Effect of growing conditions on the formation of reproductive organs in soybean varieties with different maturity dates

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Abstract. The influence of sowing methods on the process of formation of reproductive organs was studied on new soybean varieties Sentyabrinka, Kitrossa, Kruzhevniza in the conditions of the Amur Region. Generally, the methods of sowing with different row spacing widths are applied individually for each soybean variety. Choosing unfavorable methods can lead to low yields and a lack of seed quality. The development of cultivation technologies is required for each cultivar with individual morphological and biological features, which leads to the need for research in this direction. One of the reasons for low soybean yield is abortion during flowering, the formation of pods and seeds. We aim to study the process of the formation of reproductive organs in Amur Region soybean varieties of a new generation, depending on the availability of nutritional area in soil due to the method of sowing. With a wide-row method of sowing, more favorable conditions are formed for the growth and development of plants, which is confirmed by the yield.

1. Introduction

The growth and development of plants, the formation of reproductive organs, morphological features and the level of soybean productivity largely depend on the right variety and the conditions for its cultivation. The method of sowing is one of the main conditions for cultivating crops to provide plants with the necessary nutritional area [1–3].

Studies of the growth and development of soybean plants, depending on the method of sowing were carried out in the Far East by many researchers, most of them established the advantage of the wide-row method of sowing [1,3]. Favorable conditions for the illumination of soybean plants and the supply of nutrients to the soil are achieved by a wide-row method of sowing (45 cm), which leads to effective weed control. The method of sowing with a conventional row spacing of 15 cm results in stretching plant height, reduction in the number of pods on the plant and mandatory repeated use of broad-spectrum herbicides. Decreased plant productivity, seed quality, germination energy and germination often occur due to dense crops [4–8]. Therefore, cultivation development technologies are required for each cultivar with individual morphological and biological features, which leads to the need for research in this direction.

The main reasons for low soybean yield are abortion during flowering and beginning of pod stages, and the underdevelopment of pods and seeds[9,10]. According to Lopatkin, from 130 to 180 flower buds appear in Amur Region soybean varieties[11]. However, half of the buds develop into flowers, while the number of flowers formed depends on weather conditions and the background of mineral
nutrition. Most of the flowers fall upon the occurrence of adverse conditions \[11,12\].

Based on the studies conducted by the authors with varieties used in production in the last century, it becomes necessary to study modern varieties on the processes of the formation of reproductive organs and create conditions favorable for reducing the abortion of flowers, beans and seeds. Therefore, our research aims to study the process of the formation of reproductive organs in soybean varieties of a new generation, depending on the methods of sowing.

2. Materials and methods

2.1. Study site

The location of the study site was Sadovoe village near Blagoveschensk city in Amur River Basin, Russia. The studies were carried out on “meadow-chernozem-like Amur prairie” soils on plots of 5.4 m$^2$ with a row spacing of 45 cm. The plot area with a row spacing of 15 cm was 1.8 m$^2$, and the repetition was fourfold. The allocation of plots in the experiment was randomized, with the method of sowing systematic, the sowing date was May 25, 2019. For controlling weeds on the site, the Frontier Optima herbicide was applied to the soil in the spring at a dose of 1.2 l/ha 5 days before sowing with cultivators. During the growing season, weeds were removed by hand.

2.2. Objects of study

The objects of study were soybean varieties Sentyabrinka, Kitrossa, Kruzhevniza, which have different maturity dates. Sentyabrinka variety is an early ripening variety with a maturity date of 87-99 days, maturity group 0 (MG 0), a potential yield of 2.64 t/ha, the protein content of 42.3%, fat - 19.2%. Plants are resistant to fungal and bacterial diseases. The variety is characterized by an indeterminate type of growth and resistance to lodging.

Medium maturity variety of Kitrossa with a growth length of 113-114 days (MG II), a potential yield of 4.0 t/ha, the protein content of 41%, and fat - 18%. Plants are highly resistant to bacterial (bacteriosis) and fungal diseases.

Early maturity variety of Kruzhevniza with a vegetation period of 99-106 days (MG I), a potential yield of 2.93 t/ha, the protein content of 40.1%, fat - 17.4%. The variety is characterized by high photosynthetic activity, and the crop leaves are characterized by an increased number of leaf blades (from 5 to 9). Plants are resistant to fungal and bacterial diseases of soybean, are relatively resistant to waterlogging and drought.

2.3. Accounting of soybean reproductive organs

An analysis of the formation of soybean reproductive organs in the phase of the flowering (R2), beginning pod (R3), beginning seed (R4), and full seed (R8), was carried out according to the method of quantitative accounting of Lopatkina (1983). Each plant was marked with a label in the complete appearance phase of the third ternary leaf, and the labels were on the plants until harvesting. Since the beginning of the first flower phase (R1), records were made in the field journal.

Phenological observations of the growth and development of crops with a mark of the growth phases and development of each plant were carried out daily according to the Fehr method \[13\]. The registration of reproductive organs was carried out 8-12 times during the growing season, depending on the duration of vegetation period of soybean variety. The structure and accounting of biological productivity carried out by the method of State testing methodology \[14\].

3. Results and discussion

The growth, development of plants, the formation of reproductive organs, and the level of soybean productivity mainly depend on the correctly selected crop variety and the methods for its cultivation. The influence of sowing methods on the process of the formation of reproductive organs was studied on new soybean varieties Sentyabrinka, Kitrossa, Kruzhevniza.

The duration of the vegetation period under the weather conditions of 2019 was 102 days for the
varieties Sentyabrinka and Kruzhevnitsa, and 119 days for Kitrossa. The highest yield was obtained from Sentyabrinka variety with the wide-row method (45 cm) of sowing, the average yield was 3.67 t/ha, at 15 cm was 2.52 t/ha. The lowest yield was obtained from Kruzhevnitsa variety, with the method of 45 cm, the average yield was 3.15 t/ha, and 15 cm was 1.98 t/ha. With row spacing of 45 cm in three soybean varieties, the yield exceeded this indicator for varieties cultivated with 15 cm row spacing (figure 1).

Figure 1. Biological productivity of Amur Region breeding soybean variety depending on the method of sowing conducted in Blagoveschensk, Amur Region, Russia, in 2019.

The prevalent number of reproductive organs during the growing season was formed in the variety of Kitrossa, 188 flowers, 152 pods (R3), and 51 pods (R8) in the wide-row 45 cm method of sowing. With the conventional 15 cm method, the Kitrossa variety also showed the highest number of organs (figure 2).

Figure 2. The number of formed reproductive organs of Amur Region breeding soybean cultivars, depending on the method of sowing. The conventional method of 15 cm and the wide-row method of 45 cm were used.

Regardless of the method of sowing, the Kruzhevnitsa variety produced fewer reproductive organs
than the Sentyabrinka and Kitrossa varieties (figure 2), which affected the yield of the variety (figure 1). One of the reasons for the lacking realization of the high soybean yield is organ falling during the flowering (R2) and the beginning of pods (R3) stages and the reduced formation of pods and seeds during the whole vegetative period.

In the studied three varieties of Amur Region soybean breeding, the number of fallen reproductive organs in all varieties was higher with the conventional 15cm method of sowing, varying from 75.4 to 85.7% depending on the variety. (figure 3). In plants cultivated in the wide-row method, the value was lower, 67.9 - 72.8% (figure 4). The highest percent of fallen flowers were observed in plants of the Sentyabrinka variety, 46 % of flowers with a row spacing of 15 cm (figure 3), and 36.7% of flowers with a row spacing of 45 cm (figure 4). Therefore, sowing with a row spacing of 45 cm created more favorable nutrition and lighting conditions for the formation of reproductive organs in this soybean variety. During the R3 vegetative stage of Kitrossa variety, the fallen percentage of pods was the highest and reached more than 60% for both methods. All varieties showed the same average values of fallen organs at stage R8.

**Figure 3.** The percentage of fallen reproductive organs in soybean varieties of Amur Region breeding. Method of sowing-15cm. The observation was conducted in the Amur Region in 2019.

**Figure 4.** The percentage of fallen reproductive organs in soybean varieties of Amur Region breeding. Method of sowing-45cm. The observation was conducted in the Amur Region in 2019.
The study of the crop structure by the number of seeds formed in pods showed that the underdevelopment of seeds, which represented in figure 5(c), also leads to a decrease in its yield. Even though the percentage of fallen flowers was the smallest in the variety of Kitrossa, however, the pods (R3) fell more (figure 6(b)) than in the varieties of Sentyabinka and Kruzhevnitsa. Moreover, a high percentage (37.7%) of fallen pods (R8) (figure 3) in the variety of Kitrossa was observed in plants when grown with a row spacing of 15 cm. The share of all fallen reproductive organs was the smallest in the Kruzhevnitsa variety and the largest in the Kitrossa variety.

Figure 5. Sample photos of underdeveloped pods of Kitrossa soybean variety(a), (b), and underdeveloped seeds in pods grown by 15 cm sowing method (c) in the field of Soybean Institute, Amur Region, Russia, in 2019.

Figure 6. Example photos of pods during the R3 vegetative stage (a) and fallen pods (b) of the Kitrossa soybean variety in the field of Soybean Institute, Amur Region, Russia, in 2019.
Narrow sowing is caused by stretching of the plants and an increase in the distance between the nodes. Due to leaf shading and lack of light, there was a decrease in the formation and outflow of nutrients into the soybean reproductive organs. Furthermore, the thickening of crops led to a decrease in moisture. The above phenomena have led to increase in the fall and underdevelopment of reproductive organs (figure 5, figure 6).

4. Conclusion

Studies have shown that with the wide-row method of sowing at 45 cm, more favorable conditions are created for the growth and development of plants of soybean varieties Kitrossa, Sentyabrinka and Kruzhevitsa compared with their cultivation with 15 cm rows. Thereby favorable conditions were achieved, creating the illumination of soybean plants and the supply of nutrients to the soil. The wide-row method of sowing makes it easier for weeding using inter-row cultivations. Based on yield data, we concluded that the 45 cm method contributed to the better formation of reproductive organs and reduced their fall.

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