

## FORMATION OF STRUCTURAL ELEMENTS OF SOYBEAN HARVEST

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**Topicality.** Quantitative indicators of each structure element of productivity directly affect the formation of high yields. The soil and climatic conditions of the region and certain elements of the cultivation technology, in particular, the application of fertilizers, are the determining factors of soybean productivity formation. **Purpose.** To establish the influence of inoculation and nutritional conditions on the formation of structure elements of the soybean yield for ultra-early variety Mercur. **Methods.** Special and general scientific methods were used in the research. For 2019–2020, field trials were conducted on typical low-humus chernozems in the conditions of the Kyiv region. The experiment was two-factor: factor A - nutritional conditions created by different rates of fertilizers and growth regulator Huliver Stymul against the background of mineral fertilization in BBCH 13-15; BBCH 51-55; factor B – seed inoculation with Nitrofix P (dry inoculant for soybeans). **Results.** According to the results of research, the influence effectiveness of nutritional conditions, growth regulators, seed inoculation on the formation of soybean yield structure elements for the Mercur variety are presented, and the interrelationship between these factors is identified. It was established that the formation of soybean productivity elements depends on the studied factors and environmental factors. **Conclusions.** Increased fertilizer rates significantly increased the number of pods per plant and the number of seeds per pod. Dynamics of increasing the 1,000 seed weight was also observed both in variants with seed inoculation with Nitrofix P, and without seed inoculation. Correlation analysis between the soybean yield structure elements and fertilizer variants revealed a strong positive correlation between them. Correlation-regression analysis, both without seed inoculation and with seed inoculation, revealed a linear dependence, which characterized by a strong correlation between soybean yield and fertilizer variants, with an approximation confidence value of  $R^2 = 0.951$ .

**Key words:** Huliver Stymul, yield structure elements, correlation dependence, thousand seed weight, Nitrofix P, soybeans, fertilizers, nutritional conditions, yield

**Introduction.** Consumption of soybeans and soybean products is growing and will grow in the future. The crop is popular due to its high profitability and broad market demand. Despite yields averaging 1.6–1.7 tonnes per hectare, the profitability level ranges from 60 % to 100 % and higher, on condition of high resource provision. Soybean cultivation improves soil structure, its physical and chemical properties, and enriches it with nutrients, particularly nitrogen. Photosynthesis and nitrogen fixation are the biological characteristics of soybeans [1–3].

Soybean plants are also capable to fix up to 450 kg of nitrogen per hectare due to symbiosis. Thanks to their symbiotic properties, soybean plants provide 55–60 % of their nitrogen needs [4–7].

The crop fertilisation system should be aimed to create conditions that are close to optimal and capable to maximise the genetic potential of a particular crop variety or hybrid through nitrogen fixation and balanced nutrition of crops with phosphorus, potassium and microelements [8–11].

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The availability of nutrients in the soil, in particular nitrogen, is important for the productivity of legumes. The process of nitrogen fixation by legumes is not sufficiently studied and requires identifying opportunities to influence its intensification. Studying this issue will allow to more intensively increase soybean production while saving energy resources.

Today, the Ukrainian market offers a wide diversity of inoculants specifically for soybeans. The substrate for dry inoculants is produced from peat or vermiculite [12, 13].

Preliminary studies show that seed inoculation provides a yield increase from 10 to 24 % [14].

The previous studies showed that growing soybeans without inoculation resulted in a yield of 1.81 t/ha, while seed inoculation with Optimise increased the soybean seed yield of Apolon by 12.6 % and that of Valiuta by 15 %. The application of Ryzoactiv inoculation resulted in an increase in yield of 0.34 t/ha. Inoculation increases leaf surface area, number of branches, pods, seeds, and, as a result, crop productivity [15–17].

Seed treatment with Rizohumin + Khetomik ensured a yield of 2.45 t/ha in the Annushka variety (2.26 t/ha in the control variant) and 2.31 t/ha in the Ustia variety (1.94 t/ha in the control variant) [8].

The application of HiCoat Super Soybean + HiCoat Super Extender and HiStick Soybean provided an increase in yield of 28.2 and 18.3 %, respectively, compared to the control [18, 19].

The starter dose of nitrogen is recommended only on poor soils and after unfertilised predecessors. Phosphorus supply plays an important role in the nutrition of soybean plants. Phosphorus in soybean plants is contained in mineral and organic substances, nucleoproteins, and nucleic acids, which are important for protein synthesis, growth and reproduction, and the transmission of inherited traits. The application of nitrogen and phosphorus fertilisers (N<sub>60</sub>P<sub>60</sub>) increases yields by up to 0.61 tonnes per hectare. Soybean plants require a large amount of potassium for active growth and development. It is a component of protein molecules and other organic compounds [20].

The application of phosphorus in the rate of 45 kg/ha increased soybean grain yield by 0.55–0.58 t/ha. The application of potassium fertilisers alone had no effect on the quantitative

value of the yield. However, the application of potassium with nitrogen and phosphorus increased grain yield by 0.19–0.80 t/ha [21].

*The purpose of the study* was to determine the effect of inoculation and nutritional conditions on the yield structural elements of Mercur variety (ultra-early variety of soybean).

**Materials and Methods.** The field trials were conducted on typical low-humus chernozems with medium phosphorus and potassium availability and low nitrogen. The humus content was 4.17 %. It was a two-factor experiment: factor A – fertiliser variants, factor B – seed inoculation. The experiment was replicated four times. In the trial, winter wheat was the predecessor of soybeans. The nutrients were applied according to the experimental design in the form of diamphoska (N<sub>10</sub>P<sub>26</sub>K<sub>26</sub>) under the primary tillage. The compound growth regulator Huliver Stimul was applied foliarly at microstages BBCH 13-15; BBCH 51-55 in the dose of 1 l/ha. Inoculation was carried out with dry inoculant Nitrofix P – 1 kg/t of seeds.

Nitrofix-P is the bacteria *Bradyrhizobium japonicum* and *Bradyrhizobium elkanii* (*Bradyrhizobium japonicum* strain 5079, *Bradyrhizobium elkanii* strain 587 with a titer of viable bacterial cells – 2.5 billion in 1 g of the preparation).

Huliver Stimul is a compound preparation containing growth stimulants (potassium humate – at least 40 g/l, succinic acid – 3 g/l), microelements, biologically active compounds – gibberellins, cytokinins, auxins.

The analysis of the crop structural elements was carried out in accordance with the State Variety Testing Methodology for Crops by the following traits: number of pods per plant, number of seeds per pod, number of seeds per plant, seed weight per plant, thousand seed weight. For accounting purposes, the yield at the stage of full seed ripeness was harvested from each plot by the method of direct harvesting and weighing. The actual yield was recalculated to the basic moisture content (8 %) and taking into account the impurities [8, 22, 23].

**Results and Discussion.** Soybean and other crop yields are determined by the elements of crop productivity. Crop productivity elements determine its yields. The main elements of soybean productivity are the number of plants per unit area, the number of pods per plant, the number of seeds per pod and the thousand seed

weight. The formation of soybean productivity elements is shaped by environmental factors, biological characteristics of the crop and technological methods of its cultivation. Previous studies have shown that the number of pods per plant, seeds per pod and thousand seed weight are directly related to the intensity of photosynthesis and carbohydrate supply during the period of pod formation.

According to the scientific literature, moisture deficit, high air temperature, and lack of light inhibit photosynthesis and carbohydrate intake in the reproductive organs, which slow down their growth processes. If soybean plants lack carbohydrates during the flowering period, up to 80 % of the flowers die. Factors that acti-

vate the photosynthetic process during flowering and pod formation, increase the number of pods and seeds on plants also include the nutritional conditions of soybean plants. The number of assimilants determines the seed filling and ensures an increase or decrease in seed size, and therefore determines the yield.

To grow high productivity crops, it is necessary to know the optimal values of the structure elements of each variety and the conditions under which they are formed.

Studies have shown that the formation of soybean productivity elements was determined by both the studied factors and environmental factors (Table 1).

The increased fertiliser rates provide an

**Table 1. Formation of yield structural elements by soybean plants, average for 2019–2020**

Variant of fertilizers	Number of pods per plants, pcs	Number of seeds per pod, pcs	Number of seeds per plants, pcs	Thousand seed weight, g
without inoculation				
N <sub>10</sub> P <sub>26</sub> K <sub>26</sub> (background 1)	15.2	1.92	29.2	141.4
N <sub>15</sub> P <sub>39</sub> K <sub>39</sub> (background 2)	15.5	1.97	30.5	143.2
N <sub>20</sub> P <sub>52</sub> K <sub>52</sub> (background 3)	15.7	1.98	31.1	144.1
Background 1 + Huliver Stymul (3–5 leaves; budding)	15.4	1.95	30.0	141.8
Background 2 Huliver Stymul (3–5 leaves; budding)	15.8	1.99	31.4	143.9
Background 3 + Huliver Stymul (3–5 leaves; budding)	16.2	2.00	32.4	145.1
<i>V, %</i>	<i>2.24</i>	<i>1.49</i>	<i>3.65</i>	<i>0.99</i>
seed inoculation with Nitrofix P				
N <sub>10</sub> P <sub>26</sub> K <sub>26</sub> (background 1)	15.3	1.94	29.7	142.3
N <sub>15</sub> P <sub>39</sub> K <sub>39</sub> (background 2)	15.6	1.99	31.0	144.1
N <sub>20</sub> P <sub>52</sub> K <sub>52</sub> (background 3)	15.8	2.00	31.6	145.4
Background 1 Huliver Stymul (3–5 leaves; budding)	15.5	1.97	30.5	142.7
Background 2 + Huliver Stymul (3–5 leaves; budding)	15.9	2.01	32.0	144.8
Background 3 + Huliver Stymul (3–5 leaves; budding)	16.3	2.02	32.9	146.9
<i>V, %</i>	<i>2.23</i>	<i>1.47</i>	<i>3.62</i>	<i>1.19</i>

increase in the number of pods per plant and the number of seeds per pod. We observed the dynamics in the increasing of thousand seed weight,

both in the variants with seed inoculation with Nitrofix P and without inoculation.

Thus, on average in 2019–2020, thousand

seed weight varied from 141.4 to 145.1 g in variants without inoculation, and from 142.3 to 146.9 g in variants treated with Nitrofix P. The maximum thousand seed weight was in the variant when applying  $N_{20}P_{52}K_{52}$  and inoculation with Nitrofix P – 146.9 g and without it – 145.1 g.

As a result of the correlation analysis bet-

ween the elements of the soybean yield structural elements and fertiliser variants, the dependencies between the studied indicators were established (Table 2). According to the results of statistical data processing, we can conclude that there is a strong positive correlation between all elements of the structure and fertiliser variants.

**Table 2. Correlation coefficient between yield structural elements and variants of soybean fertilization**

Indicators	Variant of fertilization	Number of pods per plant, pcs	Number of seeds per pod, pcs	Number of seeds per plant, pcs	Thousand seed weight, g
Variant of fertilization	–	–	–	–	–
Number of pods per plant, pcs	0.855	–	–	–	–
Number of seeds per pod, pcs	0.785	0.923	–	–	–
Number of seeds per plant, pcs	0.839	0.966	0.991	–	–
Thousand seed weight, g	0.688	0.971	0.948	0.954	–

Our regression analysis between yield indicators ( $y$ ) and fertiliser variants ( $x$ ) allowed us to establish the dependencies described by the following linear equations: in the variants without inoculation,  $y = 0.111x + 1.996$  with the approximation reliability value  $R^2 = 0.951$ ; when using Nitrofix P inoculation,  $y = 0.129x + 2.114$  with  $R^2 = 0.976$ , which indicates a strong correlation.

**Conclusions.** Our research show that nutritional conditions and the application of seed inoculation had an impact on the plant growth and development, formation of yield structural elements and yield of soybean plants of the Mercur variety. The application of the growth regulator Huliver Stimul and the inoculant Nitrofix P against the background of mineral fertilisation contributed to the increasing of indica-

tors of crop structural elements and, accordingly, yield.

The maximum thousand seed weight was in the variant with  $N_{20}P_{52}K_{52}$  application under inoculation with Nitrofix P – 146.9 g and without it – 145.1 g.

As a result of the correlation analysis between the soybean yield structural elements and fertiliser variants, the dependencies between the studied indicators were established. According to the statistical data processing results, there is a strong positive correlation between all the yield structural elements and fertiliser variants.

The correlation and regression analysis allowed us to establish a linear relationship between soybean yield and fertiliser options, characterised by a strong correlation.

## References

- Nahorni, V. I., & Romanko, Yu. O. (2009). Agrotechnical significance and the role of soybeans in the greening of agricultural production. *Visnyk Sumskoho NAU* [Bulletin of the Sumy NAU], 18. 79–83 [in Ukrainian].
- Patyka, V. P., Kots, S. Ya., Volkohon, V. V., Sherstoboieva, O. V., & Melnychuk, T. M. (2003). *Biologichnyy azot* [Biological nitrogen]. Kyiv: Svit. [in Ukrainian].
- Kobak, S. Ya. (2016). Quality inoculation is the first step to a high yield. *Ahronomiya sohodni* [Agronomy today], 1–2. 53–55 [in Ukrainian].
- Rybalchenko, A. M. (2021). Plasticity and stability of economic characteristics of soybean collection samples. *Zroshuvane zemlerobstvo* [Irrigated agriculture], 76. 69–74. doi: 10.32848/0135-2369.2021.76.13 [in Ukrainian].
- Msondz, N. P. (2014). Formation of soybean productivity depending on the technological measures of cultivation in the conditions of the northern part of the Forest-Steppe. *Zemlerobstvo* [Agriculture], 1–2. 74–77 [in Ukrainian].
- Vozhehova, R. A., Borovyk, V. O., Rubtsov, D., & Bidnyna I. (2020). Modern aspects of solving the

- problem of saving nitrogen fertilizers when growing soybeans under irrigation. *Ahrarni innovatsiyi*. [Agrarian innovations], 1. 11–16 [in Ukrainian].
7. Kalenska, S. M., Novytska, N. V., Harbar, L. A., & Strykhar, A. Ye (2011). [There is a Bioenergetic assessment of the elements of soybean cultivation technology]. *Naukovi dopovidi NUBiP* [Scientific reports of NUBiP], 6 (28). 1–8. Retrieved from: [http://www.nbu.gov.ua/e-journals/Nd/2011\\_6/11ksm.pdf](http://www.nbu.gov.ua/e-journals/Nd/2011_6/11ksm.pdf) [in Ukrainian].
  8. Kalenska, S. M., Novytska, N. V., Harbar, L. A., & Andriets, D. V. (2010). [Productivity as an integral indicator of the reaction of soybean plants to the elements of growing technology]. *Naukovyy visnyk Natsionalnoho universytetu bioresursiv i pryrodokorystuvannia Ukrainy* [Scientific Bulletin of the National University of Bioresources and Nature Management of Ukraine], 149. 227–234 [in Ukrainian].
  9. Parfenuk, A. I., Havryliuk, L. V., Beznosko, I. V., Pasichnik, L. P., Turovnik Y. A., & Ternovyi Y. V. (2021). Influence of Filazonit biopreparation on soybean seed quality. *Ukrainian Journal of Ecology*, 11 (3). 86–89. doi: 10.15421/2021\_148.
  10. Kukol, K. P., Vorobei, N. A., Pukhtaievych, P. P., & Kots, S. Ya. (2020). Efficacy of soybean inoculation by biopreparations based on fungicide-resistant rhizobium strains under seed treaters impact. *Fiziologiya roslin i henetyka* [Physiology of plants and genetics], 6 (52). 494–506. doi: 10.15407/frg2020.06.494 [in Ukrainian].
  11. Fedoruk, I. V. (2019). Influence of seed inoculation on soybean harvest. *Tavriyskyi naukovyi visnyk* [Taurian Scientific Bulletin], 108. 110. doi: 10.32851/2226-0099.2019.108.15 [in Ukrainian].
  12. Didur, I. M., Tsyhanskyi, V. I., Tsyhanska, O. I., Malynka, L. V., Butenko, A. O., & Klochkova, T. I. (2019). The effect of fertilizer system on soybean productivity in the conditions of right bank forest-steppe. *Ukrainian Journal of Ecology*, 9 (1). 76–80.
  13. Babych, A. A., & Poberezhna, A. A. (2000). Soya is the main protein-oil culture of world agriculture. *Propozytsiia* [Proposition], 4. 42–45 [in Ukrainian].
  14. Novytska, N. V., & Yunyk, A. V. (2016). Influence of seed inoculation with Histik Soy preparation on the growth, development and productivity of soybean plants of domestic selection. *The Ukrainian Farmer*, 4. 100 [in Ukrainian].
  15. Drobitko, A. V., Drobitko, O. M., & Danilov, I. V. (2015). Influence of inoculants Intech and Optimize on the yield and quality of soybean varieties in the northern Steppe. *Naukovi pratsi. Ekologiya* [Scientific works. Ecology], 244. 256, 42–45 [in Ukrainian].
  16. Inokuliant Ryzoaktyv – harant vashoho bahatoho vrozhaiu [Inoculant Rhizoactive – the guarantor of your rich harvest]. (2017). *Zerno* [Grain], 1. 130–133 [in Ukrainian].
  17. Bakhmat, O. M. (2010). Influence of agrotechnical measures on soybean productivity in the conditions of the western region of Ukraine. *Kormy i kormovyrobnytstvo: mizhvid. temat. nauk. zb.* [Fodder and fodder production: interdisciplinary thematic scie. coll.], 66. 103–108 [in Ukrainian].
  18. Dziubailo, A. H., & Myhal, I. B. (2011). Formation of the productivity of soybean varieties depending on the seeding rates, fertilizer and inoculation. *Kormy i kormovyrobnytstvo* [Fodder and fodder production: interdisciplinary thematic scie. coll.], 69. 129–132 [in Ukrainian].
  19. Kalenska, S. M., Novytska, N. V., & Andriets, D. V. (2011). Productivity as an integral indicator of the application of technological methods for growing soybeans on typical chernozems. *Kormy i kormovyrobnytstvo* [Fodder and fodder production: interdisciplinary thematic scie. coll.], 69. 74–78. [in Ukrainian].
  20. Chaikovska, L. O., & Melnychuk, T. M. (2000). Znachennya biofosforu yak rezervu pidvyshchennya produktyvnosti soyi [The value of biophosphorus as a reserve for increasing soybean productivity]. *Vyrobnytstvo, pererobka i vykorystannia soi na kormovita kharchovi tsili: materialy tretoi vseukr. konf.* Proceedings of the *Production, processing and use of soybeans for fodder and food purposes: 3th all-Ukrainian conf.* p. 58. August 3, 2000, Vinnytsia, Ukraine. [in Ukrainian].
  21. Hlushchak, A. H. (1997). The influence of individual elements of cultivation technology on the yield of different soybean varieties. *Ahrarna nauka – selu: mizhvid. nauk. zb.* [Agrarian science – to a village: interdisciplinary scie. coll.], 3 (1). 69 [in Ukrainian].
  22. Rozhkov, A. O., Puzik, V. K., Kalenskaya, S. M. (2016). *Doslidna sprava v ahronomii. Knyha 1. Statystychna obrobka rezultativ ahronomichnykh doslidzhen* [Research case in agronomy: textbook manual: in 2 books. Book 1. Theoretical aspects of the research case]. For order. A. O. Rozhkova. Kharkiv, Maidan. [in Ukrainian].
  23. Rozhkov, A. O., Puzik, V. K., Kalenskaya, S. M. (2016). *Doslidna sprava v ahronomii 1. Statystychna obrobka rezultativ ahronomichnykh doslidzhen*. [Research case in agronomy: textbook manual: in 2 books Book 2. Theoretical aspects of the research case]. For order. A. O. Rozhkova. Kharkiv, Maidan. [in Ukrainian].

УДК 633.655:631.86

**Гарбар Л. А.<sup>1</sup>, Довбаш Н. І.<sup>2</sup>, Княп Н. В.<sup>3</sup>, Ткаченко Є. О.<sup>1</sup> Формування елементів структури врожаю сої. Зернові культури. 2022. 6 (2). 105–110.**

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**Актуальність.** Формування високих врожаїв насіння сої безпосередньо залежить від кількісного вираження кожного з елементів структури врожаю. Визначальними чинниками у

формуванні продуктивності рослин сої є вплив ґрунтово-кліматичних умов регіону та окремі елементи технології вирощування, зокрема, удобрення. **Мета** дослідження полягала у виявленні впливу інокуляції та умов живлення на формування елементів структури врожаю сої сорту Меркур (ультраранній сорт). **Методи.** У досліді використовували спеціальні та загальнонаукові методи досліджень. Польові дослідження проводили впродовж 2019–2020 рр. на чорноземах типових малогумусних в умовах Київської області. Дослід двофакторний, чинник А – умови живлення, що створювалися застосуванням різних норм добрив та ріст регулюючих речовин (Гулівер Стимул) на фоні мінерального удобрення на стадіях розвитку рослин ВВСН 13-15; ВВСН 51-55; чинник В – інокуляція насіння препаратом Нітрофікс П (сухий інокулянт для сої). **Результати.** Наведено результати досліджень ефективності впливу умов живлення, ріст регулюючих препаратів, інокуляції насіння на формування елементів структури врожаю рослин сої сорту Меркур та виявлення взаємозв'язку між ними. Установлено, що формування елементів продуктивності сої визначалося чинниками, які ми вивчали, та факторами навколишнього середовища. **Висновки.** Збільшення норм добрив забезпечувало збільшення кількості бобів на рослині, кількості насіння у бобах. Спостерігалась динаміка і у напрямку збільшення маси 1 000 насінин, як на варіантах з інокуляцією насіння препаратом Нітрофікс П, так і без інокуляції. Проведення кореляційного аналізу між елементами структури врожаю сої та варіантами удобрення показало наявність між ними сильного позитивного кореляційного зв'язку. На основі кореляційно-регресійного аналізу, як без проведення інокуляції, так і з інокуляцією, установлено лінійну залежність. Вона характеризується сильним кореляційним зв'язком між урожайністю сої та варіантами удобрення з величиною достовірності апроксимації  $R^2 = 0,951$ .

**Ключові слова:** Гулівер Стимул, елементи структури врожаю, кореляційна залежність, маса 1 000 насінин, Нітрофікс П, соя, удобрення, умови живлення, урожайність