual nitrogen). From the research conducted between 2018-2020 at ARDS Turda, regarding the soybean root nodules cultivated in four tillage systems (CS - plough, MC - chisel, MD - disk and NT- direct sowing) with the technology specific to each system, the results indicate that in a conservative system the soybeans yield correlates positively with the number and weight of nodules formed. Organo-mineral fertilization (green fertilizer - autumn rape + gulle manure + $N_{40}P_{40}$) contributes significantly positively to the number and the weight of nodules and increases the yield. As an alternative to the CS, soybean can be cultivated in a minimum tillage system (MC), the yield difference compared to the classical system (plough) being insignificant, just 38 kg. The pedo-climatic conditions of the experimental area it is favourable for this crop and for the fixation of atmospheric nitrogen, without requiring high doses of mineral fertilizers.
Key words*: soybean, tillage system, nodules, yield*

INTRODUCTION

As a basic work, the ploughing followed by seedbed preparation and the maintenance agricultural techniques specific to the classical tillage system involve an intense traffic of machines, which in time lead to soil compaction (increases the bulk density, decreases the total porosity and hydraulic conductivity, changes the regime aero-hydric, etc.). As a result of soil compaction, the negative effect on agricultural crop is reflected by reducing the production potential (Grigore et al., 2019; Rusu & Guş, 2007; Marchenko et al, 2009). Alternative minimum cultivation and no cultivation systems involve reduced intervention on the soil, keeping plant debris at the soil surface by at least 50-60% performing the role of soil-protecting mulch. Soil is thus protected from surface erosion, soil aggregates are stabilized, organic matter and fertility levels will increase, soil compaction and decrease in CO_2 emissions, increased biodiversity (Pisante & Stagari, 2011; Marin et al., 2015; Sabo et al., 2007; Topa et al., 2012). Vegetable residues left on the soil's surface protect it and, under the action of microorganisms and macroorganisms in the process of transformation, contribute to the improvement of soil structure (Ulrich et al., 2006; Wozniak et al., 2014).

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Choosing the optimal technological variant must take into account the soil's properties: texture, humidity, soil exposure, macro and microclimate, humus content, etc., but also the climatic conditions of the agricultural year and the technological capacity to capitalize on these resources (Stefănic et al., 1997; Szajdak & Rusu, 2016).

In the Transylvanian Plain there is an interaction of a large number of limiting factors for agricultural technologies, two of which show a dominant action. The first is the thermal factor with low temperature level and with large temporal variations and the second is the hilly orography of the land with numerous soils degraded by erosion (Rusu et al., 2009; 2014; Cheţan & Cheţan, 2014; Cheţan et al., 2019). Recently, there has been a slight increase in average annual temperatures, as well as a high fluctuation in the distribution of rainfall (Ignea, 2017).

The particular importance of soybean comes from its multiple usages both in the alimentation of people (oil, the mature beans and the green hulls are used in various food recipes), (Subramanian & Smith, 2013; Cvijanovic & Cvijanovic, 1988), and in the feeding of animals as well as in industry (oils for painting, the production of plastic mass, the preparation of margarine), and it is also used in the regeneration of the physical properties of the soil due to the symbiosis which is installed between the radicular system and the *Bradyrhizobium japonicum* bacteria, this symbiosis resulting in the development of special formations (nodules) for the function of fixing atmospheric nitrogen for the benefit of the plant (Stevanović et al., 2016; Popović et al., 2016, 2018). Keyser & Li (1992) mentions that „the soybean-*Bradyrhizobium* symbiosis can fix about 300 kg N/ha under good conditions". It is known that soil acidity (pH) affects nitrogen fixation, a pH of less than 6.0 decreases the production and number of root nodules of legumes (Guş et al., 2004). If there are colonies of *Rhizobium* in the soil, that cause the formation of nodules on the roots of the silk, plants are able to use atmospheric nitrogen, usually unable to fully secure their atmospheric nitrogen, therefore some must be obtained from the soil (through applied mineral fertilizers). Of the total nitrogen needed for soybeans, 70% are provided symbiotically (Vidican et al., 2013; Li et al., 2020). After the soy crop, the need for nitrogen fertilizers is greatly reduced, and against the background of this culture increases the efficiency of phosphate and potash fertilizers with an economic and agrotechnical efficiency (Höflich et al., 1999; Peoples et al., 2009; Cheţan & Cheţan, 2014).

New variants of soil cultural technologies were studied in order to reduce the negative impact of drought.

The paper presents the results of research conducted during 2018-2020, regarding the root nodules formation and the soybean yield, by applying different tillage systems, under the conditions of the Agricultural Research and Development Station Turda.

MATERIAL AND METHODS

The experiment has been conducted on a phaeozem argic soil type (SRTS 2012) in Transylvania Plain, with average multiannual rainfall of 531.4 mm and an average multiannual temperature of 9.2°C (for 63 years). The experimental field was placed on a phaeozem argic soil type (SRTS, 2012), having the following properties (MESP, 1987): neutral pH (7.2), mobile phosphorus 4.1% mg P_2O_5/100 g soil, potassium 29 mg K_2O/100 g soil and humus content 3.2%. The experiment being included in a crop rotation of 3 years: soybean - winter wheat-maize. The biological material chosen for this trial was represented by the soybean Teo TD variety.

The experimental factors were the following: factor A - tillage system with four graduations: a_1 classic with plow (CS), a_2 minimum tillage with chisel (MC), a_3 minimum tillage with heavy disk (MD), a_4 direct sowing - no-tillage (NT); factor B - fertilization with four graduation: b_1 $N_{40}P_{40}$ at sowing, b_2 gulle manure 5 tons/ha before sowing + $N_{40}P_{40}$ at sowing, b_3 green fertilizer (autumn rape) + $N_{40}P_{40}$ at sowing, b_4 green fertilizer (autumn rape) + gulle manure 10 tons/ha + $N_{40}P_{40}$ at sowing; factor C - agricultural year with three graduations: c_1 2018, c_2 2019, c_3 2020.

The sowing was performed with the Directa 400 machine (at sowing was applied the fertilizer $N_{40}P_{40}K_0$ active substance/ha, avoiding repeated passes with heavy aggregates on the soil surface), at 18 cm distance between the rows, the seed introduced at 4 cm depth, density 45 germinative grains/m^2. Weeds control was performed in two stages, in all variants: pre-emergence with 0.35 liter/ha product with active ingredient metribuzin (600 g/l) + 1.5 liter/ha product with active ingredient *S-metolachlor* (960 g/l); post-emergence with 1.0 liter/ha based on *imazamox* (40 g/l) + 1.0 liter/ha based on *propaquizafop* (100 g/l), when the soybean had 3 - 4 trifoliate leaves. To control the pest *Tetranicus urticae*, at the time of reporting, treatment with 0.5 liter/ha insecticide based on *fenpyroximate* was performed. After harvest, the yield obtained was corrected to 13% moisture content.

Analysis of root nodules were done at the end of blooming for each experimental variant, on an area of 0.25 m^2 (the metric frame), with a spade, without damaging the roots, the plants were extracted together with the volume of soil explored by the root system, from each variant, and the root nodules were counted and weighed. Harvest was performed with the combine for experimental field, each experimental plot being of 28 m^2. Soybeans were harvested in the second decade of September in each experimental year. The data was processed in two ways, ANOVA (PoliFact, 2015), and the Fisher's protected least significant difference (LSD) test was used to determine the differences among the means at the 5%, 1% and 0.1% level of significance.

The evolution of climatic conditions at ARDS Turda (Meteorological Station Turda, E23°47′N46°35; 427 m) for the last 60 years (1957- 2017) is presented in Figure 1.

RESULTS AND DISCUSSIONS

The experiment was conducted on fertile soil, with high susceptibility for compaction induced by large agricultural aggregates and also by working in conditions of high humidity at the 24 - 25% soil moisture. The experimental field was characterised by a high clay content (more than 40%). The multiannual average for 63 years was 9.2^{o}C, the number of years in which the average annual temperature was below 9^{o}C was 25 years, 25 years with a temperature of 9^{o}C and above 9^{o}C and 13 years in which average annual values of temperatures above 10^{o}C, especially in recent years (2015-2019). The highest values of average annual temperature are attributed to the year 2019 (11.4^{o}C) and the lowest temperature to the 1975 year (7.4^{o}C). Analyzing the climatic conditions data, it that can be observed that the rainfall regime was uneven and no dominant trend was observed, the multiannual amount for 63 years was 531.4 mm, the number of years in which the precipitations had values below 500 mm was 24 years, over 500 mm in 22 years, over 600 mm were recorded in 13 years and in four years the precipitations had values over 700 mm. The highest rainfall in the entire period was recorded in 2016 with 816.8 mm and the lowest rainfall was recorded in 2000 (259.7 mm). The registered climatic changes (increasing temperatures, decrease in rainfall or non-uniformity of rainfall), as well as the unpredictable ones in the future require the judicious choice of the biological material to be cultivated and the application of some technologies adequate to the new climatic conditions, that why the applied agro-technical measures must be adapted to more oscillating ecological conditions.

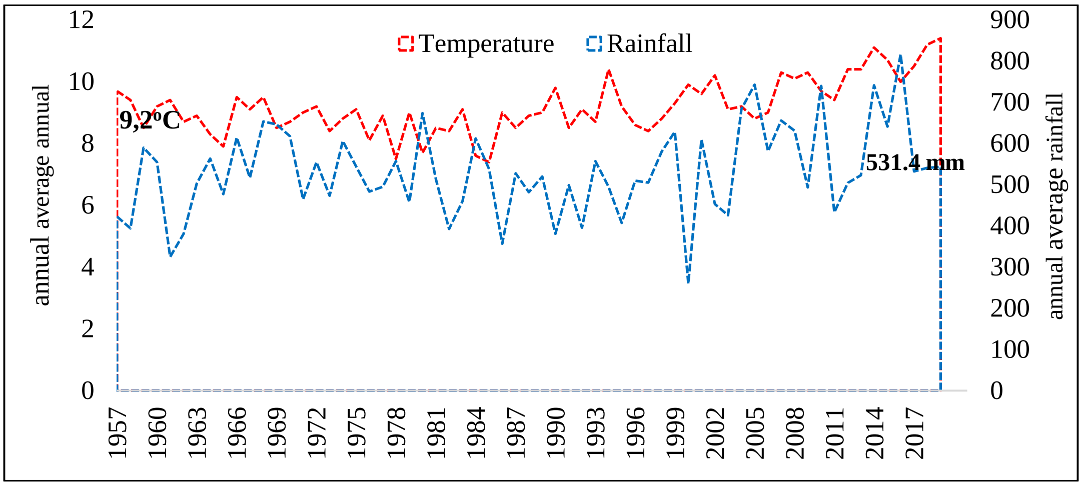

Figure 1. The evolution of the thermal and rainfall regime during 1957-2017

The values of temperature and rainfall, recorded during the April - September for de experimental years (2018-2020) is presented in Table 1 and 2. The six months in the 2018 was warm, the average of temperatures was over multiannual average by + 2.6°C and dry with deviation - 40.1 mm. The average temperature recorded in 2019 was higher with + 1.5°C comparative with multiannual average (16.2°C) with a difference of precipitation by + 26.9 mm. The year 2020 (17.1°C) was closer to the normal multiannual average for this period, but the precipitation exceeded the value of multiannual average with + 55.9 mm.

Table 1. Thermic regime during April - September 2018-2020

Year	Temperature - monthly average (°C)						Average IV- IX
	IV	V	VI	VII	VIII	IX	
Average 63 years	10.0	15.0	18.0	19.8	19.4	15.1	16.2
2018	15.3	18.7	19.4	20.4	22.3	16.7	18.8
Deviation ±	+ 5.3	+ 3.7	+1.4	+0.6	+2.9	+1.6	+2.6
2019	11.3	13.6	21.8	20.4	22.1	17.1	17.7
Deviation ±	+ 1.3	-1.4	+3.8	+0.6	+2.7	+2	+1.5
2020	10.3	13.7	19.1	20.2	21.5	17.8	17.1
Deviation ±	+ 0.3	-1.3	+1.1	+0.4	+2.1	+2.7	+0.9

Table 2. Rainfall regime during April - September 2018-2020

Year	Rainfall - monthly amount (mm)						Amount IV- IX
	IV	V	VI	VII	VIII	IX	
Average 63 years	46.2	69.6	83.9	77.1	56.1	42.2	375.1
2018	26.2	56.8	98.3	85.7	38.2	29.8	335
Deviation ±	-20	-12.8	+14.4	+8.6	-17.9	-12.4	-40.1
2019	62.6	152.4	68.8	35	63.8	19.4	402
Deviation ±	+16.4	+82.8	-15.1	-42.1	+7.7	-22.8	+26.9
2020	17.8	44.4	166.6	86.8	58	57.4	431
Deviation ±	-28.4	-25.2	+82.7	+9.7	+1.9	+15.2	+55.9

Regarding to the three years of experiments, it can be concluded the period was characterized by an uneven distribution of precipitation, there were dry periods of time, with prolonged pedological droughts followed by torrential rains.

The development of root nodules at soybean differs from the one system to another, from the date presented in Table 3, one can observe the negative influence (distinctly significantly) of the MD and NT in the number and weight nodules, difference between control variant (CS with 98.8 nodules/plant at 3.7 grams/plant) is 12.4 - 20.3 nodules/plant with 1.1 - 1.0 grams/plant. The highest value of 119 nodules/plant is recorded at soybean cultivated in the MC (distinctly significantly positive). Regarding of the nodules weight, the beneficial effect of the MC is found in the difference of only 0.4 grams/plant, this difference does not present statistical assurance. The contrary results were obtained by Dogan et al., (2011) following experiments performed in the Cukurova Region in Turkey, they states that the highest average number of nodules was obtained in the no tillage system with sowing directly in the wheat stubble and a smaller number (56 nodules) in the field with mobilization of the soil at 18 - 20 cm. The number of nodules is distinctly significantly positive influenced by the organo-mineral fertilization (green fertilizer (autumn rape) + gulle 10 tons/ha + $N_{40}P_{40}$) influence given by the value of number nodules differences (21.7 nodules) and influenced very significantly positive the weight of nodules with difference 0.6 gram/plant compared to the classical system (CS) control. The fertilizing variant with green fertilizer (autumn rape) + $N_{40}P_{40}$ did not influenced significantly the number of nodules, but presented significantly positive of the weight of nodules, difference between control variant being 0.4 grams/plant. Referring to the average of the three years considered control (95.5 nodules with 3.1 grams) the root nodules is not influenced significantly by the year factor in this case.

As can be seen from Table 4, the highest number of nodules formed is reflected on yield in the CS (2656 kg/ha) and MC (2618 kg/ha) and less nodules in lowest yield in the MD (2402 kg/ha) and NT (2314 kg/ha). It seems that the Teo TD variety is pretentious to the unconventional technology MD and NT. From the research conducted by Căpăţână et al., (2018), regarding the influence of soil tillage on soybean nodulation and yield, the experiment was placed on a chromic luvisol with a clay-loam texture, located at Moara Domnească - Ilfov, results that the number of nodules/plant recorded in the plowing at 20 cm (23.8 nodules, the yield 2351 kg/ha), the highest value obtained in chisel plow at 20 cm (27.0 nodules, the yield 2260.7 kg/ha) and the lower values in disking at 10 cm (22.9 nodules, the yield 2044 kg/ha). Regarding the beneficial influence of the classical system on soybean yield, similar results were obtained in Poland by Gawęda et al., (2020), which showed that the yield was higher by 10.3% in the classic system (plowing), compared with no tillage system.

The green fertilizer + gulle 10 tons/ha + $N_{40}P_{40}$ has a major role in the nodules formation, weight and the soybean yield, difference between the control variant (2354 kg/ha with one fertilization at sowing) is 310 kg/ha (influence significantly positive). Also the variant with green fertilizer + $N_{40}P_{40}$ presented the positively influences on the weight of root nodules (3.2 grams/plants) and contributes to the increase of yield with 176 kg/ha comparative with control variant. The minimum tillage-disk variant (MD) and direct sowing (NT) led a poor development at nodules, weight and the soybean yield.

Table 3. The influence of the experimental factors on root nodules formation

The factors		number/pl	%	Difference	weight/grams/pl	%	Difference
Tillage system (A)							
a_1	Classic (CS)	98.8^{Ct}	100	0.0	$3.7^{Ct.}$	100	0.00
a_2	Minim chisel (MC)	119	120	19.8**	3.4	90.7	-0.4
a_3	Minim disk (MD)	86.4	88	-12.4^{oo}	2.6	70	-1.1^{oo}
a_4	No tillage (NT)	78.5	80	-20.3^{oo}	2.7	73.1	-1.0^{oo}
LSD (p 5%)				5.5			0.5
LSD (p 1%)				10			0.9
LSD (p 0.1%)				22.1			1.9

Fertilization (B)							
b_1	$N_{40}P_{40}$	93.4^{Ct}	100	0.0	2.8^{Ct}	100	0.0
b_2	gulle 5 tons/ha + $N_{40}P_{40}$	92.7	99.2	0.7	2.9	102.7	0.08
b_3	green fertilizer + $N_{40}P_{40}$	96.3	103.1	2.9	3.2	114	0.4*
b_4	green fertilizer + gulle 10 tons/ha + $N_{40}P_{40}$	115.1	123.2	21.7**	3.5	121.5	0.6***
LSD (p 5%) LSD (p 1%) LSD (p 0.1%)				9.1 12.8 18.1			0.3 0.4 0.6
Year (C)							
c_0	Average	95.5^{Ct}	100	0.0	3.1^{Ct}	100	0.0
c_1	2018	94.6	99	-0.9	3.2	102.8	0.09
c_2	2019	93.7	98.1	-1.8	2.9	93.1	-0.21
c_3	2020	98.3	102.9	2.8	3.2	104	0.13
LSD (p 5%) LSD (p 1%) LSD (p 0.1%)				5.6 7.6 10			0.3 0.4 0.5

Table 4. The influence of the experimental factors on soybean yield, 2018-2020

The factor		Yield (kg/ha)	Relative yield (%)	Difference
Tillage system (A)				
a_1	Classic (CS)	2656	100	0.0^{Ct}
a_2	Minim chisel (MC)	2618	99	-38
a_3	Minim disk (MD)	2402	91	-254^{oo}
a_4	No tillage (NT)	2314	87	-342^{ooo}
LSD (p 5%) = 76 kg/ha, LSD (p 1%) = 139 kg/ha, LSD (0.1%) = 308 kg/ha.				
Fertilization (B)				
b_1	$N_{40}P_{40}$ at sowing	2354	100	0.0^{Ct}
b_2	gulle 5 tons/ha + $N_{40}P_{40}$	2441	104	87
b_3	green fertilizer + $N_{40}P_{40}$	2531	108	176**
b_4	green fertilizer + gulle 10 tons/ha + $N_{40}P_{40}$	2664	113	310***
LSD (p 5%) = 40 kg/ha, LSD (p 1%) = 76 kg/ha, LSD (p 0.1%) = 99 kg/ha.				
Year (C)				
c_0	Average	2497	100	0.0^{Ct}
c_1	2018	2478	99	-20
c_2	2019	2416	97	-81
c_3	2020	2599	104	101*
LSD (p 5%) = 32 kg/ha, LSD (p 1%) = 63 kg/ha, LSD (p 0.1%) = 107 kg/ha.				

CONCLUSSION

The highest value of 119 nodules/plant was recorded for the Teo TD variety cultivated in minim chisel system and the lowest value of 78.5 nodules/plant in no tillage (NT) system.

The number of nodules/weight/plant and the soybean yield was positive influenced by the organo-mineral fertilization.

The yield obtained was superior in classical system and very close in value to the yield obtained in the minimum tillage-chisel, the minor difference of only 38 kg suggesting the suitability of this system as well.

Due to the pedological conditions from the experimental area, soybean crop is less suitable for cultivation under the directly sown system.

The minimum tillage system can be a successful alternative to the classical system in the hilly area of Transylvania and of course by practicing this system it is intended to reduce environmental pollution.

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