

RESULTS REGARDING THE APPLICATION OF AMENDMENTS IN SOYBEAN CULTIVATION

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Abstract

During the research conducted, the positive influence of calcium on soybean plants was noted. Due to the fact that the experiment was located on an acidic soil (pH around 5.0) we used calcium-based products, namely: agrocalcium (93.6% CaCO₃), doloflor with CaCO₃ and MgO (magnesium oxide) and neutrosol 9 (97.5% CaCO₃). Thus, it was found that total biomass production was on average 6.26 t/ha, pod production was 4.19 t/ha, and grain production was 2.46 t/ha, with significant and highly significant positive differences. Analyzing the thousand grain mass (MTG), small significant positive differences were found. Quality indices of soybeans were also determined and thus the protein content was 38%, oil 25%, fiber 5%, and the moisture content of the beans was 10%. The results obtained show that the Cristina TD soybean variety adapts very well to the conditions in the station.

Key words: amendments, CaCO₃, Cristina TD, soybean.

INTRODUCTION

Due to its high agronomic and economic value, soybean cultivation occupies an important place both in national and global agriculture, making it necessary to expand the cultivated areas in various environments (Bueno et al., 2020). Soybeans are the world's main source of oil (Garima et al., 2020). It is produced across a wide range of latitudes, from the Canadian prairies and the Great Northern Plains of the USA to the tropical areas of the Brazilian Cerrados (Grassini et al., 2021). Long before the advent of ancient writings, soybeans were an important crop in East Asia (Shurtleff & Aayagi, 2013). There is evidence that soybeans were domesticated between 7000 and 6600 BC in China, 5000 and 3000 BC in Japan, and 1000 BC in Korea (Lee et al., 2011).

Calcium is an indispensable macroelement for plants, (Karley & White, 2009) contributing to the optimization of soil characteristics and the proper functioning of physiological processes (Cramer et al., 2009; Dayod et al., 2010). Natural calcium (Ca) reserves come from a wide range of minerals and rocks, the decomposition of which occurs through complex processes. In the case of albic luvisol, there is a dynamic equilibrium between the different forms of

calcium in the soil, an equilibrium that is constantly changing either in the direction of adsorption of Ca ions by clay particles, or in the direction of their consumption by plants and leaching. However, the total amounts of calcium in luvisol are low and insufficient to support proper plant growth. The existing calcium cannot ensure and maintain an adequate degree of base saturation of the soil colloids (Badea et al., 2022). Under these conditions, exchangeable aluminum ions (Al³⁺) predominantly occupy the exchange complex of clay, contributing significantly to the pronounced acidification of the soil. Mobile (soluble) aluminum becomes toxic to most plant species. Calcium deficiency, associated with excess aluminum, causes the appearance of a strongly acidic soil, an unfavorable environment for plant development, which leads to reduced growth and decreased agricultural production (Milivojevic & Stojanovic, 2003). In the cultivated soil, CaCO₃ contributes to improving soil structure, water and air permeability, stimulates the activity of microorganisms and provides an important nutritional supply for plants. Calcium, absorbed in the form of Ca²⁺ ions, is an essential element for the growth and development of fruits (Popescu et al., 2023).

Thus, several calcium carbonate-based formulations were tested, in the absence or presence of magnesium.

MATERIALS AND METHODS

The research was carried out on a stagnant albic luvisol, characterized by acidic pH (around 5), poorly supplied with nitrogen (Nt = 0.130% mg/kg) and phosphorus (P = 33 mg/kg), moderately supplied with potassium (K = 89 mg/kg), clayey structure (clay content below 30%), with a humus of 2.26%.

In the case of the experiment, the biological material used was the soybean variety Cristina TD (00) cultivated in a non-irrigated system. The surface of an experimental variant was 40 m² (5m wide and 8m long) and the method used was that of subdivided plots with 3 repetitions. The research was organized as a bifactorial experiment, with the following gradations of the analyzed factors:

- A factor: -A₁: unamended (0 t/ha);
 - A₂: Powder of the Agrocalcium (2.5 t/ha), 93.6% CaCO₃;
 - A₃: Powder of the Doloflor (2.5 t/ha), 58.87% CaCO₃ and 38.24% MgO;
 - A₄: Granules of the Doloflor (2.5 t/ha), 58.87% CaCO₃ and 38.24% MgO;
 - A₅: Neutrosol 9 (2.5 t/ha), 97.5% CaCO₃;
- B factor: -B₁: unfertilized;
 - B₂: fertilized (N₄₀P₄₀);
 - B₃: fertilized (N₈₀P₈₀).

During the experiment, the following determinations were made on the plants: total biomass, pod biomass, grain biomass, MTG (1000 grain mass), crude protein content (%), fiber content (%) and oil content (%). The determination of grain quality indices was performed using the Infracmatic IM 9500 Plus analyzer. The statistical processing of the data was performed by variance analysis and by studying the correlations between the analyzed characters, the results being graphically represented using the Excel application.

RESULTS AND DISCUSSIONS

Climatic factors (Table 1)

During the experimental period, monthly differences in temperature and, especially, in precipitation were observed.

Table 1. The influence of pedoclimatic conditions on soybean crop productivity

TEMPERATURE °C		May	June	July	August	Sept.
	Dec. I	15,2	22,1	24,7	24,7	22,6
	Dec. II	11,9	21,3	22,9	23,4	18,9
	Dec. II	15,7	24,7	25,8	20,5	14,8
	Monthly average	14,4	22,7	24,5	22,8	18,8
	Multi-year average	16,3	19,5	21,7	21,3	16,9
	Deviation	-1,9	+3,2	+2,8	+1,5	+1,9
RAINFALL mm	Dec. I	54,0	8,2	2,6	2,0	0,0
	Dec. II	43,8	0,0	30,0	9,8	14,0
	Dec. II	80,0	7,4	52,4	14,0	8,8
	Monthly average	177,8	15,6	85,0	25,8	12,8
	Multi-year average	80,5	93,6	81,1	59,7	52,9
	Deviation	+97,3	-78,0	+3,9	-33,9	-30,1

Thus, during the soybean growing season, the thermal regime recorded values higher than the multiannual average by approximately +7.5°C. The analysis of the precipitation regime highlights the fact that, in May, the amount of water exceeded the multiannual average by 97.3 mm, conditions that favored uniform emergence and proper development of plants in the initial phases of vegetation. As a result of the previous rainfall surplus, a satisfactory reserve of water was established in the soil, which partially compensated for the deficit of 78 mm recorded in the following month. In August and September, negative rainfall deviations were recorded compared to the multiannual average, quantified at -33.9 mm and -30.1 mm, respectively.

The total biomass, analyzed according to factor A - the types of amendments - presented production values between 5.96 t/ha (control variant) and 6.63 t/ha (variant with powder of the doloflor), highlighting statistical differences between the variants (Table 2). Regarding pod biomass, the production level varied between 3.82 and 4.37 t/ha, the differences being statistically significantly positive, the best being obtained with the amendments with granules and powder of the doloflor, which recorded increases of 0.55 t/ha and 0.54 t/ha, respectively. In the case of grain production, the granule of the doloflor variant stood out with an input of 0.46 t/ha. Grain biomass was between 2.18 t/ha and 2.64 t/ha. The differences between the variants were significantly positive, and the thousand grain weight (MTG) analysis revealed values between 138.00 and 143.33 g. Of these, the variant treated with powder of the

agrocalcium showed a significant positive increase of 5.33 g. The analysis of the biomass distribution showed that, on average, the pod biomass amounted to 67.41% while the grain biomass represented 37.07%, these values being considered important for the conditions of the cultivation area.

Table 2. Influence of A factor

A factor	Total biomass, t/ha	%	Pod biomass, t/ha	%	Grain biomass, t/ha	%	MTG, gr
Check plot	5,96	100,00	3,82	64,09	2,18	36,57	138,00
Powder of the Agrocalcium	6,04	100,00	4,32	71,52	2,29	37,91	143,33
Powder of the Doloflor	6,63	100,00	4,36	65,76	2,44	36,80	140,11
Granules of the Doloflor	6,46	100,00	4,37	67,64	2,36	36,53	140,78
Neutrosol 9	6,23	100,00	4,24	68,05	2,64	37,56	138,00
LSD 5%	0,219		1,130		0,080		4,755
LSD 1%	0,318		0,189		1,116		6,917
LSD 0,1%	0,478		0,284		1,174		10,394

Table 3. Influence of B factor

B factor	Total biomass, t/ha	%	Pod biomass, t/ha	%	Grain biomass, t/ha	%	MTG, gr
Check plot	5,66	100,00	3,83	67,66	1,89	33,39	131,27
N ₄₀ P ₄₀	6,66	100,00	4,44	66,66	2,42	36,33	142,00
N ₈₀ P ₈₀	6,76	100,00	4,40	65,08	2,77	36,53	146,87
LSD 5%	0,253		0,135		0,108		7,362
LSD 1%	0,345		0,184		0,148		10,040
LSD 0,1%	0,466		0,249		0,200		13,587

B factor included the application of chemical fertilizers based on nitrogen and phosphorus. Under these conditions, the total biomass varied from 5.66 t/ha in the control variant to 6.76 t/ha in the N₈₀P₈₀ variant (Table 3). The pod biomass recorded values between 3.83 t/ha and 4.44 t/ha. Regarding grain production, in the 2 chemically fertilized variants, yields of over 2 t/ha were obtained, with significantly positive differences, more pronounced in the case of the variant fertilized with N₈₀P₈₀. The thousand grain mass (MTG) recorded values between 131.27 - 146.87 g, the differences being very significantly positive.

The analysis of the interaction between the type of amendment and chemical fertilization revealed a total production ranging from 3.93 t/ha in the control variant to 7.45 t/ha in the variant treated with powder of the doloflor in association with N₄₀P₄₀, the differences being very significantly positive (Table 4). The level of pod production ranged between 2.38 and 4.81

t/ha, recording significant positive differences. Regarding grain production, the values ranged between 1.48 t/ha and 3.11 t/ha. The variants: N₈₀P₈₀, Doloflor powder + N₄₀P₄₀, Doloflor powder + N₈₀P₈₀, Doloflor granules + N₈₀P₈₀ with very significant positive differences compared to the control were noted. From the analysis of the mass of one thousand grains (MTG), the values ranged between 126.00 g and 151.00 g, with small significant positive differences. In the experiment, the total biomass of the plants was, on average, 6.26 t/ha, of which the biomass of pods amounted to 4.19 t/ha, and the biomass of grains 2.46 t/ha. The results obtained highlight the good adaptability of the Cristina TD soybean variety to the conditions in the area.

Table 4. The interaction between the two factors

A factor	B factor	Total biomass, t/ha	%	Pod biomass, t/ha	%	Grain biomass, t/ha	%	MTG, gr
Check plot	Martor	3,93	100,00	2,38	58,01	1,48	37,65	126,00
	N ₄₀ P ₄₀	6,54	100,00	3,91	59,78	2,56	39,14	137,00
	N ₈₀ P ₈₀	7,43	100,00	4,78	64,33	3,11	41,85	140,00
Powder of the Agrocalcium	0	5,65	100,00	4,06	71,85	2,31	40,88	141,67
	N ₄₀ P ₄₀	5,98	100,00	4,56	76,25	2,21	36,95	141,67
	N ₈₀ P ₈₀	6,48	100,00	4,35	67,12	2,54	39,19	146,67
Powder of the Doloflor	0	5,55	100,00	3,89	70,09	2,23	40,18	133,00
	N ₄₀ P ₄₀	7,45	100,00	4,81	64,56	2,81	37,71	147,33
	N ₈₀ P ₈₀	6,88	100,00	4,38	63,66	2,88	41,86	151,00
Granules of the Doloflor	0	5,38	100,00	4,19	77,88	2,18	40,52	128,33
	N ₄₀ P ₄₀	7,44	100,00	4,70	63,17	2,65	35,61	145,67
	N ₈₀ P ₈₀	6,55	100,00	4,21	64,27	2,75	41,98	148,33
Neutrosol 9	0	6,32	100,00	4,20	66,45	2,52	39,87	127,33
	N ₄₀ P ₄₀	5,90	100,00	4,24	71,86	2,24	37,96	138,33
	N ₈₀ P ₈₀	6,47	100,00	4,26	65,84	2,47	38,17	148,33
Average		6,26		4,19		2,46		140,04
LSD 5%		0,455		0,254		0,184		12,075
LSD 1%		0,635		0,355		0,256		16,731
LSD 0,1%		0,895		0,503		0,359		23,269

The following figures provide a visual representation of images from the soybean field experiment, illustrating the distinct morphological differences between the control group and the plants treated with amendaments (Figures 1-5).



Figure 1. Control variant without treatment



Figure 2. Influence of powder of the Agrocalcium treatment on plant development



Figure 3. Influence of powder of the Doloflor treatment on plant development



Figure 4. Influence of granules of the Doloflor treatment on plant development



Figure 5. Influence of Neutrosol 9 treatment on plant development

Table 5. Statistical indices obtained in the experiment

Statistical indices	Determined characteristics			
	Protein	Oil	Fiber	Moisture
Mediate, $\bar{x}$	37,85	24,74	5,33	10,4
Variant, s^2	4,00	1,42	0,01	0,41
The standard deviation, s	2,00	1,19	0,10	0,64
<i>LSD</i> 5%	1,677	1,252	0,195	1,065
<i>LSD</i> 1%	2,389	1,732	0,274	1,485
<i>LSD</i> 0,1%	3,476	2,401	0,390	2,087
Coefficient of variation, CV %	5,28	4,82	1,94	6,18

The statistical processing of the obtained data was carried out according to the following formula $1/n-1 * [(\sum x^2) - \sum x^2/n]$ (Table 5). The analysis of the results highlights that the average value of the protein content was 37.85 with a coefficient of 5.28%, the oil content reached 24.74 presenting a coefficient of variation of 4.82%, the average fiber content of the stock was 5.33% with a coefficient of 5.33%. The determined levels of the active principles (protein and oil) indicate a good to very good quality of the beans of the Cristina TD soybean variety.

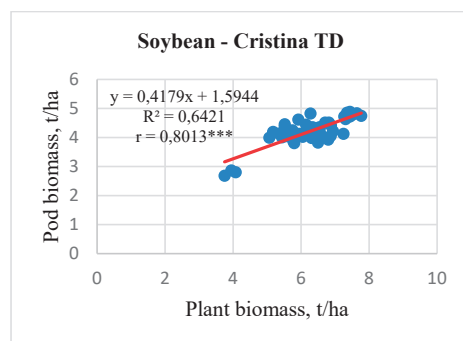


Figure 6. Correlation between plant biomass and pod biomass

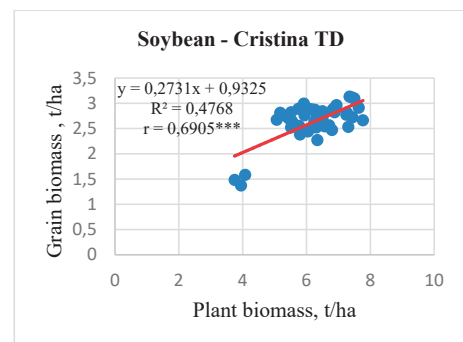


Figure 7. Correlation between plant biomass and grain biomass

The correlation analysis was performed using the mean values for each replicate. The results show a highly significant positive correlation between plant biomass and pod biomass, suggesting that the accumulation of a total biomass of 6.26 t/ha favors pod formation and development, confirming the direct relationship between vegetative growth and reproductive production (Figure 6). Comparably, the correlation between plant biomass and formed grain biomass shows the same significance (Figure 7).

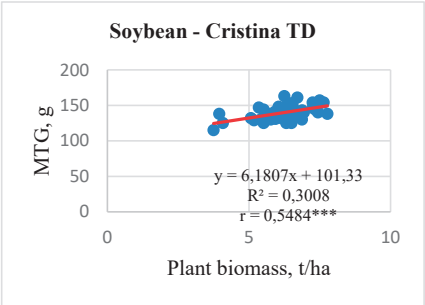


Figure 8. Correlation between plant biomass and MTG

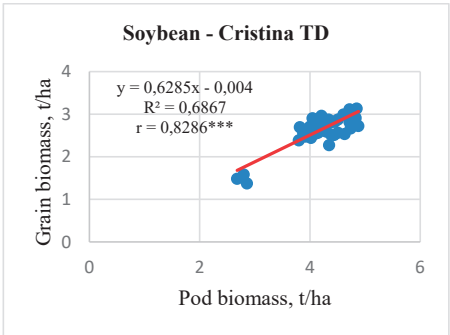


Figure 9. Correlation between pod biomass and grain biomass

The correlation between plant biomass and thousand grain mass (MTG) is positive, but less pronounced, which is explained by the relative stability of the grain weight trait in soybean (Figure 8). This is determined by the genetic peculiarities of the plant, representing an intrinsic characteristic expressed during the progeny formation stage. Correlational analysis indicates a positive correlation between pod weight and grain weight, with a much higher tendency to increase (Figure 9).

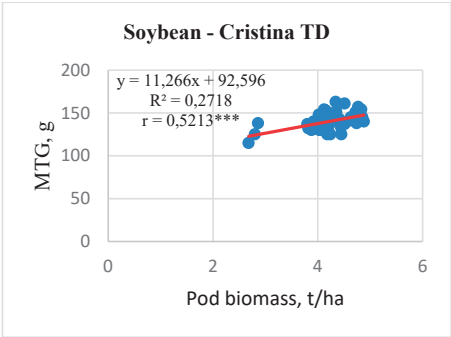


Figure 10. Correlation between pod biomass and MTG

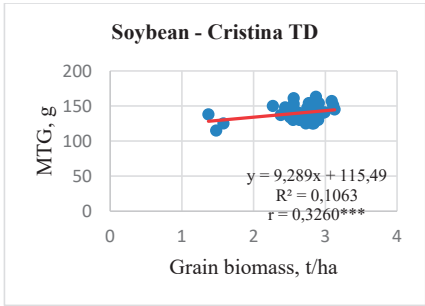


Figure 11. Correlation between grain biomass and MTG

In both correlations, the very positive statistical significance emphasizes that the thousand grain mass (MTG) is a relatively stable character, with reduced changes under the experimental conditions (Figures 10 and 11).

Table 6. Correlations between the main determined characters

	Plant biomass, gr	Pod biomass, gr	Grain biomass, gr	MTG, gr
Plant biomass, gr	1	0,8013***	0,6905***	0,5484***
Pod biomass, gr		1	0,8286***	0,5213***
Grain biomass, gr			1	0,3260***
MTG, gr				1
LSD5% = 0,19 LSD1% = 0,25 LSD0,1% = 0,32				

The relationships between the main determined characters are highly significantly positive, which demonstrates that the Cristina TD soybean variety presented high values in the experiment. The experimental data highlight the variety's ability to adapt favorably to the pedoclimatic conditions specific to the area.

CONCLUSIONS

Against the backdrop of the expansion of soybean cultivation in Romania, the need to promote the latest genetic creations, capable of ensuring high productive potential and efficient adaptation to local pedoclimatic conditions, is highlighted. However, the presence of acidic soils within the station requires the application of measures to correct the soil reaction, in order to create favorable conditions for the development of the plant root system. Based on the data obtained, the Cristina TD variety demonstrated that, in the variants treated with different types of calcareous amendments, the soil reaction was improved, and the plants responded favorably to the culture environment in which the acidity was corrected.

Biomass increased from 3.93 t/ha in the control variant to 7.44 t/ha in the variant with doloflor granules + chemical fertilizers, which indicates a favorable effect of the applied treatment. The analysis of biomass distribution highlighted a weight of 58-77% at the pod level and 37-42% at the grain level, simultaneously with relatively high values of the mass of one thousand grains (MTG), under the culture conditions achieved (126-151g).

There is a very significant positive correlation between plant biomass and pod biomass, demonstrating that achieving a total biomass of 6.26 t/ha is associated with a significant increase in pod biomass.

Total biomass correlates positively, but weakly, with thousand grain mass (MTG), confirming the stability of this trait in soybean.

At the same time, the quality of the grains presented favorable characteristics, reflected by a protein content of 38%, oil content of 25% and 5% fiber.

In terms of application, the experimental data confirm the ability of soybean for grains to adapt

favorably to the pedoclimatic conditions specific to the area.

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