THE SOYBEAN YIELD FORMATION IN THE PEDOCLIMATIC CONDITIONS FROM THE HILLY AREA OF THE TRANSYLVANIA PLAIN

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Abstract. *Soybean yield is determined by the interaction between genetic potential and environmental factors from the specific area, maturity group of the cultivar, plants height, disease and pest tolerance, culture technology, the type of soil its pH and fertility, etc. From the most important elements that compete for the formation of the crop we mention, plants height, the number of pods per plant, the number of grains in the pod, weight of grains per plant and the mass of a thousand kernels weights (TKW). Experience established at ARDS Turda, during 2020-2022, had as its main objective the study of the influence of technological factors (tillage systems) and pedoclimatic effects on some morpho-productive characters in soybeans. Climatic conditions during the experiment period, especially in the summer, they had a significant influence (positive or negative) on the studied elements. Between the two tillage systems (plow CS and chisel MTC) no significant differences were recorded regarding for most of the analyzed elements, except for the number of grains/plant (CS 87.9 și MTC 95.8).*

Keywords: *soybean, productivity elements, technology, environmental conditions*

INTRODUCTION

Worldwide, soybeans is cultivated on extensive areas, being recognized and appreciated due to its various uses: in human food, animal feed, industry, to obtain ecological fuel but also as a plant that improves the physical properties of the soil by improving the soil in nitrogen (Jayachandran and Xu, 2015; Hemingway et al., 2015; Voora et al., 2020). One of the very important technological links in the success of the crop is the fight against weeds (Nagy et al., 1988). It is known that soybeans in the first weeks after emergence have a slow growth rate and is vulnerable to weeding (Berca, 2004), the same situation also occurs at maturity when it loses its foliage (Chețan, 2015).

As an agrotechnical point, soybean contributes to increasing soil fertility and it is an economic crop, using 35-50% nitrogen from the soil solution (the nitric, ammoniacal and amide form) and 50-65% nitrogen from symbiosis with bacteria *Bradyrhizobium japonicum* which are found in soybean root nodules (Veteri and Schmidt 1987; Mullen et al., 1988; https://www.agro.basf.ro). Nitrogen-fixing bacteria thrive on well-supplied soils with phosphorus, potassium, sulphur, calcium, molybdenum, magnesium, cobalt, in optimal humidity and temperature conditions (https://agrobiznes.ro). The specialized literature mentions that leguminous plants, depending on the crop conditions, species, cultivar and growing season, can fix between 100-300 kg N/ha (https://www.legumehub.eu/ro). Some authors recommend concurrently with weed control treatments, diseases and crop pests also the application of foliar fertilizers N:P:K type in equal proportion or in favor of phosphorus (Mandal et al., 2009; Lana et al., 2003; https://agrobiznes.ro).

At Turda, the soils are in the area of the unit, characterized as fertile soils and the presence of bacteria of *Rhizobium* have somewhat limited the application of mineral nitrogen to soybeans (Chețan, 2019). Soybean is less demanding than the preceding plant, but prefers straw cereals, maize, sugar beet and potato. Other leguminous plants are not indicated as precursors (Ion, 2010) but also sunflowers and rapeseed, because of common diseases (Samuil, 2007) such as white rot (*Sclerotinia sclerotiorum*). Supports monoculture for 2-3 years, but in this case outbreaks of diseases increase, specific pests multiply and the degree of weeding of the land increases (Li-ming et al., 2016; Chamberlain et al., 2021; https://www.cartiagricole.ro/cultura-soiei).

“In the current conditions, when the lack of protein in the food of the population and in the rations of animals is acutely felt, when there is a reduction in the possibilities to buy mineral fertilizers, of pesticides and other preparations, growing importance belongs to leguminous crops, including soybean” (https://www.sanatatea plantelor.ro).

The yield is conditioned to the greatest extent by the pedoclimatic conditions in the experimental area, the tillage system and the applied technological elements (Chețan, 2020; Doorenbos and Kassam, 1979; Chilambwe et al., 2022; Zhang et al., 2022; Chețan et al., 2022). Numerous other studies, conducted worldwide, specifies that the yield of this crop decreases considerably with the deviation from the optimum (positive or negative) of temperatures and precipitation, in different phases of vegetation, especially at flowering and beans formation (Pedersen et al., 2004; Tacarindua et al., 2013; Kim et al., 2020). The prolonged drought of this period correlated with high temperatures, considerably reduces production (Setiyono et al., 2007; Novikova et al., 2018; Hodges and French, 1985). As it appears from the research, the biggest impact in the success of the culture is attributed to the crop conditions, and here we primarily refer to the action of the main abiotic factors of temperature and precipitation. In this work, the results of the research on the influence of climatic conditions and the type of tillage are presented, on the main elements of soybean production in the hilly area of Transylvania.

MATERIAL AND METHODS

At Agricultural Research and development Station (A.R.D.S.) Turda, an experimental field was established with two tillage systems, which is included in a three-year rotation: winter wheat - corn - soybean. The experiment was located on a vertic clay illuvial chernozem soil type (SRTS, 2012) with neutral pH, good supply of phosphorus and potassium, an average content in humus and total nitrogen and clay content over 41% (OSPA Cluj). The experience is organized according to the method of subdivided plots. The surface of the experimental plot is 48 m ^{2}. The biological material was the soybean variety "Felix" created at ARDS Turda.

Experimental factors:

- factor A, the climatic conditions of the year of experimentation: a_1 2020, a_2 2021, a_3 2022;
- factor B, the tillage system: b_1 conventional, plow(CS), b_2 unconventional, chisel (MTC).

Agricultural lands in the unit area are infected annually with different species of weeds (Şimon et al., 2020), the highest frequency belongs to annual dicotyledonous weeds (Chețan et al., 2016, 2022). Weed control treatment was carried out in stages: in preemergence with 0,35 l/ha product based on Metribuzin 600 g/l + 1,4 l/ha based on Dimetenamid-P; in post-emergence, when the soybean plants had formed 3-4 trifoliate leaves, with 1,9 l/ha product based on Bentazon 480 g/l and Imazamox 22,4 g/l + after 3 days 1,0 l/ha product based on Propaquizafop 100 g/l. Soybean sowing + fertilization (Amonium nitrate 100 kg ha^{-1}) was performed in the first decade of April in each year of experimentation, with the seeder Directa 400, population densities 650.000 plants ha^{-1} and row spacing of 18 cm. In the years 2021 and 2022, against the backdrop of high temperatures correlated with low rainfall in June, the red spider attack was reported (*Tetranychus urtice* Koch) at the beginning of July, being necessary the treatment with 0,5 l/ha acaricide based on Fenpiroximat 50 g/l.

Before soybean harvesting, 20 plants were extracted from each experimental variant for determining productivity elements (plant height, number of pods, grains/plant, weight of grains/plant, TKW). The interpretation of the experimental results was carried out by the variance analysis method (Polifact, 2015) and establishing LSD (5%, 1%, 0.1%). To analyze the relationship between the studied characters, we used the calculation of linear regressions expressed by the degree equation I $y = a+bx$. The correlation coefficients were established using the correlation coefficient "r" (Ceapoiu, 1968). The climatic conditions for the period 2020-2022 are presented in Table 1 (source Turda Meteorological Station: long. 23°47, lat. 46°35', alt. 427 m).

RESULTS AND DISCUSSION

If we analyze climatic the April September period of the years of experimentation (Table 1) and we refer to the multi-year average of the last 65 years (1957-present) it is noticed as well that the weather is warming up in Turda. Compared to the multi-year temperature average (16.3ºC) and the amount of precipitation (376.1 mm) close values were recorded only in 2021 (16.5ºC and379.3 mm) the deviation being of 0.2ºC and 3.2 mm. In the two years, 2020 and 2022, the deviation from multi-year was of 0.8ºC and between 30.8-54.9 mm. Requirements, water consumption of soybeans, it is higher starting from the early flowering phenophase (mid June) and until the grains are full (mid-August), the lack of precipitation during this period inevitably leads to a yield decrease(Ashley and Ethridge, 1978; https://www.agro.basf.ro). Specific to June of the year 2021, is the alarming increase in temperature compared to the multi-year monthly average, the deviation being of 3.1ºC and in the other two experimental years, significant deviations from the multi-year monthly average were recorded in July of 2.9ºC in 2021 and by 3.3ºC in 2022 (Şimon, 2022).

Table 1. Thermal regime (ºC) and rainfall (mm) for the period April-September 2020-2022, at Turda

Year	Climate values	Month						Average/sum IV-IX
		IV	V	VI	VII	VIII	IX	
2020	ºC	10.3	13.7	19.1	20.2	21.5	17.8	17.1
	mm	17.8	44.4	166.6	86.8	58	57.4	431
2021	ºC	7.8	14.1	19.8	22.7	19.7	15	16.5
	mm	38.4	80.8	45	123.1	52.9	39.1	379.3
2022	ºC	8.8	16.3	21.1	23.1	22.3	14.3	17.7
	mm	42.5	82.9	41.8	25.2	94.6	119.9	406.9
65 years	ºC	**10**	**15**	**18**	**19.8**	**19.5**	**15.2**	**16.3**
		45.6	**69.4**	**84.6**	**78**	**56.1**	**42.4**	**376.1**

Plant height is a particularly important character, which positively or negatively influences the arrangement of the nodes and implicitly the number of pods per stem. In the first two experimental years, were more favorable climatic conditions for soybean crop and the rains in June and July led to an increase in plant height (91.3 cm respectively 96.3 cm) if we refer to the control variant of 80.8 cm (the average of the experimental years). The drought and heat of the summer in 2022 has distinctly negatively influenced the development of crop, the average height of the plants being only 54.8 cm. The difference in height between plants grown in CS and MTC it's just by 1.7 cm and has no statistical significance. And from the interaction of the factors year x tillage system the positive influence can be observed (significantly, distinctly significant) of the two years (2020, 2021) and the negative influence of the year 2022 (distinctly significant) regardless of the tillage system (Table 2). Rezi et al. (2016) obtained similar results regarding plant height fluctuation. Following their research, during 2012-2014 at Turda, it turned out that in a dry year the height of the plants is reduced by up to 32.7 cm.

Table 2. The influence of the experimental factors on plant height

The experimental factor		Plant height (cm)	%	Differences ± control
Year (A)	a_0 years average	80.8	100.0	control
	a_1 2020	91.3	113.0	10.5^{**}
	a_2 2021	96.3	119.2	15.5^{**}
	a_3 2022	54.8	67.8	-26^{oo}
	LSD (p 5%) = 4.3; LSD (p 1%) = 9.9; LSD (p 0.1%) = 31.4			
Tillage system (B)	b_1 conventional (CS)	81.7	100.0	control
	b_2 unconventional (MTC)	79.9	97.9	-1.7^{ns}
	LSD (p 5%) = 3; LSD (p 1%) = 5.4; LSD (p 0.1%) = 12			
The interaction of AxB	a_0b_1	81.7	100	control
	a_1b_1	91.2	111.7	9.6^{*}
	a_2b_1	97.0	118.8	15.4^{**}
	a_3b_1	56.8	69.5	-24.9^{oo}
	a_0b_2	8.0	100.0	control
	a_1b_2	91.5	114.4	11.5^{*}
	a_2b_2	95.7	119.6	15.7^{**}
	a_3b_2	52.8	66.0	-27.2^{oo}
	LSD (p 5%) = 5.5; LSD (p 1%) = 11.5; LSD (p 0.1%) = 31.7			

Compared to the control variant (51.7 pods/plant), the number of pods formed in the year 2020 (52.1 pods) it result not to have been significantly influenced by climatic conditions and tillage system (CS 51.5 pods and MTC 51.9 pods) but this particularly important element was influenced very significantly positive of 2021 conditions and both tillage systems. Both in the CS and MTC system in the year 2022, against the background of the high thermal regime and poor rainfall, had a very significant negative influence on pod formation, their number being very reduced (Table 3).

Table 3. The influence of experimental factors on the number of pods/plants

The experimental factor		No.pods/plants	%	Differences ± control
Year (A)	a_0 years average	51.7	100.0	control
	a_1 2020	52.1	100.8	0.43^{ns}
	a_2 2021	80.9	156.6	29.3^{***}
	a_3 2022	22.0	43	-29.7^{ooo}
	LSD (p 5%) = 2; LSD (p 1%) = 4.7; LSD (p 0.1%) = 14.9			
Tillage system (B)	b_1 conventional (CS)	51.5	100.0	control
	b_2 unconventional (MTC)	51.9	100.7	0.4^{ns}
	LSD (p 5%) = 4.8 ; LSD (p 1%) = 8.9; LSD (p 0.1%) = 19.7			
The interaction of AxB	a_0b_1	51.5	100.0	control
	a_1b_1	51.0	99.0	-0.53^{ns}
	a_2b_1	81.1	157.5	29.6^{***}
	a_3b_1	22.4	43.5	-29.1^{ooo}
	a_0b_2	51.9	100.0	control
	a_1b_2	53.3	102.7	1.4^{ns}

	a_2b_2	80.8	155.7	28.9***
	a_3b_2	21.6	41.6	-30.3ººº
	LSD (p 5%) = 6.2; LSD (p 1%) = 11.7; LSD (p 0.1%) = 27			

The number of grains/plant is directly influenced by the number of pods/plant and climatic conditions are the main limiting factor in their formation. The favorability of 2021 is reflected in the average number of grains/plant (148.8 boabe) which was recorded (tabel 4). As is presented, the "Felix" soybean variety in this study has the potential to form a larger number of grains/plant if favorable conditions are met, as he mentions Mureșanu et al., (2010). Și Choi et al., (2016) following the research carried out in South Korea (37.27°N, 126.99°E; Suwon), in soybeans grown under controlled humidity and temperature conditions (greenhouse), states that the number of pods and grains is greatly reduced if heat stress occurs.

Table 4.The influence of experimental factors on the number of grains/plants

The experimental factor		No.grains/plants	%	Differences ± control
Year (A)	a_0 years average	91.8	100.0	control
	a_1 2020	99.6	108.5	7.8ns
	a_2 2021	148.8	162.0	56.9*
	a_3 2022	27.1	29.5	-64.7ºº
	LSD (p 5%) = 26.4; LSD (p 1%) = 60.9; LSD (p 0.1%) = 193.9			
Tillage system (B)	b_1 conventional (CS)	87.9	100.0	control
	b_2 unconventional (MTC)	95.8	109.1	8.0*
	LSD (p 5%) = 7.8; LSD (p 1%) = 14.7; LSD (p 0.1%) = 31.8			
The interaction of AxB	a_0b_1	87.9	100.0	control
	a_1b_1	98.3	111.9	10.5ns
	a_2b_1	137.3	156.3	49.5*
	a_3b_1	28.0	31.8	-59.9º
	a_0b_2	95.8	100.0	control
	a_1b_2	100.9	105.4	5.1ns
	a_2b_2	160.2	167.2	64.4**
	a_3b_2	26.3	27.4	-69.6ºº
	LSD (p 5%) = 27.9; LSD (p 1%) = 62.5; LSD (p 0.1%) = 191.2			

*, **= significant at 5% and 1% probability levels, positive values; º, ºº= significant at 5% and 1% probability levels, negative values; ns= not significant

It should be mentioned that in 2022 there were five scorching heat days in June (Tmax ≥32ºC) and a day with hot temperatures (Tmax ≥35ºC) and in July there were 16 scorching heat days and six days with hot temperatures. The year 2021 featured 11 scorching heat days in July (Șimon, 2022). The average grain weight/plant was distinctly significantly negatively influenced by the climatic conditions of the year 2022, and less than the tillage system, as are from the data presented in Table 5.

Table 5. The influence of experimental factors on the weight grains/plants

The experimental factor		Grains weight /plants (g)	%	Differences ± control
Year (A)	a_0 years average	13.3	100.0	control
	a_1 2020	14.2	107.0	0.9ns
	a_2 2021	22.1	166.4	8.8ns
	a_3 2022	3.5	26.6	-9.7ºº
	LSD (p 5%) = 10.1; LSD (p 1%) =23.4 ; LSD (p 0.1%) = 74.4			
Tillage system (B)	b_1 conventional (CS)	13.1	100.0	control
	b_2 unconventional (MTC)	13.5	102.9	0.38ns
	LSD (p 5%) = 0.7; LSD (p 1%) = 1.3; LSD (p 0.1%) = 2.8			
The interaction of AxB	a_0b_1	13.1	100.0	control
	a_1b_1	14.2	108.6	1.13ns
	a_2b_1	21.1	161.3	8.0ns
	a_3b_1	3.9	30.1	-9.1ºº

a_0b_2	13.5	100.0	control
a_1b_2	14.2	105.4	0.7^{ns}
a_2b_2	23.1	171.3	9.6^{ns}
a_3b_2	3.1	23.3	-10.3^{oo}
LSD (p 5%) = 10.1; LSD (p 1%) = 23.4; LSD (p 0.1%) = 74.3			

The thousand kernel weight (TKW) may have different values from one year to another, depending on the thermal and water regime recorded during the vegetation period of the crop. So compared to the average of the years (control 136.7 g), TKW is significantly negatively influenced by the conditions in 2022 (121.7 g). In 2021 it seems that soybeans benefited from temperatures and precipitation that favored better plant development and obviously also the increase in the values of some production elements, as is the case TKW (149.9 g), situation presented in Table 6.

As stated by Toleikiene et al., in 2021 "Soybean yield is a function of plants per unit area, pods per plant, seeds per pod and seed weight". These yield components are influenced by environmental conditions, management practices, and cultivar". And from other research it was concluded that soy the yields fluctuates according to climate conditions (Van Roekel et al., 2015; Mandal et al., 2009).

Table 6. The influence of experimental factors on the TKW

The experimental factor		Grains weight /plants (g)	%	Differences ± control
Year (A)	a_0 years average	136.7	100.0	control
	a_1 2020	138.6	101.4	1.9^{ns}
	a_2 2021	149.8	109.6	13.0^{*}
	a_3 2022	121.7	89.0	-15.0^{o}
LSD (p 5%) = 18 ; LSD (p 1%) =41.7 ; LSD (p 0.1%) = 132.7				
Tillage system (B)	b_1 conventional (CS)	138.2	100.0	control
	b_2 unconventional (MTC)	135.2	97.9	-2.97^{ns}
LSD (p 5%) = 1.9; LSD (p 1%) = 3.4; LSD (p 0.1%) = 7.5				
The interaction of AxB	a_0b_1	138.2	100.0	control
	a_1b_1	140.7	101.8	2.5^{ns}
	a_2b_1	152.5	110.3	14.3^{*}
	a_3b_1	121.4	87.9	-16.8^{o}
	a_0b_2	135.2	100.0	control
	a_1b_2	136.5	100.9	1.3^{ns}
	a_2b_2	147.1	108.8	11.9^{*}
	a_3b_2	122.1	90.3	-13.1^{o}
LSD (p 5%) = 18.2; LSD (p 1%) = 41.8 ; LSD (p 0.1%) = 132.2				

*= significant at 5% probability levels, positive values ^{o}= significant at 5% probability levels, negative values; ^{ns}= not significant

For both systems we performed the analysis of the correlations between the quantitative components of the production. Thus, from figure 1 results that there is a very significant positive relationship between the number of grains/plant and their weight, with the correlation coefficients range of 0.95 and 0.92. Also, from the same figure it results that the points are quite close to the regression lines, a fact that suggests that the two tillage systems do not have a considerable impact on the two analyzed components.

A very significant direct relationship (r = 0.699 in MTC and 0.753 in CS) there is also between grain weight/plant and the thousand kernel weight (TKW), correlation coefficients having high and highly significant values (figure 2). The regression lines for the two systems are almost parallel and quite close, a fact that suggests that the relationship between the two components is not affected by the tillage system.

Between plant height and number of pods/plant, there is a positive, highly significant relationship, aspect that is reproduced in figure 3. It can also be observed as well that in the case of these two components, tillage systems do not have a significant impact on this relationship, the regression lines being very close to each other and almost overlapping. However, this relationship must be viewed with some sensitivity because too large plant height can negatively affect resistance to falling. For the plants it would be normal to have a short waist and short internode length and a high number of pods per node.

And regarding the relationship between the number of pods/plant and the number of grains there is a very close relationship, the correlation coefficients "r" being of 0.938 in MTC respectively 0.940 in CS (Figure 4). In the relationship between the number of pods and the number of grains, the difference between the conventional system (CS) and the unconventional system (MTC) is almost non-existent. He reached the same results Sturzu et al., (2016) following the research carried out in the period 2012-2014 at A.R.D.S. Teleorman, but in another leguminous plant (peas). They state that research on production elements is especially important in the field of plant breeding, by knowing the close links between some production characters, more efficient cultivation can be obtained and we can also say that the selection carried out for a certain property can simultaneously lead to the improvement of another property of interest. Certain unfavorable correlations could also be corrected to some extent with the help of technology elements (the indirect relationship between protein and production etc.).

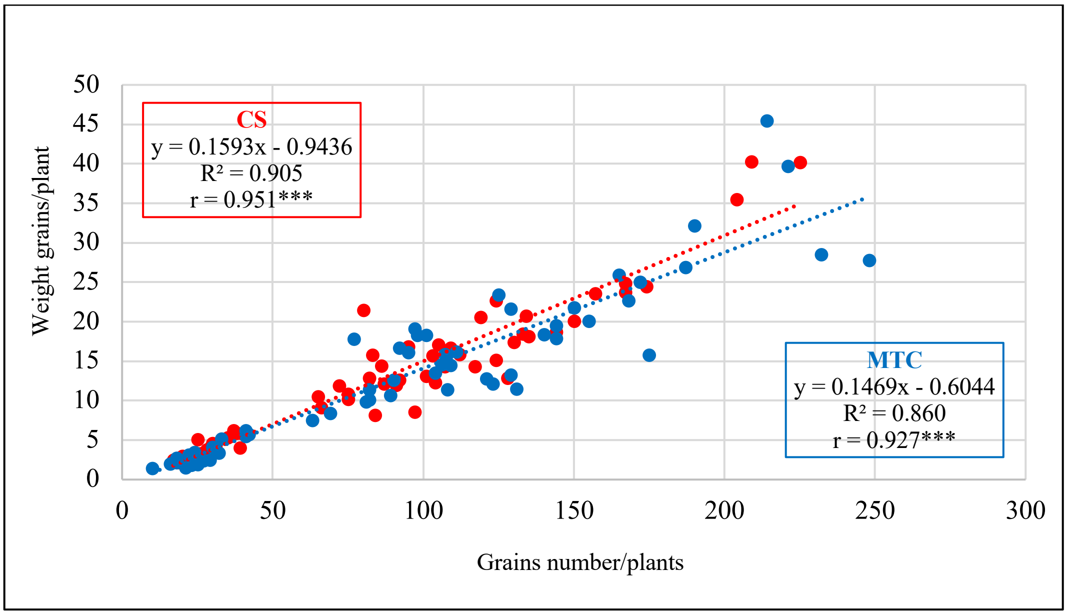

Figure 1. The relationship between the weight of the grains (g) and the number of grains/plant

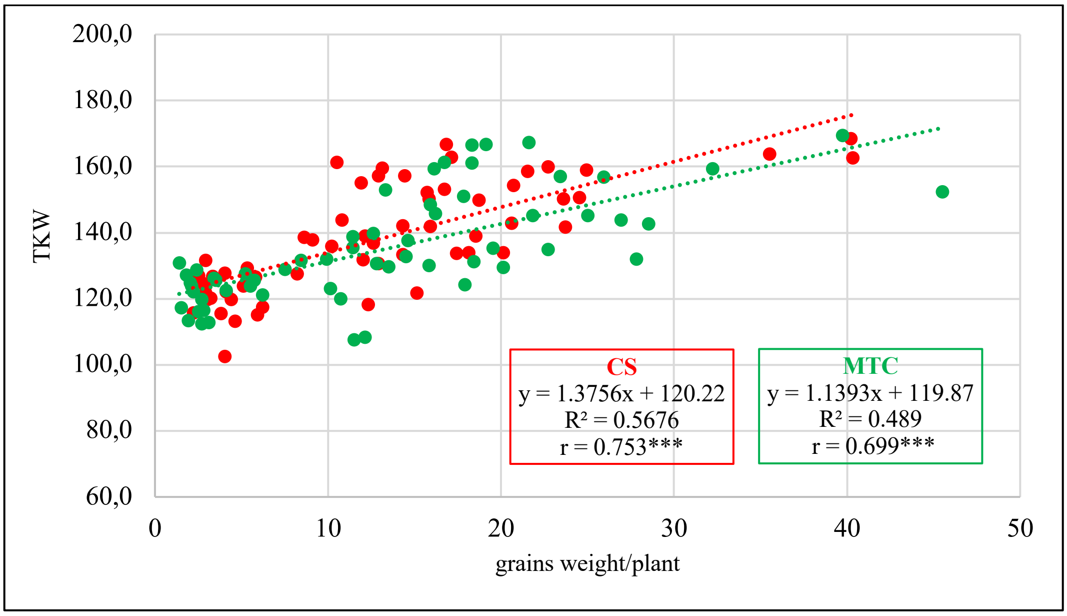

Figure 2. The relationship between TKW and the weight grains/plant (g)

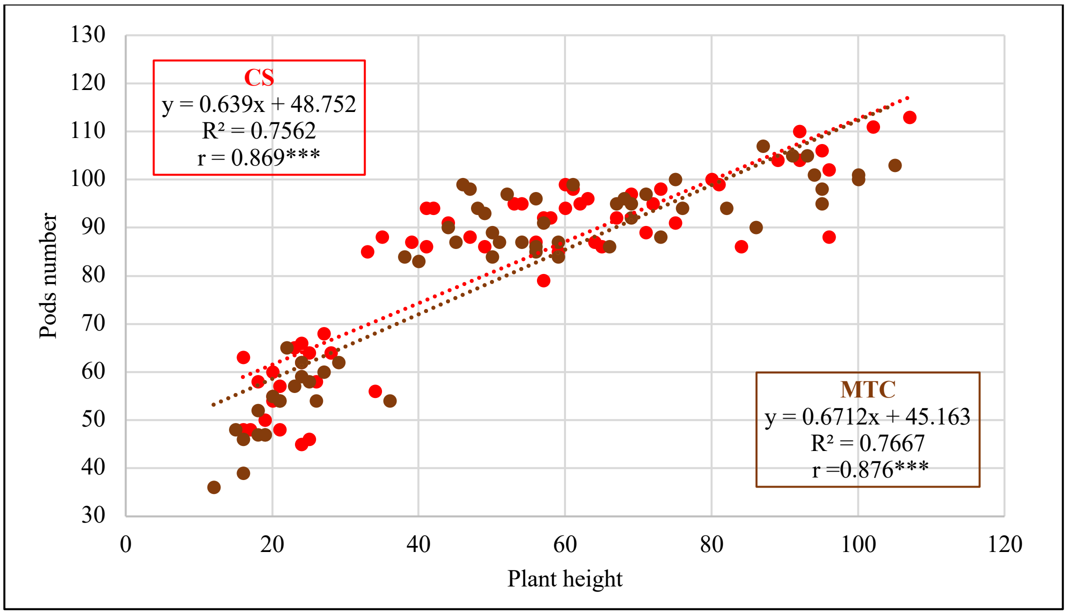

Figure 3. The relationship between pods number and the plant height (cm)

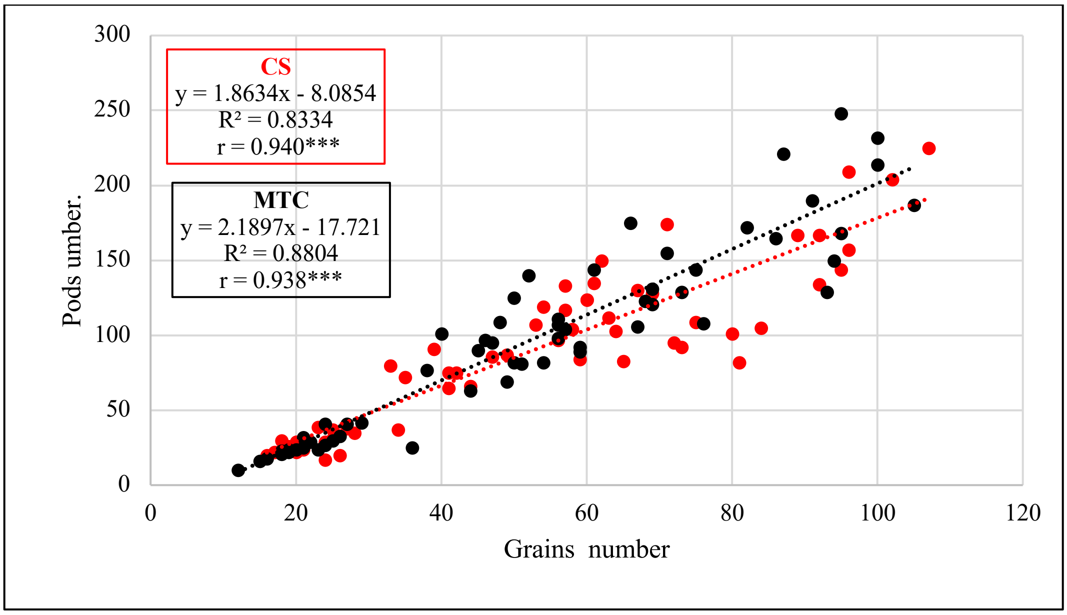

Figure 4. The relationship between pods number and the grains/plant

CONCLUSIONS

Climatic conditions greatly influenced the morphological and production elements, the drought in the summer of 2022 led to a reduction in plant size by almost half, the number of pods formed, the number and weight of the grains and implicitly of TKW compared to years 2020 and 2021, which showed a more favorable impact on the mentioned components.

Correlation coefficients "r" characterizes the existence of very significant positive links between productivity elements in this study: the number of grains/plant and their weight, grain weight/plant and TKW, plant height and number of pods/plant and between number of pods/plant and number of grains. These direct relationships between the listed elements are not affected by the two systems, CS and MTC, a fact that indicates the suitability of soybeans for cultivation in the MTC system as well.

REFERENCES

1. Ashley D.A., Ethridge W.J.,. - Irrigation Effects on Vegetative and Reproductive Development of Three Soybean Cultivars 1. Agron. J. 1978, 70: 467-471.

2. Berca M., - Managementul integrat al buruienilor. Ed. Ceres, Bucureşti, 2004
3. Ceapoiu N., - Metode statistice aplicate în experiențele agricole și biologice. Edit. Agro-Silvică, București, 1968.
4. Chețan C. - Cercetări privind combaterea buruienilor la cultura de soia cultivată în sistemul de agricultură convenţională şi conservativă. Teza de doctorat, USAMV Cluj-Napoca 2015.
5. Chețan C., Vass L., Felicia Chețan, - Cercetări privind influența unor scheme de fertilizare inovative asupra producției cantitative și calitative la soia. Revista Agricultura Transilvană. 2022, Buletin informativ nr. 36, martie, p: 79-84. Ed. SC Ela design Turda. ISSN 1454-7287.
6. Cheţan Felicia, - The influence of the tillage system and the crop rotation on the soil availability in the main nutrients and the yields obtained in Turda area. International Conference "Agriculture for Life, Life for Agriculture" 6-8 June 2019, USAMV Bucureşti. Scientific papers. Series A. Agronomy, Vol. LXII, No.1, 2019.
7. Cheţan Felicia, - Influence of different tillage systems on soybean nodulation and yield in the Transylvanian Plain conditions. Bulletin UASVM series Agriculture 77(2)/2020, p: 1-8.
8. Cheţan Felicia, Rusu T., Cheţan C., Paula Ioana Moraru, - Influence of soil tillage upon weeds, production and economic efficiency of corn crop. AgroLife Scientific Journal, 2016, Volum 5/1:36-43. Bucureşti.
9. Chețan Felicia, Carmen Calistru, Chiriță S., Chețan C. - Influence of agricultural system on the control of *Bromus tectorum* on winter wheat. Journal "Life Science and Sustainable Development'', Lovrin Agricultural Research and Development Station, România, 2022, LSSD -ISSN 2734 –5068. Vol. 3, no.1.
10. Chilambwe A., Crespo O., Chungu D. - Climate change impacts on maize and soybean yields in Zambia. Agronomy Journal, 2022, 114, 2430– 2444. https://doi.org/10.1002/agj2.21092.
11. Choi D.H, Ban H.Y., Seo B.S., Lee K.J., Lee B.W. - Phenology and Seed Yield Performance of Determinate Soybean Cultivars Grown at Elevated Temperatures in a Temperate Region. PLoS ONE 11(11): e0165977. 2016, https://doi.org/10.1371/journal.pone.016597.
12. Cigelske B., Kandel H., DeSutter T. - Soybean Nodulation and Plant Response to Nitrogen and Sulfur Fertilization in the Northern US. Agricultural Sciences, 2020, 11, 592-607. doi: 10.4236/as.2020.116037.
13. Chamberlain L.A., Whitman T., Ané J.M., Diallo T., Gaska J.M., Lauer J.G., Mourtzinis S., Conley S.P. - Corn-soybean rotation, tillage, and foliar fungicides: Impacts on yield and soil fungi. ELSEVIER Field Crops Research. Volume 262, 2021.
14. Doorenbos J., Kassam, O.W., - Yield Response to Water. FAO Irrigation and Drainage, 1979, Paper no. 33, FAO, Rome.
15. Hemingway J., Eskandari M., Rajcan I., - Genetic and Environmental Effects on Fatty Acid Composition in Soybeans with Potential Use in Automotive Industry. Crop Science. 2015, 51:1-11.
16. Hodges T., French V., - Soybean: Soybean stages modeled from temperature, day lenth and water availability. Agron. J. 1985, 77, 500–505.
17. Ion V. - Fitotehnie. Capitolul 3. Leguminoase pentru boabe. 2010, 3.1. Soia, p.77-86.
18. Jayachandran M., Xu B. - An insight into the health benefits of fermented soy products. Food Chemistry. 2015, 271:362-371.
19. Kim Y.U., Choi D.H., Ban H.Y. Seo B.S., Kim J., Lee B.W., - Temporal patterns of flowering and pod set of determinate soybean in response to high temperature. Agronomy 2020, 10, 414.
20. Lana R.M.Q., C.E. Vilela Filho, L.A. Zanão Júnior, H.S. Pereira, Lana A.M.Q., -.Adubação superficial com fósforo e potássio para a soja em diferentes épocas em pré-semeadura na instalação do sistema de plantio direto. Scientia Agraria 4, 2003, (1-2):53-60.
21. Li-ming Z., L. Shuang, S. Zhe, H. Jing, C. Qiu-ming, S. Bing, D. Jun-jie, L. Wei-ting, W. Jing-zhi., - Impact of crop rotation on pathotype and genetic structure of Phytophthora sojae in fields. J. Northeast Agr. Uni. 2016, 23: 1–12.
22. Mandal K. G., Hati K. M., Misra A. K., - Biomass yield and energy analysis of soybean production in relation to fertilizer-NPK and organic manure. Biomass and Bioenergy, 2009, 33(12), 1670–1679. https://doi.org/10.1016/J.BIOMBIOE.2009.08.010.
23. Mullen M.D., Israel D.W., Wollum A.G., - Effects of *Bradyrhizobium japonicum* and Soybean (*Glycine max* (L.) Merr.) Phosphorus Nutrition on Nodulation and Dinitrogen Fixation. Appl Environ Microbiol. 1988 Oct, 54(10):2387-92. doi: 10.1128/aem.54.10.2387-2392.1988. PMID: 16347750; PMCID: PMC204268.
24. Muresanu E., Raluca Mărginean, Silvia Negru, - Soiul timpuriu de soia Felix, Analele INCDA, 2010, Fundulea Vol. LXXVIII, 2:55-62.
25. Nagy C., Şarpe N., Ciorlăuş A., - Combaterea integrată a buruienilor din cultura de soia. Probleme de agrofitotehnie teoretică şi aplicată, 1988, vol. X, nr.3:269-285.
26. Novikova L.Y., Seferova I.V., Kozlov K.N., - Model Parameterization: The Timing of Flowering in Soybean Accessions. Biophysics (Russ. Fed.) 2018, 63, 956–958.

27. Pedersen P., Boote K.J. Jones J.W., Lauer J.G., - Modifying the CROPGRO-Soybean Model to Improve Predictions for the Upper Midwest. Agron. J. 2004, 96, 556–564.
28. Rezi Raluca, Camelia Urdă, Mureșanu E., - Study of a set of soybean varieties in non-competitive system- ”Honey comb" experimental design. Research Journal of Agricultural Science, 2016, 48 (4), 201, p. 144-150.
29. Rusu T., Chețan C., - Controlul buruienilor la cultura de soia. SCDA Turda, Revista Agricultura Transilvană, 2014, buletin informativ nr. 21, pag.81. Ed. ELADESIGN SRL Turda.
30. Samuil C., - Tehnologii de agricultură ecologică, 2007,Cap. 3. Soia, p.33-39. USAMV Iași.
31. Setiyono T.D., Weiss A., Specht J.E., Bastidas A.M., Cassman K.G., Dobermann, A., - Understanding and modeling the effect of temperature and day length on soybean phenology under high-yield conditions. Agron. Hortic. Fac. Publ. 2007, 112, 1–17.
32. Sturzu Rodica, Alina Mihaela Ene, Cristina Melucă, Iordan C., - Assessing main morpho-productive traits of the field pea genotype (*Pisum sativum* L.) belong to ARDS Teleorman collection. An. INCDA Fundulea, vol.LXXXIV, 95-106. Genetica și ameliorarea plantelor. Electronic, 2016, ISSN 2067-7758. www.incda-fundulea.ro.
33. Şimon Alina, Oltean V., Popa A., Felicia Cheţan, Valeria Deac, Bărdaş M., - Specii de buruieni întâlnite în culturile agricole de la SCDA Turda. Revista Agricultura transilvană, Buletin informativ, Nr. 32, martie 2020, p: 91-94, Ed. SC Ela Design SRL Turda.
34. Şimon Alina, - Caracterizarea climatică a lunilor iunie și iulie din ultimul deceniu pentru zona Turda. SCDA Turda. Revista Agricultura transilvană, Buletin informativ, Nr. 37, septembrie 2022, p: 9-14, Ed. SC Ela Design SRL Turda.
35. Tacarindua C.R.P., Shiraiwa T., Homma K., Kumagai E., Sameshima, R., - The effects of increased temperature on crop growth and yield of soybean grown in a temperature gradient chamber. Field Crop, 2013, Res. 2013, 154, 74–81.
36. Toleikiene M., Slepetys J., Sarunaite L., Lazauskas S., Deveikyte I., Kadziuliene Z., - Soybean Development and Productivity in Response to Organic Management above the Northern Boundary of Soybean Distribution in Europe. Agronomy 2021, 11, 214.https://doi.org/10.3390/agronomy11020214.
37. Travasso Maria Isabel, Magrin G.O., Rodriguez G.R., López G.M., - Potential impacts of climate change on soybean yields in the Argentinean pampas and adaptation measures for future sustainable production. IOP Conference Series. Earth and Environmental Science; 2009, Bristol Vol. 6, ISS. 37, 2009.
38. Van Roekel R.J., Purcell L.C., Salmerón M., - Physiological and management factors contributing to soybean potential yield. Field Crops Res. 2015, 182, 86–97.
39. Veteri E.L, Schmidt J.S., - Ecology of indigenous soil rhizobia: response of *Bradyrhizobium japonicum* to readily available substrates. Appl Environ Microbiol 1987;53:1872–5.
40. Voora V., Larrea C., Bermudez S., - Global market report: Soybeans. Winnipeg, MB, Canada: International Institute for Sustainable Development, 2020.
41. Zhang J., Liu Y., Dai L., - Agricultural practice contributed more to changes in soybean yield than climate change from 1981 to 2010 in northeast China. J Sci Food Agric, 2022, 102: 2387-2395.
42. Polifact - ANOVA and Duncan's Test PC, Program for variant analyses made for completely randomized polyfactorial experiences. 2015, USAMV Cluj-Napoca.
43. SRTS, - Romanian System of Soil Taxonomy. Ed. Estfalia, Bucharest, 2012.
44. Meteorological Station Turda.
45. Office for Pedological and Agrochemical Studies (OSPA) Cluj-Napoca.
46. https://www.cartiagricole.ro/cultura-soiei.
47. https://agrobiznes.ro/articole/aplicarea-ingrasamintelor-la-cultura-de-soia.
48. https://www.agro.basf.ro/ro/stiri/basf-in-camp/cultura-soia-sfaturi-infiintare-cultura-ingrijire.html.
49. https://www.legumehub.eu/ro/is_article/fixarea-biologica-a-azotului-prin-plantele-leguminoase.