The Influence of the Tillage System and Fertilization on Soybean Yield at ARDS Turda, 2015-2017

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Abstract

Soybean is currently one of the most important agricultural crops being used in human and animal nutrition, as a raw material for industry but also has agro-phyto-technical importance because it contributes to the raising of soil fertility by fixing atmospheric nitrogen by symbiosis between soybeans and *Rhizobium japonicum* bacteria, which forms root-nodules. To achieve the aims, a poly-factorial experience has been placed during the period 2015-2017 at ARDS Turda, with the factors: Factor A - the tillage system (a_1 the classical tillage system by plowing with the return of the furrow and a_2 the minimum tillage system, chisel variant; factor B- the fertilization (b_1-$N_{20}P_{20}K_0$ 100 kg/ha, applied simultaneously with sowing, b_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, b_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 b_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 C-climatic conditions in the experimental years (c_1-2015; c_2-2016; c_3-2017). The soybean variety studied was Malina TD. Following the application of the minimum tillage system, the yield decreases with a significant difference of 86 kg/ha compared to the conventional tillage system. A very significant influence in the yield of superior quantitative yields is fertilization, in the three variants where the supplementary fertilization was applied, there were obtained very significant yield increases of over 199 kg/ha compared to the control variant which produced a yield of 2373 kg/ha.

Keywords: tillage system, soybean, climatic conditions, fertilization, yield

Introduction

It is known that in recent years the climate has undergone major changes, increasing the average annual temperature and the lack or unevenness of precipitation being the most important factors influencing the production of a culture (Şimon and Ignea, 2018). In order to reduce the impact of these changes on crops, researchers from all over the world have sought for the most efficient technological alternatives to produce quantitatively and qualitatively yields in line with plant needs and current climate change (Szajdak *et al.,* 2003; Şimon *et al.,* 2014). The main directions in which research has been carried out and which have achieved results with applicability have been the implementation of conservative tillage systems that have evolved over time (Guş *et al.,* 2003), the reduction of imputations by rotation of zoned varieties and the introduction of leguminous into crops.

Soybean (*Glycine max* (L.) Merrill) is considered to be the “golden plant” of mankind, the “wonder plant” or the “plant of the future” (Singh, 2010), a culture of special nutritional value for both human nutrition and animals fodder, being the main source of plant protein worldwide (Conner et al., 2004). In addition to the importance of food, soybean also contributes to the improvement of soil fertility by fixing the atmospheric nitrogen by symbiosis between soybeans and *Rhizobium japonicum* bacteria, which forms root-nodules (Roman *et al.,* 2006). The increase in nitrate content of NO_3^-

or ammonium NH_4^+ in the soil has the effect of decreasing the activity of the nodules formation, being correlated with a decrease of the nodules formation capacity of the leguminous species (Eaglesham, 1989), but analyzed in complex with the soil tillage system, phase fertilization is necessary, giving a distinctly significant yield increase compared to the conventional system of works (Chețan *et al*., 2014).

The rise and development of soybeans are influenced by soil temperature and humidity (Hunter and Erickson, 1952), and the implementation of conservative tillage systems, whose characteristics include increasing or maintaining water for a long time in the soil, can lead to a more efficient use of precipitation water in the processes of germination, growth and development of plants.

The purpose of this paper is to study the influence of fertilization of soybean culture on the number of nodules that are formed and yield obtained.

Materials and methods

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

The soybean was sown with a distance of 18 cm, with the Gaspardo Directa 400 seed drill at 65 g.s./m^2. The soybean has been grown in a crop rotation system for 3 years, the pre-plant being maize.

Factor A - the tillage system: a_1 - The classical tillage system, which includes a 30 cm deep, hole after harvesting the previous crop and soil processing to prepare the germinating bed with the disc and combiner before sowing; a_2 - Minimum tillage system with the chisel at 30 cm deep, after harvesting the previous crop and soil processing to prepare the germinating bed with the rotary before sowing; factor B- the fertilization (b_1-$N_{20}P_{20}K_0$ 100 kg/ha, applied simultaneously with sowing, b_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, b_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 b_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 C-climatic conditions in the experimental years (c_1-2015; c_2-2016; c_3-2017). The soybean variety studied was Mălina TD.

After sowing, treatment with Gliphosate (*glifosat* 360g/l) (4 l/ha) was performed in the two systems. Control of monocotyledonous and dicotyledonous weeds was performed with Pulsar herbicides (*imazamox* 40g/l) (1 l/ha) and Agil (*propaquizafop*) (1 l/ha) in weed rosette phenophase.

To protect the soybean culture against the red spider (*Tetranicus urticae*), the Omite 570 EW (*propargit* 570 g/l) (0,8 l/ha) insecticide treatment was performed and with the Ridomil Gold MZ 68 WG (*mancozeb* 40 g/kg, *mefenoxam* 680 g/kg) (2,5 kg/ha) fungicide was treated the *Peronospora manshurica*.

The obtained results were statistically processed by the variance analysis method and the lowest significant difference was determined - DL - (5%, 1% and 0.1%) (ANOVA, 2015).

The climate conditions during 2015-2017 are presented according to ARDS Turda Meteo Station (Tab. 1 and Tab. 2). During the last 60 years, the annual temperature average recorded was 9.1^{0}C and the annual amount of rainfall was 531.0 mm. The average temperatures recorded during the months from the vegetation period of soybean crop have varied during all three years, but they were higher than the average during 60 years by 1.5^{0}C in 2015, being considered a hot year, by 0.9^{0}C in 2016, being considered a warm year and by 1.4^{0}C in 2017, considered a hot year.

The amount of rainfall recorded in the first half of 2015 was under the monthly amount during the last 60 years, in 2016 the amount of rainfall was higher than the average during 60 years, being considered an excessively rainy year. In 2015, the rainfall was more reduced, and its absence during the optimal moments for the development of the crop resulted in a significant production loss. In 2016, temperatures and rainfall were beneficial for the soybean crop, the yield obtained were the result of the interaction between optimal climate conditions. In 2017, the rainfall were close to the average of the past 60 years.

Results and discussions

Soybean yield varies from one crop to another, but yield stability is influenced by several factors,

Table 1. The mean air temperatures (^{0}C), Turda 2015-2017

Monthly average	2015											
	Ian.	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
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
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
2016												
Monthly average	Ian.	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
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
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
2017												
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
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
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

Source: Turda Meteo Station, longitude: $23^0$47 '; latitude $46^0$35 '; altitude 427 m

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

Monthly amount	2015											
	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
Average 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
Deviation	-9.5	+2.1	-10.8	-13.7	-2.7	+30.9	-24.9	+15.7	+130.1	+9.8	+3.5	-20.2
2016												
Monthly 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
Average 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
Deviation	+4.2	+5.0	+23.4	+16.3	+21.7	+38.4	+47.8	+34.5	-17.9	+116.6	+16.8	-19.9
2017												
Monthly 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
Average 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
Deviation	-19.2	+0.4	+25.5	+19.3	-3.3	-54.2	+33.1	-20.5	+13.7	+13.6	+2.3	-6.4

Source: Turda Meteo Station, longitude: $23^0$47 '; latitude $46^0$35 '; altitude 427 m

the most important being climatic conditions, soil fertility, crop protection against diseases, weeds and pests, and tillage. The suitability of a crop to tillage by a particular method is dependent on the soil type, texture, structure and water retention capacity of the soil. From the data presented in Tab. 3 it can be noticed that the yield obtained from the application of the conservative tillage system is lower than the yield obtained in the classical tillage system, with a distinct difference of 86 kg/ha. The results obtained by Cheţan *et al.* (2016) also shows that soybean yield obtained on the same soil type is lower due to the application of the conservative tillage system, with very significant differences from the classical tillage system.

Although soybean is a plant that does not require a high level of nitrogen fertilization (thanks to the atmospheric nitrogen fixation due to symbiosis with *Rhyzobium japonicum* bacterium), it responds very well to the application of additional fertilization, especially those containing

Table 3. The influence of the tillage system on the yield of soybean

Tillage system	Yield (kg/ha)	Differences (kg/ha)
Classic (control variant)	2599	-
Conservative	2513^{00}	-86
LSD (p 5%) 19	LSD (p 1%) 49	LSD (p 0.1%) 140

Table 4. The influence of the fertilization on the yield of soybean

Fertilization	Yield (kg/ha)	Differences (kg/ha)
$N_{20}P_{20}K_0$-simultaneously with sowing (control variant)	2373	-
$N_{20}P_{20}K_0$-simultaneously with sowing+$N_{20}P_{20}K_0$-in the 4-6 leaves	2678^{***}	305
$N_{20}P_{20}K_0$-simultaneously with sowing+N_{30}-in the 4-6 leaves	2601^{***}	228
$N_{20}P_{20}K_0$-simultaneously with sowing+N_{20}-in the 4-6 leaves	2571^{***}	199
LSD (p 5%) 17	LSD (p 1%) 26	LSD (p 0.1%) 42

Table 5. The influence of the year factor on the yield of soybean

Tillage system	Yield (kg/ha)	Differences (kg/ha)
Average year (control variant)	2556	-
2015	2057^{000}	-499
2016	3429^{***}	873
2017	2182^{000}	-374
LSD (p 5%) 16	LSD (p 1%) 39	LSD (p 0.1%) 112

Table 6. The influence of the tillage system on the number of root nodules

Tillage system	Root nodules	Differences
Classic (control variant)	324	-
Conservative	354^{*}	30
LSD (p 5%) 7	LSD (p 1%) 38	LSD (p 0.1%) 135

phosphorus, from the data presented in Tab.4 shows an increase with very significant positive differences in yield in all three variants where additional fertilization was applied, especially in the second variant where the application of 100 kg/ha of $N_{20}P_{20}$ resulted in an yield increase over 305 kg/ha. The results obtained by Cheţan *et al.,* (2017) confirm the data presented by the yield obtained following application of additional fertilization to the soybean cultivated under similar conditions.

The yield of soybean culture is determined by the weight and number of seeds. The seed weight is a production item influenced by the duration of the actual grain filling period, and the number is determined by the duration of the flowering period, which requires average temperatures (to avoid abortion of the flowers) and quantitative precipitation, this period from the beginning of the flowering and until grain filling is critical to soybean culture. In 2016, when the rainfall in the important phases of the vegetation period was above the average of 60 years, the registered soybean yield was 3429 kg/ha, with a significantly higher difference than the average of the years 2015-2017, while in the other two years the yields were relatively lower, of only 2057 kg/ha in 2015 and respectively 2182 kg/ha in 2017, the yield differences from the average of the three studied years being significantly lower (Tab. 5).

Soil tillage has complex effects on the physical, chemical and biological properties of the soil, and the change of these soil properties directly influences the parameters of microbial activity in soil, organic matter, soil humidity and temperature.

The development of the soybean plant is influenced by the nutritional state of the crop, climatic conditions, genotype and nutrition space, but the development of roots and, implicitly, the number, size and weight of the root nodules

Table 7. The influence of the fertilization on the number of root nodules

Fertilization	Root nodules	Differences
$N_{20}P_{20}K_0$-simultaneously with sowing (control variant)	270	-
$N_{20}P_{20}K_0$-simultaneously with sowing+$N_{20}P_{20}K_0$-in the 4-6 leaves	291^{*}	21
$N_{20}P_{20}K_0$-simultaneously with sowing+N_{30}-in the 4-6 leaves	259^{0}	-11
$N_{20}P_{20}K_0$-simultaneously with sowing+N_{20}-in the 4-6 leaves	262^{0}	-8
LSD (p 5%) 8	LSD (p 1%) 23	LSD (p 0.1%) 40

Table 8. The influence of the year factor on the number of root nodules

Tillage system	Root nodules	Differences
Average year (control variant)	289	-
2015	273^{0}	-16
2016	314^{**}	24
2017	281^{0}	-8
LSD (p 5%) 6	LSD (p 1%) 19	LSD (p 0.1%) 32

developed on the roots of plants is the result of physical properties and the way tillage. According to the data presented in Tab. 6, the number of root nodules on soybean roots is higher in the system with conservative tillage, with a significant difference from the control, similar studies have resulted in the conservative tillage system having positive effects on the soil microbial activity.

The root system of soybean plants cultivated in the classical tillage system is better developed than in the conservative system, but the number of root nodules determined on the roots of plants is higher in the conservative system, their layout being on the main roots compared to the ones determined in the classical system that were arranged on both the main and the secondary roots.

Mineral fertilization of soybean culture with nitrogen leads to a decrease in the number of root nodules, but in the case of phosphorus-containing fertilizers, the number of root nodules is higher, phosphorus stimulating their development. The activity of developing and fixing nitrogen by the root nodules is suppressed when the nodules roots are exposed to a high nitrogen concentration. As can be seen from the data presented in Tab. 7, the number of root nodules decreases with significant differences due to the application of additional mineral fertilization with nitrogen, and after application of phosphorus mineral fertilization the number of root nodules on the roots of the plants increases with a significant difference compared to the basic fertilization applied simultaneously with sowing. When the availability of nitrogen is low in the soil, the plant preferentially supports root nodules growth and nitrogen fixation, on the other hand when the nitrate level in the soil is high, the plant stimulates lateral growth of the roots to absorb nitrates more efficiently (Saito *et al*., 2014).

Natural soil fertility, especially phosphorus content in the soil, is an important factor contributing to the formation of root nodules resulting from the symbiosis process between soybean roots and *Rhizobium japonicum* nitrogen fixation bacteria. In the experiments performed by Pavanelli and Araújo (2009) there was a low soy nodulation, a decrease attributable to the low level of fertility of the soil.

Climate conditions are the most important factor in the development of a crop, soil temperature being very important during the formation of nodosites on the roots of soybean plants, which contributes to the assimilation of atmospheric nitrogen, temperatures too low or too high, preventing their good development ($<20^0$ and $> 30^0$C), temperatures close to 25^0C are optimal for the bacteria activation and symbiotic process between bacteria and soybean roots, favoring the increase in the amount of nitrogen assimilated and transformed into available plant nitrogen.

The data presented in Tab. 8 shows that in 2016 recorded temperatures and precipitations have reached optimal conditions for the formation and development of soybean root nodules, thus the number of root nodules is higher than the number obtained by calculating the average of the three years with a dinstinct significantly positive difference, and in the years 2015 and 2017, the lack of precipitation during the formation of the nodosities resulted in a significant decrease in the number of toor nodules formed on the root of a plant.

From the determinations made by Cheţan *et al.* (2016) shows that in the years favorable to the development of soybean culture, the number of root nodules is significantly higher than the control, fallen temperatures and precipitations favoring the formation of root nodules and the assimilation of atmospheric nitrogen.

Conclusions

The yield of a crop is determined by several factors that interfere with the physiological processes of a plant and which vary according to the interaction between these factors.

Additional fertilization of the soybean crop produces significant yield increases, but by applying nitrogen-based fertilization, the number of nitrogen-fixing root nodules on the roots of soybean plants is reduced.

The climatic conditions of the soybean crop growing season are the most important factor in the development of soybean root nodules and in the formation of yield.

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