The spring wheat yield formation in Russia Central Region as productive stalks density function

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Abstract. There are three major negative factors, which constrain the potential productivity of spring wheat in the Central Region. The first is the damage to the plants inflicted by Oscinella frit. The crops being heavily pitted and their slow growth due to internal and external infection caused the second biological minimum. The third limiting factor were the spring droughts, commonplace for the Central Region. All those three factors proportionally influence the spring wheat productive stalk density. In agricultural conditions of the Central Region, the high positive correlation between spring wheat yield and number of productive stems per 1 m² was observed. This correlation proven to be stable by years. By concentrating selection-breeding efforts on such parameter improvement, several new, highly productive varieties, which demonstrated their superiority over the standard one, were created. Thus, one of the most important principles in new Central Region spring wheat varieties development is the creation of varieties with high potential productivity, provided by higher productive stalk density (no less than 450-500 plant per 1 m²) even in different humidity conditions – in combination with other main yield structural elements.

1. Introduction

Work on the spring soft wheat varieties creation for the Central Non-Chernozem Region of Russia began in 1935 at the Institute of Grain Farming of the Non-Chernozem zone (now the Moscow Scientific-Research Institute of Agriculture "Nemchinovka") under the direction of V.E. Pisarev. The results of his research were presented in the article "Biological minimum of spring wheat culture in the conditions of the Non-Chernozem zone" [1], which for the first time gave the idea of the spring wheat breeding variety ecotype for the Non-Chernozem zone and proposed a "variety model". So far, in the selection of this crop, these developments are basic. The author identified three limiting factors that constrain the potential yield of spring wheat in the region. The first of them is the damage to plants by the Swedish fly. The second biological minimum was due to the strong sparsity of seedlings and their weak growth due to the defeat of the grain by internal and external infection. The third negative factor was the spring droughts which are typical for the Central Non-Chernozem region. Each of these factors in one way or another affects the spring wheat productive stem density. This indicator is one of the determining factors in the formation of the spring wheat yield level in this region and at present time [2, 3, 4, 5, 6].
2. Results and discussion

The center of the Non-Chernozem zone of Russia is the zone of changing moisture conditions over the years: from arid to excessively moist. For the period from 1984 to 2019, the closest relationship between the level of yield and moisture availability \( (r=0.55) \) was observed in June. In May, during the first decade of which spring wheat is mainly sown, it is \( r=0.39 \). The closest positive relationship of the yield in the years with the May shortage of moisture supply for this period was noted with the following structural elements: the number of productive stems per 1 m\(^2\) \( (r=0.37...0.72) \) and the weight of grain per ear \( (r=0.30...0.70) \) [7].

The analysis of the yield level dependence on the elements of the structure allows to conclude that almost every second year there was a positive correlation between the yield and the number of productive stems preserved for harvesting per 1 m\(^2\), which largely depends on the moisture supply in the initial period of development. The most reliable dependence is observed in the years with the May drought, when the hydrothermal coefficient (HTC) in May is below 0.5 and above 1.0. Therefore, it is the number of productive stems per 1 m\(^2\) that is one of the elements of the structure that most affects the level of spring wheat yield. This dependence is stable over the years and covers a wide range of varieties with different biological properties [8, 9, 10].

The degree of spring wheat varieties productivity dependence on its structure varieties elements, Ester, Zlata, Lyubava, Agatha, the most popular in production, and new varieties Lisa and Radmira held by the State for the two periods of observation (2011-2014 and 2015-2019). In each period there was a significant positive correlation of yield of plants number of per 1 m\(^2\) and number of productive ears per 1 m\(^2\) with greater severity in recent years.

The highest stem density in the years of research was noted in 2017 in the varieties Lisa (645 pcs), Agata (585 pcs) and Radmira (560 pcs), which allowed them to form a yield of 7.0-8.0 t/ha.

In the years with the optimal value of the HTC-more than 1.0 in the May-June period (1984-2019), the number of productive stems per 1 m\(^2\) (the average indicator for competitive variety testing) varied from 381 up to 550 pieces (with the average value of 418 pieces), while the dependence of the yield on this indicator was positive, but not reliable and amounted to only \( r = 0.18 \). In the years with the May drought (HTC less than 1.0), the density of the productive stem varied from 213 to 420 pcs per 1 m\(^2\) (with an average value of 352 pcs) with the correlation coefficient of \( r = 0.58 \), i.e. more than 50% was determined by the level of moisture availability.

The task facing the selection of spring wheat in the conditions of the Central Non-Chernozem region is to increase the ability of varieties to maintain a stem density of at least 400 pcs per 1 m\(^2\), even in years with a low HTC in the initial period of development. The number of productive stems per 1 m\(^2\) is influenced by three main factors: field germination, lateral development and plant survival during the growing season.

The field germination is determined by a complex of biological characteristics: resistance to pathogenic soil microorganisms, coleoptile length, growth strength, reaction to increased acidity and can vary from 40-60% to 80-90%. The highest density of seedlings in the years with the May shortage of moisture is characteristic of the varieties Ester, Zlata, and of the new ones-for the varieties Agata, Lisa and Radmira. In years with optimal HTC in May, which accounts for the emergence, the highest germination was observed in cultivars Lisa and Radmira: up to 550-620 plants per 1 m\(^2\) at the seeding rate of 650 grains per 1 m\(^2\). In general, for the period 2011-2019, which includes both extreme years for low moisture availability in May and quite favorable, the highest field germination was observed in the varieties Ester, Zlata and the new variety Radmira, which are characterized by rapid growth in the initial period of development and are able to more efficiently use the spring supply of moisture in the soil. The number of plants that have sprung up is always lower than the calculated norm, even with high seed quality and normal depth of their embedding, up to 25-30% of the sown seeds do not germinate. One of the reasons for low field germination is both high infection of seeds (surface and internal), and the defeat of seeds in the soil by fungal diseases. Therefore, an important role in increasing field germination belongs to the correct pre-sowing preparation of seeds and the use of certified seeds that meet the requirements of the State Standard R 52325-2005.
Along with field germination, plant survival during the growing season is an important feature that determines the number of productive stems per unit area. This is especially evident in extreme years with a strong defeat of diseases and pests, with prolonged drought.

The analysis of the spring wheat plants field germination and survival dependence on the level of HTC allows to conclude that in optimal years for the level of moisture availability, the greatest dependence is traced between HTC and plant survival, and in years with a May drought, field germination and lateral development depend more on moisture availability. This dependence is typical both for the Moskovskaya 35 variety, which was zoned more than 40 years ago, and for the modern varieties Ester, Zlata and Lubava. Therefore, we can talk about a certain pattern for the spring wheat culture in the conditions of the Central Non-Chernozem region of Russia.

The highest lateral development in the years with high moisture availability in May-June (HTC more than 1.8) in 2011-2019 was observed in the varieties Lada, Ester and Agata - 2.5-3.2 productive ears per plant. In other varieties, it varied from 1.4 to 1.7 pcs. Varieties of spring wheat breeding (Moscow Research Institute of Agriculture "Nemchinovka") differ significantly in the propensity to tillering. Thus, the Lada variety in conditions of sufficient moisture supply is able to produce up to four productive ears per plant.

In general, the weather conditions during the growing season in most areas of the Non-Chernozem zone of Russia do not contribute to spring wheat strong tillering. In addition to the lack of moisture supply in the initial period of development, there is a risk of damage by the Swedish fly, which is especially true for well-growing forms, which are characterized by the delay in development at the initial stages of the growing season. The current seeding rate is 5.5-6.0 million germinating seeds per 1 m² is the most acceptable for most varieties of spring wheat, taking into account the soil and climatic characteristics of the zone. Therefore, for the Center of the Non-Chernozem zone of Russia, it is optimal to create varieties of spring wheat with limited tillering (1.5-2.0 productive ears), which would differ in the friendly development of the main and side shoots in order to avoid the formation of a fit.

The focus of breeding work on increasing the number of productive stems per 1 m² allowed to create varieties of Agate, Lisa, Radmira, which exceeded the standard for this feature. If the period 2000-2010 regression line from varieties entered in the State register of breeding achievements admitted for use, was determined by the equation \( y = -19.4x + 477 \), indicating that the decrease in stand density for the period 2011-2019 with the new varieties, a positive trend on this indicator. A new variety of Agate, entered in the State Register for the 3rd (Central) region, is able to form up to 500-550 pieces of productive stems per 1 m² for harvesting. The variety was created by using Artemovka spring wheat, which is characterized by a high survival rate (up to 70-75%). Among the varieties of the earlier period, the grade Ester stands out, it was obtained from the winter wheat two components: varieties Serba and lines No 15080 (Germany) and capable to form to 600 productive stems per 1 m² in favorable moisture years due to the high productive tillering (up to 2.7 pcs per plant). These varieties are widely involved in the breeding process. The Radmira variety, transferred to the State Variety Testing since 2018 and entered in the State Register of breeding achievements allowed for cultivation in the territory of the Russian Federation from 2020 for 3 and 4 regions, is able to form up to 560 and higher productive stems per 1 m² in favorable years for moisture availability. Currently, high-yielding lines with high stem density are undergoing competitive variety testing: line 327/1-1H2647(B/O-2(F1-115-07) × Podmoskovnaya 10); line 201/1-12H2712 (Zlata × line 422/1 (Zernogradka 9 × Milturum 63); line 402/2H2754 (Zlata × line 63/2 (selection from Ester)); and a number of others. Most of them obtained either with the participation of winter component and capable in favorable moisture years to give to 2 or more productive stems per plant or when the participation grade Ester, which characteristics were described above.

3. Conclusion

Thus, one of the key moments in the creation of spring bread wheat highly productive varieties for the conditions of the Central black earth is the creation of varieties that provide high yields due to the high
density of productive stalks (not less than 450-500 pieces per 1m²) in different water supply years, the optimal combination of this indicator with the main structural elements.

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