The efficiency of the spring wheat production process depending on the seeding rate in the arid zone of Mongolia

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Abstract. The paper presents the experience of assessing the efficiency of the spring wheat production process depending on the seeding rate in the arid zone of Mongolia. The research was conducted in 2017 at the experimental field of PROLOG SYSTEMS LLC (Mongolia). The experiment used different norms of wheat varieties Novosibirskaya 15. Arable chestnut soils for land use in PROLOG SYSTEMS LLC have the light granulometric composition, characterized by a shortage of productive moisture and a low level of potential fertility. Low availability of humus, alkaline reaction, very low availability of mobile phosphorus, low-exchange potassium significantly reduce the productivity of the company’s fields. The evaluation of wheat biometric indicators revealed the dependence of plant height, spikelets number in the ear and productive bushiness on the seeding rate. A lower seeding rate in the arid zone of Mongolia reduces species competition between plants before the bushiness phase, but increases it in later phases of plant development due to the increased productive bushiness. Also, crops of wheat varieties Novosibirskaya 15 in Mongolia with an optimal seeding rate of 140-180 kg/ha had more intensive growth, maximum yield and minimum lodging compared with a higher seeding rate of 210-230 kg/ha. The decrease in the seeding rate is permissible in hot and arid conditions of Mongolia, while the presence of productive moisture in the spring period will be a determining factor.

1. Introduction

Wheat (Triticum aestivum L.) is cultivated in many countries of the world. The important issue in the cultivation technology of spring wheat intensive varieties is to establish the optimal seeding rate. It is believed that the yield of 50% is determined by the density of the productive stem, 25% by the number of grains in the ear and 25% by the weight of 1000 grains. There is a large amount of research devoted to wheat agrotechnology [1, 2, 3]. At the same time, the study of adaptation potential and peculiarities of cultivation technology of each particular wheat variety for specific soil and climatic conditions is relevant. Research to assess the adaptive potential of the Siberian selection spring wheat varieties in Mongolia have been carried out since 2016 [4, 5].

Devastating droughts are common in most of Mongolia’s steppe regions. The struggle to accumulate, conserve and manage extremely limited water resources in these conditions is a key issue of any modern farming system used in these areas.

The research was carried out at the experimental field of PROLOG SYSTEMS LLC (Mongolia), located in the Khentii Aimak, in the Khurkh tract, which belongs to the Dauro-Mongolian steppe province.
Wheat Novosibirskaya 15 refers to early-ripening varieties. The originator and the patentee is the SSI Siberian regional branch of the Russian academy of agricultural sciences: Siberian research institute of agriculture (Russia). Pedigree: inter-varietal stepped hybridization ((Bezenchukskaya 98 x Irtyshanka 10) x (Tulunskaya 10)) x Novosibirskaya 22. The variety is lutescense. The growing season is 75-83 days. This variety is resistant to lodging and has excellent baking qualities.

Tillage included autumn ploughing and spring disking. Sowing was carried out in May, 16-18 by tractor K-700 and seeder SKP 2.1. Seeds of wheat varieties Novosibirskaya 15 were treated with a protectant Bunker before sowing (the rate of the preparation consumption was 0,4 l / t). The following variants of seeding rate were used in the experiment (figure 1).

![Figure 1. Seeding rate on the registration sites of the experiment (kg / ha).](image)

2. Characteristics of soil conditions
The agrophysical and agrochemical soil condition at the experimental site was assessed in July and August 2017. Soil samples were taken on three test areas laid on each variety to a depth of 0-10 and 10-20 cm. The main chemical indicators for soil characteristics were obtained using conventional methods [6, 7]: the reaction of the soil solution was determined by the potentiometric method; the sum of exchange bases – according to Cappen-Gilkowit; humus according to Tyurin; nitrate nitrogen (State standard 26951-86); exchange ammonium (State standard 26951-86). 26489-85); mobile phosphorus (State standard 26204-91); exchange potassium (State standard 26204-91). In the samples, the density of addition was determined by N. A. Kachinsky; humidity was determined by the thermal weight method [8].

The soil of the experimental site is represented by chestnut deep-boiling medium-sandy loam soil. It is characterized by an average humus content in the upper part of horizon A (4.0%) and low humus reserves in the 0-20 cm layer (89 t / ha). The sum of exchange bases within the profile varies from 17 to 13 mmol / 100g, reaching minimum values (11 mmol/100g) at the end of horizon B. The reaction of aqueous extract is slightly alkaline in the 0-20 cm layer. With depth alkalinity increases to 8.0-8.5 that testifies to average alkaline reaction of the environment. Light granulometric soil composition, the abundance of sand mechanical elements in it contributes to soil compaction up to 1.4-1.5 g / cm³. This density is typical for sandy loam soils of granulometric composition and is estimated as compacted. The given chemical and agrophysical characteristic of chestnut soils testifies to low potential fertility of the experimental site chestnut soils.

The productivity of agricultural crops is determined by a complex of factors, but the main ones are the availability of water and nutrients. It is known that the moisture content of plants is determined by meteorological conditions, methods of soil cultivation, features of crops cultivation and other conditions. Acute arid conditions of the growing season in 2017 did not contribute to the replenishment of productive moisture in the soil during periods of wheat intensive growth. It was found that during spring wheat bushiness and booting stage moisture reserves in the soil were critical and did not exceed 5 mm (table.1). Soil sampling carried out on the layers showed that in July the
humidity of 0-10 cm layer was usually higher than 10-20 cm layer. In August, a different pattern is formed, characterized by an increase in humidity of 10-20 cm layer by 0.2-2.4%. During this period, precipitation contributed to an increase in productive moisture reserves to 13 mm in the 0-20 cm layer. Such stocks are rated as bad.

**Table 1** Humidity and reserves of productive moisture in chestnut soil (n = 3).

| Variety          | Layer, cm | July W, % | RPM, mm | August W, % | RPM, mm |
|------------------|-----------|-----------|---------|-------------|---------|
| Novosibirskays   | 0-10      | 6,8       |         | 8,9         |         |
|                  | 10-20     | 4,7       | 4,6     | 9,1         | 13,0    |
|                  | 10-20     | 4,2       |         | 7,8         |         |

Note: W – soil humidity, RPM – reserves of productive moisture

The survey of the experimental field and the analysis of samples showed that chestnut soils of land use are characterized by a very high supply of ammonium nitrogen (24,5-25,8 mg / kg) (table.2). The dynamics of ammonium nitrogen is related to soil moisture and temperature. As a rule, its maximum accumulation falls on the warmest and most humid period. Crops are provided with ammonium and nitrate nitrogen not only due to spring stocks, but also due to current ammonification and nitrification. The proportion of current ammonification and nitrification due to low nitrogen removal by wheat in arid conditions is markedly reduced. This is well demonstrated in the acutely arid July and August periods.

**Table 2.** The mineral nitrogen content in chestnut soils (n = 3).

| Variety          | Layer, cm | July N-NH₄, mg/kg | September N-NH₄, mg/kg | July N-NO₃, mg/kg | September N-NO₃, mg/kg |
|------------------|-----------|-------------------|-----------------------|------------------|-----------------------|
| Novosibirskaya15 | 0-10      | 26,1              | 23,8                  | 14,2             | 13,2                  |
|                  | 10-20     | 25,5              | 25,2                  | 13,9             | 13,9                  |
|                  | 0-20      | **25,8**          | **24,5**              | **14,1**         | **13,6**              |

Increased supply of the nitrogen nitrate form is preserved from the period of wheat bushiness to its maturation (14 mg / kg). A slight decrease in nitrate nitrogen concentration by August by 0,5-0,8 mg/kg indicates that mineral nitrogen is not consumed by plants in drought conditions. The effect of the variety on the mode of ammonium and nitrate nitrogen in the absence of its removal by wheat could not be established. It was revealed that the concentration of ammonium and nitrate nitrogen in the average layer of 0-20 cm is estimated at a close level.

The potential availability of phosphorus in crops according to the content of its mobile forms is estimated as very low (1,2-6,0 mg / kg) (table.3). It is believed that plants extract all the phosphorus they need from the soil solution. In dry soil, phosphorus uptake by plants slows down.

**Table 3.** Content of mobile phosphorus and exchange potassium in chestnut soil (n = 3).

| Variety          | Layer, cm | July P₂O₅, mg/kg | September P₂O₅, mg/kg | July K₂O, mg/kg | September K₂O, mg/kg |
|------------------|-----------|------------------|-----------------------|----------------|----------------------|
| Novosibirskaya 15| 0-10      | 4,2              | 1,2                   | 136,3          | 152,5                |
|                  | 10-20     | 3,4              | 6,0                   | 145,4          | 199,6                |
|                  | 0-20      | **3,8**          | **3,6**               | **140,9**      | **176,1**            |

Alternating periods of the soil moisture and drying contribute to the release and fixation of potassium and, consequently, its seasonal variability. Studies have found that the experimental site soil is characterized by low availability of exchange potassium (140,9-176,1 mg / kg). Replenishment of
moisture reserves by September contributed to an increase in the concentration of exchange potassium in the soil solution.

The obtained results allow to conclude that land use arable chestnut soils, having a light granulometric composition, are characterized by a shortage of productive moisture and a low level of potential fertility. Low availability of humus, alkaline reaction of the medium, very low availability of mobile phosphorus, low-exchange potassium significantly reduce the productivity of the fields. During the period of the wheat intensive growth, the reserves of productive moisture decreased to a critical state (3-5 mm), which affected the nitrogen mineral forms consumption by plants.

3. Results and their substantiation

Before harvesting, with each repetition of the wheat variety Novosibirskaya 15, sheaves with 1 m² were selected and their analysis was carried out. The following parameters were considered: the plant height, the total number of stems, the number of stems with a full spike, the spike length, the spikelet number per a spike. Crop accounting was determined by biological threshing of selected sheaves. The structure of wheat grain yield was determined by the method of Yu. B. Konovalov (1987).

Varieties with high stem stands have less resistance to lodging. Lodging of grain crops, as a rule, can occur in the phase of the grain filling and ripening with a strong, gusty wind with rainfall of a stormy nature.

Plant height of the wheat varieties Novosibirskaya 15 in the registration sites ranged from 27,4 cm to 50.9 cm. There is a marked and inverse connection \( r_{x,y} = 0.816 \) between sowing rates and registration sites; the lower seeding rate is, the higher the plants are. The shortest-stemmed plants were formed in the variety Novosibirskaya 15 at the registration sites with the highest plant safety per 1m² and high seeding rates. The tallest plants were formed in the variety Novosibirskaya 15 on the registration sites with the lowest safety of plants per 1m² and the seeding rate less than 180 kg / ha (figure 2).

![Figure 2. Height of plants to be harvested on the registration sites, cm.](image)

The yield of the variety depends on the productive bushiness, the length of the ear, the number of spikelets in the ear. The inflorescence in wheat is a complex spike consisting of a cranked rod and spikelets. On each segment (ledge) of the spikelet rod there is one spikelet. The distance between the spikelets may be different depending on the plant variety. The spike length depends on the variety genotype and is related to the length of the variety growing season of. The wheat variety Novosibirskaya 15 refers to early-ripening varieties, and, as a rule, the ear is shorter in these varieties than in the varieties of early and middle-ripening.

The assessment of the ear length in the wheat varieties Novosibirskaya 15 showed slight variability at the registration sites and made up from 4,0 to 6,3 cm. The spikes of the varieties Novosibirskaya 15 refer to the medium category in length (8-10 cm) according to the classification of Blyakhferov (1966). But there are no significant differences between the length of the ear. The relationship between the
length of the spike and the number of spikelets is high and direct \( (r_{xy}=0.816) \). On average, the number of spikelets in the ear was 8.5 pieces on the registration sites (figure 3).

![Figure 3](image)

**Figure 3.** The length of the plant ear (cm) and the number of spikelets (pieces).

There are significant differences between the number of spikelets in the variants of the experiment. With an increase in the seeding rate, the number of spikelets decreases almost twice. A lower seeding rate in the extreme arid conditions in Mongolia reduces species competition between plants, but increases it due to the increased productive bushiness. The calculation of the productive bushiness coefficient is presented in figure 4.

![Figure 4](image)

**Figure 4.** The productive bushiness coefficient.

Analysis of the seeding rate showed that in areas with a high seeding rate, biometric indicators and indicators of productive bushiness are significantly lower than in areas with a seeding rate of 180 kg/ha and below. In the registration sites with a seeding rate of 210 kg/ha or more, this figure is lower than one, which suggests that the varietal competition of wheat plants of Novosibirskaya 15 variety, especially during the vegetation season, did not allow them to form mature productive stems. The relationship between the seeding rate and the productive bushiness is high and inverse \( (r_{xy}=-0.739) \). Thus, the reduced seeding rate from 140 kg/ha and below increases the number of ears and grains in the ear on each plant, but reduces the number of ears per unit area, which does not happen with an increased seeding rate.

During the vegetation season, the following phases of growth and development are observed in grain crops: shoots, bushing out, stalking, booting, earing, flowering and maturation. As it is known, the decrease in potential yield begins with the loss of shoots at the end of bushing out and continues with the death of flowers before flowering. Weather conditions during these periods, called critical, determine the magnitude of potential yield losses (figure 5). According to the observations of the company’s specialists during the growing season of 2017 there was no precipitation at the site of
PROLOG SYSTEMS LLC, in the period from May 13 to July 6, and from July 8 to July 21. The average temperature for June was +28°, and July +35°.

When studying different seeding rates, the maximum yield was achieved at the seeding rate of 160 kg / ha, and the minimum at 230 kg / ha. The relationship between the seeding rate and the wheat yield is high and direct (r<sub>x,y</sub>=0,792).

4. Conclusions
Crops of the wheat varieties Novosibirskaya 15 in Mongolia with an optimal seeding rate of 140-180 kg / ha had more intensive growth, maximum yield and minimum lodging compared with a higher seeding rate of 210-230 kg/ha. In hot and arid conditions of Mongolia, a decrease in the seeding rate is permissible, while the presence of productive moisture in the spring period will be a determining factor.

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