Structure elements features formation of soybean plants yield in the conditions of the southern forest-steppe of Western Siberia

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Abstract. The results of the study in 2016 - 2018 are presented varieties of common cultivated soybeans on chernozem soils in the southern forest-steppe zone of Western Siberia. The aim of the research was to study new highly productive early ripening varieties of soybeans suitable for cultivation in the forest-steppe conditions of Western Siberia. The object of research is plants of common cultivated soybean varieties (Glycine hispida Maxim (L.) Merrill). The study used field and statistical methods. Field studies were carried out in a selection experiment based on a four-field grain-fallow crop rotation, the predecessor was winter triticale after pure fallow. The experimental scheme included four early maturing soybean varieties zoned in the steppe and forest-steppe zones of Western Siberia. In terms of productivity, the Cheremshanka and Eldorado varieties stood out on average over three years (3.83; 3.60 t/ha, respectively). The use of mathematical statistical methods showed that in our experiment the productivity of plants had a strong positive relationship with the number of productive nodes (r = 0.91), beans (r = 0.87) and seeds per plant (r = 0.89); with a mass of 1000 seeds, the relationship is also positive, but of medium strength (r = 0.60). Studies have shown that weather conditions influenced the weight of seeds per soybean plant. By the number of seeds per plant, the Eldorado variety stood out - 42.2 pcs. The greatest mass of 1000 seeds was in the Sibiryachka variety and amounted to 183.5 g, only the Cheremshanka variety was closer - 179.6 g. The most productive plants were in the Cheremshanka and Eldorado varieties - 6.6 and 6.5 g/plant, respectively. It is 8% better than the standard variety.

1. Introduction
The duration of the growing season of soybeans in Western Siberia is of decisive importance in the formation of the yield [1]. As you know, the growth and development of plants can proceed normally, without delay, under a certain set of external conditions. And the duration of the growing season of varieties bred for a certain zone should correspond to the period of time during which the climatic conditions of a given zone are most favorable for the growth and development of plants. Its length should fit into the frost-free period, typical for the natural and climatic zone [2, 3].

According to the CMEA International Classifier, the early ripening specimens are those with the length of the germination period - ripening from 91 to 110 days, and the mid-ripening ones - from 111 to 130 days. In connection with the climatic features of the southern forest-steppe zone of the Omsk
Gradation of the attribute, the duration of the growing season was modified in relation to local conditions (Table 1) [4].

**Table 1.** Soybean varieties classification according to growth season duration.

| Period Sprouts-ripening | Duration, days | CMEA International Classifier | For local conditions (L. V. Omelyanyuk and etc., 2009) |
|-------------------------|----------------|------------------------------|-------------------------------------------------------|
| Very short              | Less than 81   |                              | –                                                     |
|                         | 81–90          |                              | –                                                     |
|                         | 91–100         | 91–100                       | –                                                     |
| short                   | 101–110        |                              | –                                                     |
| middle                  | 111–120        | 101–110                      | –                                                     |
| long                    | 121–130        |                              | –                                                     |
|                         | 131–140        | 111–120                      | –                                                     |

Growth season duration of soybeans depends on the air temperatures in individual interphase periods. In cold years, ultra-early ripening varieties can be in the group of mid-early-ripening and even mid-late-ripening ones.

The total production of soybeans in the Russian Federation reached 3.9 million tons in test weight, which is 10% ahead of last year’s result. In 2018, another record was set - sowing of soybeans on the area of 2.78 million hectares (+141 thousand hectares by 2017). At the same time, the gross harvest in the Central Federal District increased by almost one and a half times - up to 1.7 million tons; Siberian farmers also added over 40% (165 thousand tons) [5]. The sowing area of soybeans also increased - from 6.7 thousand hectares in 2016 to 10.7 thousand hectares in 2018, but so far its yield is very low - from 0.82 to 0.92 t / ha. In this regard, the purpose of our research was to identify new highly productive early ripening varieties of soybeans suitable for cultivation in the forest-steppe conditions of Western Siberia.

2. Materials and methods

The studies were carried out in 2016–2018 in the southern forest-steppe zone of the Omsk region on the breeding field of the laboratory for breeding leguminous crops of the Federal State Budgetary Scientific Institution "Omsk Agrarian Scientific Center". For comparison, the following varieties were selected: Sibiryachka (standard), Zolotistaya, Eldorado and Cheremshanka.

According to the AHEM “Ob-Irtyshskoe”, the growth season in 2016 was warm and sufficiently humid: 239 mm of precipitation (104% of the average annual) fell in May - September at an average daily air temperature of 16.7 °C (1.6 °C above the norm). In 2017, the growth season was characterized by an uneven distribution of heat and insufficient moisture: in May - September, 173 mm of precipitation fell (75% of the average annual) with an average daily air temperature of 15.8 °C (0.7 °C above the norm). The conditions of the period May - September 2018 were characterized by low heat supply - the average air temperature was 14.3 °C (-1.2 °C from the norm) and excessive moisture - 264.3 mm (112.4% of the norm).

The experiment was carried out in a 4-field grain-fallow crop rotation, the predecessor of winter triticale after fallow. The soil of the experimental site is poorly leached medium-thick medium loamy chernozem, the humus content is about 6%, the pHKcl of the soil solution is 6.5. The content of N-NO3 in the 0-40 cm soil layer before sowing is low, P2O5 (according to Chirikov) is high, and K2O is very high.

Sowing of soybean varieties was carried out on May 19 with an SSFK-7 seeder, harvesting on September 25 with a Hege 130 combine. The area of the plots was 15 m2 in 4 replicates (the location of the plots was randomized), the seeding rate was 0.8 million germinating grains per hectare. Observations
and records according to generally accepted methods [2]. The system of agrotechnical measures in crop rotation was built taking into account the recommendations of the Federal State Budgetary Scientific Institution "Omsk Agrarian Scientific Center" for the forest-steppe zone of Western Siberia [6]. Statistical processing in the experiments was carried out by the method of analysis of variance according to B.A. Dospekhov [7].

3. Results and discussion

One of the most important indicators that determine the manufacturability of soybean varieties are the length of the stem and the type of soybean plants growth, the attachment height of the lower bean, because these indicators largely characterize the suitability of the variety for cultivation [8]. Under the conditions of 2016, the plant height was 120 cm on average for the varieties, under the conditions of 2017 - 110 cm, under the conditions of 2018 - 97.5 cm. The cultivars had the maximum indicator: Cheremshanka (130 cm - 2016). Also, on average for three years, the height of plants of the Sibiryachka variety was 100 cm, the Zolotistaya variety 111.7 cm, the plants of the Cheremshanka and Eldorado varieties stood out in terms of stem length - an average of 112.5 cm for three years (table 2).

Table 2. The height of attachment of the lower pod and the length of the stem in soybean varieties in 2016–2018.

| Variety      | Stem length | Attachment height of the lower bean, cm |
|--------------|-------------|---------------------------------------|
|              | 2016 g.     | 2017 g.     | 2018 g.     | average | 2016 g. | 2017 g. | 2018 g. | average |
| Sibiryachka  | 100.0       | 110.0       | 90.0        | 100     | 10.50   | 11.25   | 12.75   | 12.50   |
| (standard)   |             |             |             |         |         |         |         |         |
| Cheremshanka | 130.0       | 110.0       | 97.5        | 112.5   | 10.25   | 11.57   | 15.50   | 12.44   |
| Eldorado     | 125.0       | 110.0       | 102.5       | 112.5   | 15.30   | 12.75   | 14.50   | 14.18   |
| Zolotistaya  | 125.0       | 110.0       | 100.0       | 111.7   | 10.75   | 16.75   | 15.50   | 14.33   |
| Average on years | 120.0      | 110.0       | 97.5        | 109.2   | 11.70   | 13.08   | 14.60   | 13.36   |

The attachment height of the lower bean under the conditions of 2016, in most varieties, was lower than in 2017–2018. For high-quality harvesting of the grown crop, this indicator should be at least 10 - 12 cm. Analysis of table 2 shows that the analyzed indicator depends on both the genetic characteristics of the variety, and on the growing conditions. Thus, under the conditions of 2016, a sufficient height of attachment of the lower pod was noted in all cultivars. The maximum attachment height of the lower pod was noted in the Zolotistaya variety in 2018 (16.75 cm). In 2016, the maximum attachment of the lower bean of 15.3 cm was in the Eldorado variety, in 2017 - 16.75 in the Zolotistaya variety, in 2018 - in the Cheremshanka (15.5 cm) and Zolotistaya (15.5 cm) varieties. The lowest attachment of the lower bean was noted in the Cheremshanka variety in 2016 and amounted to 10.25 cm. In 2016, the average attachment of the lower bean by varieties was a minimum of 11.7 cm and increased every year, in 2018 this figure was 14.6 cm.

The most complete picture of the productivity of plants is provided by their biometric analysis, which is composed of such elements as the number of branches, productive nodes, beans per plant and per node, the number of seeds per plant, the mass of seeds per plant and the mass of 1000 seeds.

The main elements of the structure of the yield of the studied soybean varieties on average for 2016-2018 are presented in table 3.

Studies have shown that weather conditions influenced the weight of seeds per soybean plant. By the number of seeds per plant, the Eldorado variety stood out - 42.2 pcs. The greatest weight of 1000 seeds was in the standard variety and amounted to 183.5 g, the closest indicator was in the Cheremshanka variety - 179.6 g. The most productive plants were in the Cheremshanka and Eldorado varieties - 6.6 and 6.5 g / plant, it is better than the standard variety by 8%.
Table 3. Yield structure elements of soybean varieties (on average for 2016–2018).

| Variety              | Vine numbers, pcs | Beans number, pcs | Seeds number on a plant, pcs | Seeds weight, g From 1 plant | 1000 pcs |
|----------------------|-------------------|-------------------|------------------------------|-----------------------------|----------|
| Sibiryachka (standard) | 0.28              | 20.9              | 1.8                          | 38.7                        | 6.1      | 183.5   |
| Cheremshanka         | 0.18              | 31.0              | 1.9                          | 34.2                        | 6.5      | 179.6   |
| Eldorado             | 0.37              | 20.9              | 1.8                          | 42.2                        | 6.6      | 154.0   |
| Zolotistaya          | 0.12              | 17.0              | 1.9                          | 35.5                        | 5.5      | 160.0   |
| HCP05                | 0.2               | 4.4               | 0.3                          | 8.5                         | 1.2      | 18.3    |

The calculation of the correlation coefficients showed that in our experiment the productivity of plants had a strong positive relationship with the number of productive nodes \((r = 0.91)\), beans \((r = 0.87)\) and seeds per plant \((r = 0.89)\); with a mass of 1000 seeds, the relationship is also positive, but of medium strength \((r = 0.60)\).

One of the most important criteria for evaluating varieties in terms of productivity is directly the grain yield per unit area. The yield is influenced by many factors, including the meteorological conditions during the growth of the crop, as well as the genetic ability of the varieties themselves, the duration of the growing season, elements of the crop structure, as well as the height of attachment of the lower bean. Nevertheless, the variability of environmental conditions remains the main factor in determining the yield of soybeans.

In the conditions of 2018, the yield indicator for most varieties was lower than in the conditions of 2016–2017 (table 4).

Table 4. Productivity of the studied soybean varieties.

| Variety            | 2016 | 2017 | 2018 | Average ± to St |
|--------------------|------|------|------|----------------|
| Sibiryachka (standard) | 3.44 | 3.62 | 2.90 | 3.32 – |
| Cheremshanka       | 3.89 | 3.93 | 3.68 | 3.83 0.51 |
| Eldorado           | 3.80 | 3.75 | 3.26 | 3.60 0.28 |
| Zolotistaya        | 3.81 | 3.53 | 2.96 | 3.42 0.10 |
| HCP05              | 0.4  | 0.5  | 0.6  | – 0.25 |

In 2018, the yield of the Cheremshanka variety was significantly higher compared to Sibiryachka by 0.78 t/ha, the yield of the Eldorado and Zolotistaya varieties was also higher than the standard by 0.36 t/ha and 0.06 t/ha, respectively.

In 2017, the Cheremshanka variety significantly exceeded the standard, the yield of this variety was 3.93 t/ha, which is 0.31 t/ha more than the standard. The yield below the standard is observed only in the Zolotistaya variety. In 2016, all three varieties exceeded the standard by about an equal measure by 0.39 t/ha on average.

In 2018, a significant increase was provided by the varieties Cheremshanka and Eldorado. For the rest of the varieties, the yield was within (HCP05) - 0.4 t/ha.

Calculation of pairwise correlations shows that the yield of soybean varieties during the research years most of all depended on the number of productive nodes \((r = 0.73)\) and beans per plant \((r = 0.84)\), the mass of seeds per plant \((r = 0.64)\) and the length of the stem \((r = 0.69)\); also a positive, but moderately strong, relationship was revealed by the mass of seeds per plant \((r = 0.48)\).
4. Conclusion
We found that when growth varieties in soybeans in the southern forest-steppe of Western Siberia, the Cheremshanka variety was the best. This variety in many respects exceeds the standard, or is at its level, has the highest yield (on average, over three years it exceeds the standard by 0.51 t/ha). The Zolotistaya variety is the most technologically advanced in terms of the attachment height of the lower bean, this figure was 16.75 cm.

Since the research was aimed at identifying the most highly productive and technological varieties for cultivation in the conditions of the Omsk region, it is possible to recommend the Cheremshanka and Zolotistaya soybean varieties to increase the cultivated areas of this crop and replace the unproductive varieties.

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