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THE EFFECT OF CROP ROTATION AND SEED INOCULATION ON SOYBEAN YIELD, YIELD ELEMENTS AND SEED QUALITY

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Abstract

In order to evaluate the effect of crop rotation and seed inoculation on soybean yield, yield elements and seed quality, an experiment was conducted in Amati village, Satu Mare County, in 2020, using three early soybean varieties (Onix, Felix, Cristina TD). Crop rotation (two graduations) and seed treatment (three graduations) factors were studied. The experiment was based on a split plot design. Yield, yield elements (plant size, insertion of the first pod, number of pods/plant, number of grains/plant, weight of grains/plant, size of grains and seed quality (protein and fat) were determined, highlighting the influence of genotype and of seed treatment on studied parameters. In terms of crop rotation, generally no influence was identified. Cristina TD was a high yielding genotype with 5361 kg/ha obtained in the experimental variant when soybean was included in rotation and Nitragin product was applied.

Key words*: crop rotation, inoculation, quality, soybean, yield.*

INTRODUCTION

The global climate scenario faces a drastic depletion of soil nutrients due to various anthropogenic activities, burning of fossil fuels and excessive use of agrochemicals (Sarfraz et al., 2019), and the use in agricultural systems of legumes living in symbiosis with nitrogen-fixing bacteria can be a good way to increase soil fertility and production.

Soybean is the most important protein (Joiţa-Păcureanu et al., 2023; Badea et al., 2023) and oil plant in the world, but Europe relies mainly on imports due to the small area of legume cultivation (only 1.5% of agricultural land) compared to the global needs (Watson et al., 2017).

Due to its widespread use in many industries, soybeans are classified as a strategic crop (Guzeler and Yildirim, 2016). The value of soybean seeds depends on their oil content and fatty acid composition (Carrera and Dardanelli, 2017; Kurt and Baloch, 2023). The chemical composition of seeds is primarily genetically determined (Tamagno et al., 2020) but also by environmental and technological factors that intervene in soybean production.

Soybean yield depends largely on the availability of nitrogen that affects plant growth and development (Salvagiotti et al., 2008), but through its ability to absorb atmospheric nitrogen, soybean becomes an important crop in agricultural rotations (Moldovan et al., 2022; Ionescu et al., 2022).

Due to the growing interest in biological methods to improve soil fertility in recent years as well as increasing crop production and quality, interest in inoculating soybeans with bacteria is growing (Fatima et al., 2007). Inoculation of seeds with symbiotic bacteria, especially in soils naturally lacking them, but also optimal fertilization with nutrients are considered particularly important elements in soybean cultivation (Jarecki, 2023) and Salvagiotti et al. (2008) argued that when cultivating high-yielding varieties, fertilization with a small dose of nitrogen might be necessary. Inoculation of soybeans with bacteria of the genus *Bradyrhizobium japonicum* in combination with the optimal

level of fertilization results in the most effective biological fixation of N (Grossman et al., 2011).
Although soybean is a crop that requires fertilization in the early stages of development, until the formation of active nodosities, a high amount of N can slow down the process of symbiosis. The activity of developing and fixing nitrogen by the nodules on the roots is suppressed when the nodulated roots are exposed to a high concentration of nitrogen. Mendes et al. (2003) reported that the average number of nodules was 50% lower for plants to which an additional 40 kg/ha N was applied.
To obtain a high soybean yield, a good nodulation and a high and long-lasting activity are very important, because the availability of nitrogen in the soil is generally insufficient to support the growth of soybeans, and mineral nitrogen is lost within a few weeks of application (Șimon et al., 2022).
In the current context of climate change and the need to reduce the effects of global warming, the implementation of crop systems that reduce the amount of chemical fertilizers and have a positive impact on long-term agricultural sustainability (Lemessa and Wakjira, 2015) is of real importance.

MATERIALS AND METHODS

In order to evaluate the influence of crop rotation, inoculant with bacteria applied to soybeans seeds before sowing, and genotype on yield and quality of this crop, a polifactorial experiment (A x B x C) was conducted in 2020, in Amati village, Satu-Mare County.
The agricultural area of the experiment is characterized by lower fertility potential for soil with a clay-loam texture.
The biological material studied consisted of three commercial soybean varieties created at the Agricultural Research and Development Station (ARDS) Turda. Felix, Onix and Cristina TD are early soybean varieties that are cultivated on large areas in Romania.
The experiment was conducted according to the method of split plot design, each experimental variant having an area of 700 m^2.
The varieties were sown in two different rotations, a rotation in which soybeans was included five years ago and a rotation in which the soybean crop followed after four years of fodder plants.
The seed inoculation factor with products based on nitrogen-fixing bacteria had the following three graduations: the control variant (without treatment), the variant in which Poliriz S was applied and the variant in which the product Nitragin was applied. The application of the products was carried out on the day of sowing, respecting the recommendations of the companies.
Mechanized sowing of Felix, Onix and Cristina TD soybean varieties, with narrow row spacing and chemical weed control by using pre-emergence and post-emergence herbicides were practiced.
At the end of the growing season, 10 plants from each experimental variant were invasively analyzed for: plant size, insertion of the first pod, number of pods/plant, number of grains/plant, weight of grains/plant, size of grains (TKW). The yield was estimated based on the weight of grains /plant and number of plants/m^2, at the end of the maturity.
For each experimental variant, the protein and fat content of soybeans was determined using a near-infrared method.
The experimental data were statistically processed using Polifact program for Anova, Past4 for chemometric analysis and Pearson coefficients, respectively Excel for graphic presentation.

RESULTS AND DISCUSSIONS

Worldwide, in the context of current climate change, soybean breeding programs have as a priority the creation of high-performance varieties, adapted to environmental conditions, which meet the dynamic requirements of the market. Also, an important aspect pursued in increasing productivity is represented by the improvement of crop technologies applied to this crop plant. Based on data collected (https://www.meteoblue.com/ro) the temperatures recorded in the experimental field in 2020 (Figure 1), close to the multiannual average in the summer months, as well as the rainfall in the same calendar period positively influenced the reproductive stages of soybean plants and, of course, the yield obtained in the three soybean varieties analyzed.

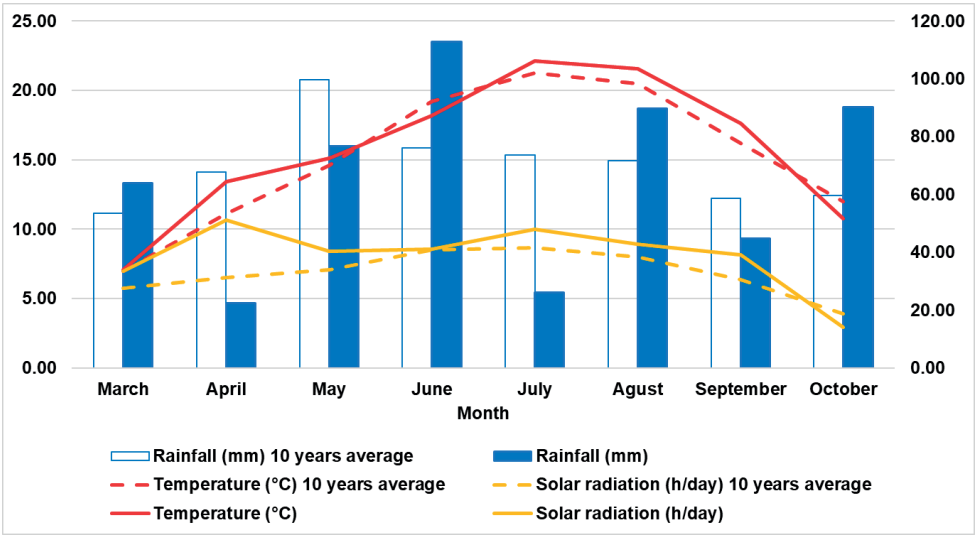

Figure 1. Monthly temperature, solar radiation average and rainfall in Amați (2020) compared to the ten year average (2010-2019)

Based on the values obtained in F test, the influence of each factor analyzed during the experiment on: production, plant height, insertion of the first pod, number of pods/plant, number of grains/plant, weight of grains/plant and thousand kernel weight was established (Table 1). It can be seen that, in general, production and productivity elements did not vary according to crop rotation, but were very significantly influenced by genetic factor (soybean genotype). In terms of seed inoculation factor, it seems that it had a very significant influence on production, insertion of the first pod, number of pods and grains/plant and on the size of grains.

The results obtained by Szpunar-Krok et al. (2023) show that inoculation of seeds with nitrogen-physicalizing bacteria resulted in a higher number of seeds and a higher seed weight/plant compared to uninoculated seeds, with the use of seeds inoculated with Nitragin resulting in an increase in seed number and weight per plant by up to 3.9% and 2.7%, respectively, compared to uninoculated seeds, however, there was no statistically significant effect of inoculation on the value of the obtained mass of 1000 seeds.

Other authors such as Namozov et al. (2022) showed that inoculation increased the number of pods by 16.5%, the number of grains/pod by 14.3%, the weight of pods by 20.7%, and the MMB by 10.5%, compared to the variant without inoculation.

The soybean yield varied depending on the genotype studied, the Cristina TD variety being the most productive, regardless of the rotation studied or the type of inoculation experimented. In both crop rotations, the application of seed treatment with products containing nitrogen-fixing bacteria led to higher yields than the control variant. It would seem that for all varieties the highest yields were obtained in the experimental variant in which seed treatment with Nitragin product was applied.

When soybean was included in crop rotation (Figure 2), the obtained yield varied between 4181 kg/ha (Felix) and 5361 kg/ha (Cristina TD, in the experimental variant where Nitragic was applied). For Felix variety were obtained similar values for yield, regardless of seed treatment. When soybean was new in crop rotation (Figure 3), the obtained yield varied between 4228 kg/ha (Felix) and 5232 kg/ha (Cristina TD, in the experimental variant where Nitragic was applied). Experimental date highlights the yields obtained in the Cristina TD variety, which had a small variation depending on the inoculant used.

Table 1. ANOVA Test for yield and yield elements as influenced by crop rotation, seed inoculant and soybean genotype

Cause of variability	Yield	Height	Insertion	Number of pods/plant	Number of seeds/plant	Seed weight/ plant	TKW MMB
Rotation (A)	ns	ns	*	***	ns	ns	ns
Seed inoculation (B)	***	ns	***	***	***	ns	***
A x B	***	ns	***	***	***	ns	ns
Soybean genotype (S)	***	***	***	***	***	***	***
A x S	***	ns	ns	***	***	ns	ns
B x S	***	ns	**	***	***	ns	ns
A x B x S	***	ns	ns	***	***	ns	ns

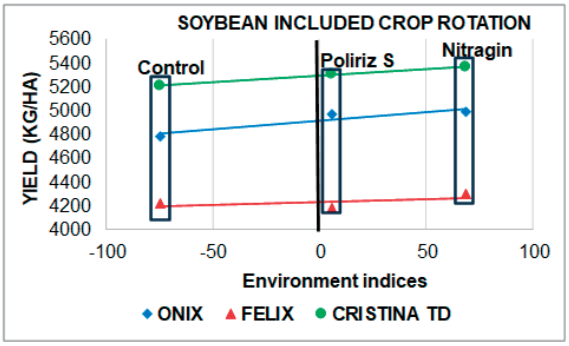

Figure 2. Yield obtained at three soybean varieties depending on seed inoculation

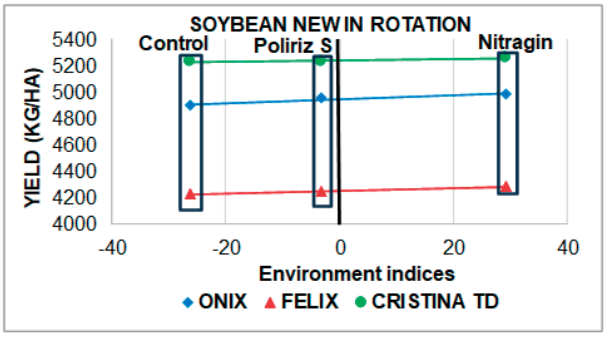

Figure 3. Yield obtained at three soybean varieties depending on seed inoculation

Because crop rotation did not have an influence on obtained yield and productivity elements analyzed, only the results obtained in the experimental variant in which soybean was included in the five years rotation will be following presented in the paper. The principal component analysis (PCA), confirmed by the cluster analysis (Figure 4) point out the experimental variant in which the product Nitragin was applied, with high values obtained for most of the agronomic parameters: production (4843 kg/ha), plant size (117 cm), insertion of the first pod (17 cm), number of pods/plant (38), number of seeds/plant (97), weight of grains/plant (16.32 g), thousand kernel weight (170 g). Similar results were obtained by Vollmann et al. et al. (2011), which confirmed that nodulation had a significant effect on biometric traits of plants, including some yield components.

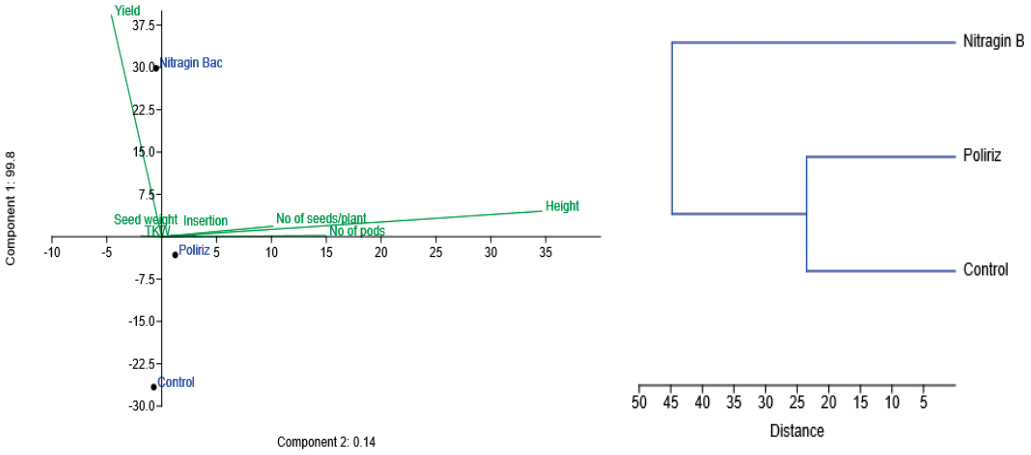

Figure 4. Principal component analysis (PCA) and Cluster analysis

Based on the plot of correlations (Figure 5), the close positive relationship between grain yield and: plant height (r = 0.96), grain weight/plant (r = 0.98) and grain size (r = 0.89) are highlighted. Regarding the negative correlations established between the studied parameters, it is noted the relation between production and protein content (r = -0.62), oil content and number of pod/plant (r = -0.98), respectively between TKW and protein content (r = -0.91).

Data obtained by Szpunar-Krok et al. (2023) in a similar experiment showed that soybean production was positively correlated with plant density after sprouting, weight of 1000 grains, and seed/plant mass. Other authors stated that next to production elements that vary depending on factors that intervene during the growing season, the protein and oil content is strongly influenced by environmental conditions (Popa et al., 2023).

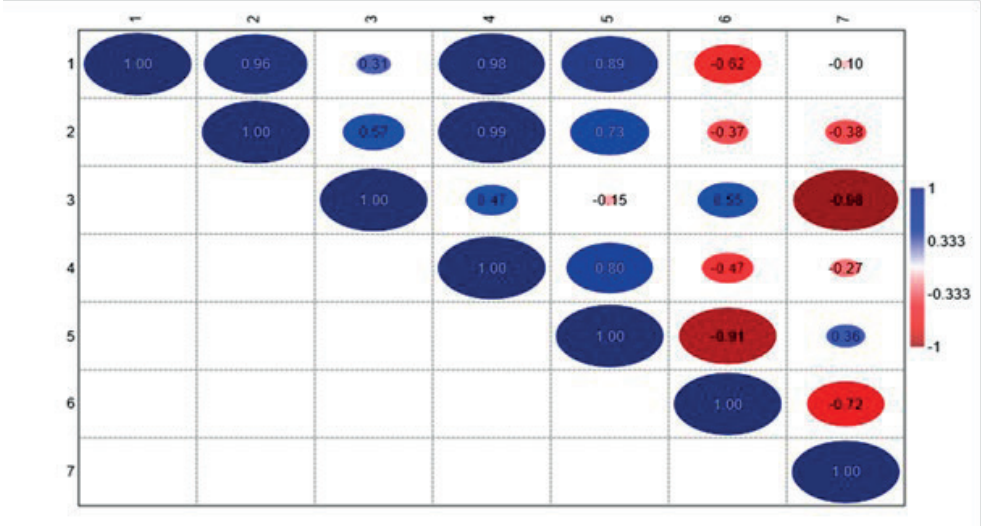

Figure 5. Person coefficient analysis between yield (1), yield elements [height (2), no of pods/plant (3), seed weight/plant (4), TKW (5)) and seed quality (protein (6), oil (7)], when soybean was included in crop rotation

CONCLUSIONS

The results obtained in this study indicated that, soybean yield could be increased by applying bacteria inoculation regardless of crop rotation.
Inoculant applied to soybean seeds determined different results for studied varieties in terms of yield and yield elements. A positive yield response to Nitragin seed inoculant when soybean was included in 5 years crop rotation was observed at Cristina TD variety with the highest value for this parameter (5361 kg/ha). A slightly increase, a lack of response or negative influence on yield has been observed with seed inoculants applications to Felix soybean variety.
The variety Cristina TD in combination with Nitragin BAC inoculant, in both crop rotations, can be recommended for cultivation in the North West part of Romania.
In terms of Pearson coefficient, were identified close positive relationship between grain yield and: plant height (r=0.96), grain weight/plant (r=0.98) and grain size (r=0.89) are highlighted. Regarding the negative correlations established between the studied parameters, it is noted the relation between production and protein content (r = -0.62), oil content and number of pod/plant (r = -0.98), respectively between TKW and protein content (r = -0.91).

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