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The impact of seed density on the yield and plant development of soybean cultivars (*Glycine max* (L.) Merill)

ABSTRACT

During the years 2017 – 2019 a research was conducted on the Głubczyce Plateau, concerning the reaction of soybean cultivars on seeding density. The aim of the research was to discover the reaction of soybean cultivars included in different groups of earliness (very early – Augusta; mid early – Abelina, Mavka, Merlin, SG Anser; and late – Aligator, Lissabon, Sultana) on the distribution of plants in a canopy, shaped by the number of seeds sown on 1 m^2. In the working hypothesis it was assumed that the studied cultivars – because of their properties which determine, among other results, plant's height, the setting height of the first pod, and the number of branches on the plant – would show differentiated reaction to sowing density and that the latter would influence:

- the yield level of the seeds,
- the chemical composition of the seeds by the interaction of sowing rate with cultivars,
- the cost efficiency of crops, alongside with differentiating the cost of production of 1 tonne of seeds and 1 kilogram of protein.

Specific goals of the research were to determine the influence of the studied factors on:

1. The length of vegetative development and generative growth and the period of vegetation,
2. Shaping of morphological characteristics of soybeans,
3. Chemical composition of seeds,
4. Seeds productivity regarding important nutrients,
5. Cost-effectiveness of crops

The scope of research included:

- conducting field experiments,
- analysis of chemical composition,
- economic balance.

The experiments were conducted in three replications in the "split-plot" system with two variables, which were:

I. number of seeds of full use value sown per 1 m^2: 30, 45, and 60,
II. soybean cultivars: Abelina, Aligator, Augusta, Lissabon, Mavka, Merlin, SG Anser, Sultana.

Size of plots: length – 11 m, width – 1,5 m, area for harvest – 15 m^2.

Soybeans were sown in 21,4 cm row spacing and the distances between seeds in a row, depending on the number of seeds sown per 1 m^2 – 30, 45 and 60, were 15,8; 10,4 and 7,8 cm, respectively.

During vegetation the observation of the plants growth was conducted, and the density was determined for 2 linear metres of medium row before blooming time, after which the results were calculated into 1 m^2.

Before harvest measurements were conducted in 10 of randomly selected plants from each plot. These measurements took the following factors into account:

- height of plants up to the top of main shoot,
- height of the setting of the first pod,
- number of branches of the first row per plant,
- number of pods per plant,
- number of seeds per plant,
- mass of seeds per plant,
- number of seeds per pod,
- mass of seeds per pod,
- mass of sterns per plant,
- mass of stems per plant.

During harvest the following were specified:

- seed yield,
- mass of post-harvest residue – straw and sterns,
- mass of 1000 seeds.

Seed yield and post-harvest residue were converted to a constant of 15% humidity.

Qualitative assessment of seeds and straw was conducted with the use of the following methods:

- dry mass – by a dry oven test at the temperature of 105 ± 2°C within the period of 5 hours,

- total nitrogen (total protein) – with a modified Kjeldahl method: total nitrogen was measured in seeds and then converted into total protein using the 6,25 coefficient,
- K and Ca with the flame photometry method,
- P and Mg with the colorimetric method.

In addition, the following were analyzed in the seeds:

- crude fat by the extraction in anhydrous ethyl ether in Soxhlet extractor for approximately 7-8 hours,
- crude fibre was analyzed in non-fat mass remaining after fat extraction in the apparatus with the use of the Henneberg-Stohmann method,
- crude ash by burning organic substance in plant sample in an electric stove for 3 hours at 600°C.

On the basis of chemical analyses the content of nitrogen-free extract, total protein yield and crude fat from seeds were calculated, as well as the accumulation of macronutrients in seeds and straw from 1 hectare.

Cost calculations were based on price lists:

- of agricultural services, drawn up on the basis of data collected from entities providing agricultural services within the territory of Poland,
- published on websites of Centres for Agricultural Consultancy.

As the criterion for estimating the cost-effectiveness of soybeans grown during the years 2017 – 2019, the income from one hectare was taken, which was calculated as the difference of production value (revenue from sales + subsidies) and the sums of direct and indirect costs. Benefits from growing soybean as a previous crop were not estimated.

In the accounting approach, the costs are the sum of investments necessary for the creation of product or service expressed in money [Ludwiczak 1989]. In the cost statements the direct and indirect costs as well as the sums of costs for the tested soybean cultivars in particular years with the different number of seeds sown per 1 m^2 were taken into account. Direct costs include these elements of costs which may be indisputably classified as the cost of manufacturing of a particular product [Ludwiczak 1989]. Direct costs at work include: mineral fertilisers, seeds, and costs of plant protection products.

Indirect costs are borne for a production department as a whole or for the whole farm and it is difficult to assess at which level they encumber the production of particular products [Ludwiczak 1989]. Indirect costs include: soil cultivation, seed sowing, spraying, combine

harvesting, agricultural tax and 10% mark-up from the sum of direct costs of soil cultivation, as well as the remaining machines operation costs.

The value of production resulted from the achieved seed yield of soybeans and the price of their sale. Subsidies to 1 hectare took into account payments resulting from the functioning within the framework of common agricultural policy (single area payment, payment for grain legumes, for greening and subsidies to the certified C1 seed used). The factor which differentiated costs were the investments for seed.

The analysis of cost and financial effectiveness as a whole was omitted from the thesis, as it did not constitute the aim of the thesis. Also, no keys of cost division of the use of machines and devices in the crop and livestock production were used. During the performance of research, the comparability of different cultivars of crops was not affected as a result of different fortuitous events. The analysis did not include the costs of crops insurance. In the synthesis for the years 2017 – 2019 the sum of sale of 1 tonne of soybeans seeds was PLN 1 505 – the average amount obtained by Top Farms Głubczyce.

The research results were used in the variance analysis for orthogonal arrays with the 0,05 level of significance. In the analysis of variance a randomized split-block design with three replications was applied. Calculations were made using the AWA program.

The research on the **influence of the amount of seeds on the development and yielding of soybeans cultivars** conducted in 2017 – 2019 allows us to draw the following conclusions:

1. The shortest average vegetation time within the three-year research period was that of the Augusta variety – 124 days (118 – 132). Successively, the remaining cultivars showed the following vegetation times: Abelina – 133 (124 – 149), Lissabon and Mavka – 134 (125 – 148; 123 – 152), Merlin and Sultana – 135 (123 – 156; 127 – 149) Aligator and SG Anser – 136 (123 – 161; 125 – 157).
2. The period of vegetative development in all tested cultivars was little diversified and amounted to 46 – 48 days, however, the genetic factor had a significant influence on generative growth which lasted from 76 to 90 days and determined the length of vegetation period.
3. The increase of the number of seeds sown per 1 m^2 from 30 to 60 increased the plant's height by 8% as well as the setting of first pod by 20% and resulted in the decrease of branches, pods on the plant, and seeds from the plant by 38%, 41% and 40%, respectively.

4. The genetic factor affected all tested morphological characteristics. The variety with the highest growth and the setting height of the first pod was Mavka, the ones with the greatest number of branches were Augusta and Lissabon, the variety with the most pods and seeds per plant was Merlin, and the highest number and mass of seeds per pod and the greatest mass of 1 000 seeds were observed in SG Anser.
5. The tested factors and their interaction influenced the mass of seeds, sterns and stems from a plant and the total mass of the whole plant. Increasing the number of seeds sown per 1 m^2 from 30 to 60 lowered the mass of seeds, sterns, stems and the whole plant by 39%, 39%, 28% and 37%, respectively. The greatest mass of seeds was obtained from the Lissabon variety, of sterns and the whole plant from Sultana, and of stems from Mavka.
6. Increasing the number of seeds sown per 1 m^2 from 30 to 45 caused a statistically significant growth of yield. It also caused an increase in costs of soybeans cultivation per 1 hectare approximately by PLN 189,08, including investments in seeds by PLN 171,89, which at the sale price of 1 tonne of seeds amounting to PLN 1 505 covers the seed yield growth in the amount of 114 $kg \cdot ha^{-1}$. The average yield growth amounted to 210 $kg \cdot ha^{-1}$, which compensated for the increased investments for the cultivation with a surplus.
7. The highest seed yield was achieved from Abelina. The other cultivars turned lower yield successively Merlin – by 2%, Lissabon and Sultana – by 3%, Aligator – by 8%, SG Anser – by 9%, Mavka – by 11% and Augusta – by 27%.
8. The tested factors and their interaction influenced the chemical composition of seeds. Regarding the content of crude ash, the influence of genetic factor was proved, however the set of humidity and thermal conditions, which varied across the years, differentiated the content of all tested components.
9. The yield of total protein and crude fat was shaped by the tested factors. Increasing the number of seeds sown per 1 m^2 from 30 to 45 caused the increase in the yield of total protein and crude fat by 6% and 7%, respectively.
10. The greatest yield of total protein was achieved from the Abelina variety. The remaining cultivars turned lower yield successively: Merlin and Sultana – by 3%, Lissabon – by 5%, Aligator – by 8%, SG Anser – by 11%, Mavka – by 14% and Augusta – by 27%.
11. Economic balance taking into account the income from 1 hectare as the main criterion showed that in the very good soil conditions of the Głubczyce Plateau, for the

Aligator, Mavka, Merlin, SG Anser and Sultana cultivars it is enough to sow 45 seeds per 1 m^2, while for the Abelina, Augusta and Lissabon cultivars the number of 60 seeds should be used per 1 m^2.

12. On average, for the sowed amounts, increasing the number of seeds sown per 1 m^2 from 30 to 45 resulted in the increase in income from 1 ha by 6,3%.
13. Across the cultivars, the highest average income was obtained from the Merlin variety. The other cultivars turned lower income successively: Sultana – by 0,5 %; Abelina – by 1,1%; Lissabon – by 4,3%; Aligator – by 8,4%; SG Anser – by 19,9%; Mavka – by 24,7% and Augusta – by 53,7%.
14. With the average costs of cultivation of 1 ha of soybeans amounting to PLN 3 511,82 and the price of sale of 1 tonne of seeds equal to PLN 1 505, the break-even point, without subsidies, is obtained with the yield of 2,33 $t \cdot ha^{-1}$.