SUMMARY OF PhD THESIS

Influence of some technological factors on the soybean yield and seed quality

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INTRODUCTION

Soybeans [*Glycine max (L.) Merrill*] occupies a dominant position among agricultural crops, being the most important source of good quality protein as well as vegetable oil (BOUIS, 2003; LU, 2008). Soybeans have been used in Asia and other parts of the world for many centuries to prepare a variety of fresh, fermented or dried foods (PROBST, 1973, NWOKOLO, 1996).

The management of fertilization systems for soybean cultivation is essential for obtaining superior quality and quantitative yields and also for preserving soil fertility and protecting environmental resources. Soybean is less dependent on synthetic nitrogen due to its biological fixation capacity of atmospheric nitrogen, a natural, non-polluting process that does not require additional costs (Nandini și colab.2012).

Due to the highly appreciated nutritional and functional properties, there is an increased interest in soybean crop in recent decades, some of the research related to this species being focused on improving technological aspects. Globally, there are plenty discussions over the nutritional support provided to soybeans. In order to improve the knowledge and contributes to the rational development, during the years 2019-2020, at Research and Development Station for Agricultural Turda, two different field experiments were placed: first one aimed the influence of NPK type mineral fertilization on yield, yield elements and seed quality in 13 soybean genotypes, from 3 different maturity groups (000, 00 and 0); and the second experiment studied the influence of different mineral or organic fertilization plans on the yield and quality of early soybean Caro TD.

The research carried out during the present PhD thesis is useful and actual bringing relevant information on the response of soybean to various fertilization schemes, mineral or organic, ensuring the success of this crop. They encourage the implementation of a fertilization system that ensures, in long term, the achievement of high soybean yield as well as good quality of seed with reaching food safety parameters and sustainable use of the land.

The PhD thesis "Influence of some technological factors on the soybean yield and seed quality" is structured in two parts and ten chapters.

The first part: THE CURRENT STAGE OF KNOWLEDGE, is structured in 2 chapters that presents important aspects of the studied literature.

The second part: PERSONAL CONTRIBUTION, combines theoretical and methodological aspects with practical ones and is structured in eight chapters. Chapters 6, 7 and 8 where are added the general conclusions, recommendations, originality, and bibliography represent the largest part of the paper.

1. Current state of research of the importance of soybean crop

Chapter 1 consists of the three sub-chapters presenting current information on the importance of soybean crop; the history, origin and spread of the crop; biology, ecology and chemical composition of soybean.

2. Ecological and nutritional requirements for soybean crop [*Glycine max (L.) Merrill*]

Chapter 2 consists of six subchapters covering technological features and agro-technical advantages of soybean cultivation, particularities of fertilization, soybean crop requirements for primary, secondary and microelements.

3. Research objectives

Chapter 3 includes the objectives of the research that aimed to evaluate the influence of NPK type mineral fertilization on the level of yield and quality in soybeans. Also, the present paper aimed the influence of different fertilization variants, mineral or organic on the yield, yield elements and quality of the early soybean variety Caro TD. These objectives led to the achievement of results that allowed the elaboration of valuable conclusions and recommendations, both for the research environment and for the soybean growers in the Transylvanian Plain, contributing greatly to the improvement of soybean cultivation technology in the reference area.

4. The features of the natural environment in the experimental field from RDSA Turda

Chapter 4 presents: landscape, hydrography, climate, temperature, rainfall and soil in the crop area where the experiment was located.

5. Material and method

Chapter 5 presents the description of the biological material used, the field design of the two experiments, the factors of the experiment, research methods, observations and the performed analyses. The first experiment studies a genetic material of different maturity, consisting of commercial varieties and perspective lines in advanced generations of selection, created at RDSA Turda (13 very early, early and semi-early soybean genotypes), and within the second experiment, the early soybean variety Caro TD is used as biological material.

6. Climatic conditions of the two experimental years, growing season, height and basal pod insertion in the experimented soybean genotypes

Chapter 6 is divided into 3 subchapters that presents the thermic and pluviometric regime of the experimental period as well as the influence of experimental factors on the growing season, plant height and basal pod insertion height. The two years were very different from a climatic point of view, in 2020 the growing season of the experimented genotypes being longer than in the previous year by: 7, 8 and 12 days for very early, early and respectively, semi-early soybean genotypes. The mean values for the plant height and the insertion height of the basal pod showed small variations from one year to another, within each analysed maturity group.

7. Research on the influence of two types and four doses of fertilizer on yield and quality of very early, early and semi-early soybean genotypes

Chapter 7 is structured in 2 subchapters and 11 sub-sub-chapters and presents the results obtained in the experiment that studied the influence of two types of mineral fertilizer (NPK 16:16:16 and NPK 27:13.5:0) and four different doses (unfertilized, 150 kg/ha, 200 kg /ha and 250 kg/ha) on yield, yield elements and quality in very early, early and semi-early soybean genotypes.

In the semi-early soybean genotypes, the highest yields were obtained, in both years, the year 2020 offering the cultivars the possibility to express themselves at a

high productive level, of almost 3 tons. It would seem that in the climatic conditions of 2020, the three studied doses of the second type of fertilizer (NPK 27:13.5:0) led to higher yields compared to the non-fertilized variant, regardless of the analysed maturity group.

In terms of TKW, the highest values were obtained in very early soybean cultivars in both experimental years. If in 2019, fertilization played a decisive role in the fluctuation and growth of TKW, in the climatic conditions of the second experimental year, soybeans were higher compared to the first year, regardless of the maturity group studied.

For the number of pods/plant, while the control variant set the highest value in the first year, in 2020, fertilization led to increased internodes with positive impact on the number of pods/plant, the reaction of genotypes to fertilization being dependent on climatic conditions from the soybean growing season.

In general, very early and early soybean genotypes had a higher number of grains/plant in both experimental years compared to semi-early soybean genotypes. In 2019, in all three maturity groups, fertilization with 250 kg/ha NPK 16:16:16 led to an increase in the number of grains/plant and fertilization with the second type of fertilizer led to smaller number of grain/plant compared to unfertilized variant. In the second experimental year, the genotypes studied responded positive to fertilization, the average number of grains/plant being higher than the control in both types of fertilizer.

In both experimental years, grain mass/plant was higher in very early and early soybean genotypes fertilized with a dose of 200 kg/ha complex fertilizer type NPK 16:16:16. In 2020, the fertilization with the first type of fertilizer of the semi-early soybean genotypes led to the decrease of the grain mass/plant, increases of this parameter being obtained following the application of doses of 150 and 200 kg/ha of complex fertilizer type NPK 27:13.5:0. In the climatic conditions encountered in the second experimental year, the grain mass/plant was up to 100% higher than in the first year, noting the very early soybean genotypes which, after fertilization with 150 kg/ha NPK 27:13.5:0, had an average grain weight of 14.5 g.

Regarding the quality of soybeans, in the experiment performed in Turda, no specific dose of fertilizer from a certain type of fertilizer was identified that would cause large increases in the protein content of soybeans, the response of genotypes being different depending on the maturity group and the climatic conditions encountered. In 2019, the protein content ranged between 34.6% (NPK 27:13.5: 0 x D3 x GM 000) and 39.1% (NPK 16:16:16 x D3 x GM 0), at the control variant were obtained good results for all maturity groups. In the climatic conditions of the second experimental year, very early soybean genotypes accumulated a protein content of 41.7% when fertilized with 250 kg/ha NPK 27: 13.5: 0 complex fertilizer.

The first dose of the first type of fertilizer was favourable for the accumulation of fatty substances in the grain in both years. In 2020, the non-fertilized variant had the highest values of fat content compared to those obtained when NPK fertilizer 27: 13.5:0 was applied, while in the first year, cultivars fertilized with 200 kg/ha of the same type of fertilizer led to oily grains. In both years, the temperatures in July and August were higher than the multiannual average, the drought in July 2019 leading to the accumulation of a lower amount of fatty substances in the grain, compared to 2020.

In the experiment, very early soybean genotypes had the highest values of fat content, at the opposite pole being located the semi-early cultivars. The maximum of the experiment was registered for the soybean cultivars from the maturity group 000, fertilized with 150 kg/ha complex fertilizer of NPK type 16:16:16, in both experimental years (24.1% and respectively 25%).

For the stearic acid content, the results obtained in the first experimental year were close for all three studied maturity groups, in both types of fertilizer and doses analysed, the highest values being recorded in the control variant. An increase in stearic acid content was identified in 2020, when 250 kg/ha NPK 27:13.5:0 complex fertilizer was applied.

As with the other quality parameters, oleic acid fluctuation was higher in the second experimental year. In general, in 2019 the semi-early soybean genotypes fertilized with the first type of fertilizer recorded higher values of this monounsaturated acid compared to the control variant. A slight increase in oleic acid was observed after fertilization of early and semi-early soybean genotypes with both types of fertilizer in the second experimental year.

In terms of linoleic acid content, in 2019, higher values were obtained in the maturity group 000 after fertilization with 150 kg/ha and 200 kg/ha of both types of fertilizer. In 2020, the latest genotypes in the experiment had a higher content of linoleic acid and fertilization, regardless of dose and maturity.

For the linolenic acid content, in both experimental years, the genotypes of early and very early maturity recorded the highest values. If in 2019 the best results were obtained for the control variant, in the second experimental year the highest doses (200 kg/ha, 250 kg/ha) of both types of fertilizer determined the accumulation of a higher amount of linolenic acid in soybeans.

In the climatic conditions of 2019, fertilization led to a decrease in the linolenic acid content of soybeans for all the studied maturity groups. In the second experimental year, a slight increase of this parameter was identified following the fertilization of the earliest experienced genotypes, the largest increase being recorded after the application of 250 kg/ha NPK:16:16:16.

8. Research on the influence of different fertilization variants within the Donau Soja Demonstration Platform, on the yield and quality of the soybean variety Caro TD (Turda 2019-2020)

With a 7-year tradition in Romania, the soybean demo platform by the Donau Soja Association in different locations of the country, aimed to contribute to the expansion of the cultivated areas with this crop by offering the best technological solutions. At RDSA Turda, the platform on soybean crop fertilization included 16 experimental variants in 2019, respectively 12 in 2020.

The results obtained in the first experimental year indicated that some treatments seem to improve the yield and quality of soybeans, being identified variants with maximum values for the studied parameters: the T1 treatment showed maximum values for: yield (3549 kg / ha), number of pods/plant (32.9) being at the same level with T2, T6, T9, T12 and T13 (29.4, 27.5, 28.2 and respectively 28.3) and the height of the plants (87 cm); the T4 treatment recorded the maximum values for the insertion of the first basal pod (16 cm); T6 had maximum values for the number of grains/plant

(90.2) and the weight of the grains/plant (11.18 g); T11 had the heaviest grains (146.5 g). The insertion of the first basal pod, the number of grains/plant and the weight of the grains/plant in the Caro TD soybean variety varied significantly for different combinations of organic and unorganic fertilizers.

The results obtained for the quality parameters indicated that the composition of the seeds is influenced by the types of applied fertilization. The small increase in protein concentrations in soybeans was observed at T1 (protein content 4% higher than T0). The highest value of oil content was reported for the treatment of T14 (26.54%), registering an increase of 5.6% compared to the control variant (T0). At T13 treatment was obtained: a high content of: oil (26.26%), total carotenoids (23.56 mg / kg DW) and total phenols (2.2 mg GAE/g DW), associated with the lowest content of protein (37.44%). The low CV (%) to the studied quality parameters indicates an insignificant variation for the content of: dry matter, protein, ash, oil, total carbohydrates and total phenols.

Based on the Pearson correlation coefficient calculated for: number of plants/m^2, plant height; insertion height of the first pod, number of pods/plant, number of seeds/plant, grain mass/plant, TKW, yield, dry matter, proteins, lipids, carbohydrates, flavonoids, phenols, carotenoids, the close connection between the size of the plant is highlighted and: the number of pods/plant, the number of grains/plant and the mass of grains/plant, statistically proved distinctly significant positive for the first two (r = 0.7 **), respectively very significant positive for the last (r = 0 , 8 ***).

The number of pods/plant correlates positively and very significantly with the mass of grains/plant (r = 0.8 ***) and with the number of grains/plant (r = 0.9 ***); at the same time a very significant strong correlation was identified between the number of grains/plant and the mass of grains/plant.

Distinctly significant positive correlation was also identified between the dry matter content and the total carbohydrate content, respectively between the total phenol content and the carotenoid content of soybeans. Yield, the most important quantitative indicator of soybean crop correlates significantly positively with number of pods/plant.

The insertion height of the first pod was significantly negatively correlated with the number of pods/plant and distinctly significantly negative with: the number of seeds/plant and the mass of seeds/plant.

In the second experimental year, based on the obtained performances, a classification of the best variants was made, highlighting variant 11, with an experimental protocol that included both basic fertilization and treatment to seed, respectively on vegetation. Although it did not excel in the ranking made for each agronomic studied feature, the high values, close to the maximum of the experiment, placed variant 11 in the top, when taking into account both the quality of soybeans and the yield and yield elements analysed. At the opposite pole, with a total rank of 119, was treatment 3. Caro TD soybean variety responded positive to variant 1, where it achieved both the highest yield (3031 kg/ha) and the top position among the fertilization variants, obtaining in this case the lowest total rank (21) for yield and the studied elements of yield.

It would seem that the inoculation of soybeans as well as the fertilization applied, were not found in a better quality of the grain; in the control variant, with a

total rank of 21, the highest content was obtained in: oil (23.72%), oleic acid (25.30%), linolenic acid (8.9%) and stearic acid (4, 97%), but also the best place in the general ranking made for the chemical composition of soybeans.

As in the first experimental year, the Pearson correlation coefficients confirmed by the chemometric analysis highlighted the positive correlations between the size of the plant and: the number of pods/plant, the number of grains/plant, the mass of grains/plant; between the number of pods/plant and: the number of grains/plant and the mass of the grains/plant respectively between the number of grains/plant and the mass of the grains/plant.

9. CONCLUSIONS AND RECOMMENDATIONS

Chapter 9 consists of 2 subchapters and includes the conclusions and recommendations based on research conducted in the 2 field experiments, in the years 2019-2020 located at RDSA Turda.

The researches that followed the effect of the mineral fertilization with complex fertilizers of NPK type on the yield and of its agronomic properties, on soybeans, in the pedo-climatic conditions from the Transylvanian Plain allowed the formulation of the following conclusions:

In terms of yield, the response of soybean genotypes to fertilization varied depending on the climatic conditions encountered in the two experimental years. If the fertilization with the complex fertilizer NPK 16:16:16 did not determine yield increases compared to the unfertilized control, in the two analysed years, it would seem that in the climatic conditions 2020, in all maturity groups fertilized with NPK 27:13,5:0, higher yields were obtained compared to the non-fertilized variant, regardless of the applied dose.

Overall, the semi-early soybean genotypes were the most productive, responding favourably to fertilization with a dose of 200 kg/ha NPK 16:16:16 in 2019 (2641 kg/ha) and NPK 27:13.5:0 (2960 kg/ha) in the second year.

The group of very early cultivars behaved favourably in terms of yield. In 2020, it was found that the application of mineral fertilizer and especially of complex fertilizers such as NPK 27:13.5:0 marked positively some properties of yield.

Regarding the protein content, in 2020, higher values than the first experimental year were obtained in all maturity groups, fertilized with two types of fertilizer and four different doses. A positive reaction was observed in the maturity group 000, in 2020, following the application of the dose of 250 kg/ha NPK 27:13.5:0, where the highest value of this parameter was recorded (41.7%).

The climatic conditions during the grain filling period of the two experimental years influenced the fluctuation of the oil content, the drought of July 2019 leading to the accumulation of a smaller amount of fatty substances in the grain, compared to 2020. Early genotypes, fertilized with 150 kg/ha complex fertilizer type NPK 16:16:16, in both experimental years, were the oiliest (24.1% in 2019, respectively 25% in 2020).

From the obtained results from the analysed fatty acids it can be seen that similar values were obtained for all three groups, both in terms of oil quality and its stability.

The variability of the experimental data identified within the soybean genotypes from the three analysed maturity groups in 2019-2020 at RDSA Turda, on two agrofunds, with different fertilization doses, indicates that the agronomic properties studied are more influenced by the maturity group, than by experienced technological factors.

Recommendations:

When soybean crop is cultivated for a long period of time in certain areas, fertilization must be smaller than 200 kg/ha complex fertilizer. Also on soil with high N , P content, fertilization can be excluded. Also, on soils with a moderate to good content of N and P and in a location where soybean crops are extensive, fertilization is npt recommended.

The Transylvanian Plain remains a very favourable cultivation area for soybean early genotypes, but given the very pronounced differentiation of cultivation years, we recommend the presence on the farm of at least two soybean genotypes from different maturity groups.

Qualitative properties (protein and oil) have a pronounced hereditary conditioning, but their variation is influenced by climatic conditions and fertilization. For example, very early cultivars fertilized with moderate doses of NPK 27: 13.5: 0 complex fertilizer recorded significant increases in protein content.

Finally, we recommend moderate doses of fertilization, or even missing, depending on the variety, the crop area, and by the physico-chemical analyses of the soil.

Research on the influence of different fertilization variants within the Donau Soja Platform, on the yield and quality of the soybean variety Caro TD (Turda 2019-2020) allowed the following conclusions:

The early soybean variety Caro TD reacted differently to the analysed fertilization variants, depending on the climatic conditions of the two experimental years.

In general, the behaviour of the Caro TD variety in terms of yield was better in the first year of study, so the T1 variant (NPK 20:20:0 -200 kg/ha x seed treatment with BIO products x treatment / vegetation with BIO products), at which the maximum of the experiment was reached (3549 kg / ha), was identified as the optimal treatment option. In 2020, the seeds inoculated with *Rhizobium* and bacterial protector (T1), sown after a fertilization based on N, CaO, MgO (Nitrocalcar - 130 kg/ha) led to an increase in yield of about 11% compared to control variant.

If in the first experimental year, the quality of soybeans was improved when organic fertilization plan was applied (T7). In general, in the climatic conditions of 2020, fertilizers and various treatments applied to seed or vegetation did not lead to increased quality seeds, good results being obtained in the control variant.

Based on the Pearson correlation coefficients, confirmed by the chemometric analysis, some more or less close relationship between the studied agronomic properties were highlighted. Positive correlations were identified between plant size and: number of pods/plant, number of grains/plant, mass of grains/plant; between the number of pods/plant and: the number of grains/plant and the mass of the

grains/plant respectively between the number of grains/plant and the mass of the grains/plant.

The cluster analysis allowed the grouping of experimental variants according to the observed similarities, being identified fertilization schemes accompanied by inoculation of seeds with products based on *Bradyrhizobium japonicum*, which led to high values for most agronomic properties studied.

Recommendations:

In choosing the optimal fertilization scheme the particularities of the cultivated variety and the physical and chemical characteristics of the soil must be taken into account.

It is recommended to inoculate soybeans with products based on *Bradyrhizobium japonicum* to stimulate the nodules and the biological fixation of atmospheric nitrogen, with positive effects on soybean yield.

In dry years it is recommended to adopt a treatment scheme based mainly on organic products to increase yield and improve the quality of the soybean crop.

10. THE INNOVATIVE AND ORIGINALITY CONTRIBUTIONS OF THE THESIS

Although the use of fertilizers is considered to be one of the most important factors in increasing crop yield, this study elucidates important issues related to how nutrient support for soybeans influences the quantity and quality of crops in different maturity soybean genotypes.

It is known that genetic progress through classical breeding methods is long-lasting, so identifying an optimal fertilization scheme can be a future solution for increasing soybean yield and quality. For example, in the experiment, very early genotypes, fertilized with moderate doses of NPK 27:13.5:0 complex fertilizer, recorded significant increases in protein content.

The originality of the thesis is also given by the complex quality analyses performed in the experiment.

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