Agromeliorative methods of cultivation of a new variety of soybeans Volgogradka 2 under irrigation conditions

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Abstract. The Volgogradka 2 variety is highly responsive to irrigation water, especially under differentiated irrigation regimes with an average of 3.18-3.23 t/ha compared to the control (2.87 t/ha). In favorable years, it provides grain harvesting up to 3.52 t/ha, in dry years – less (up to 3.28 t/ha). The average crude protein content is high - 39.5...41.6%, especially in 2014 - 40.6...43.9%. The process of fat accumulation is less subject to variability over the years – 14.6...19.5%. Complex-valuable indicators, such as the gross collection of protein, fat and their total output significantly increases in the options of fractional irrigation mode compared to the control – by 5.8-7.3%. Over the years of research, the productivity potential of the new soybean variety Volgogradka 2 has been significantly realized, which contributes to improving water management, increasing productivity, grain quality, and spreading the area under cultivation. Thus, a fundamentally new soybean variety with a complete type of stem growth during the period of mass flowering, a low lodging-resistant stem and high attachment of lower beans, a short growing season was developed using traditional breeding methods, which contributes to a significant increase in the yield and quality of grain in terms of protein content relative to standard varieties VNIIOZ 76 and VNIIOZ 86. The introduction of the new variety will expand soybean crops in the Lower Volga region and increase the production of domestic soybeans.

1. Introduction
The world production of the ranking soybean crop in the 2019/2020 agricultural year reached 344 million tons from a total sown area of 127.4 million hectares and a yield of 2.7 t/ha. In the Russian Federation, by the end of 2019, 4.3 million tons of grain of this crop were produced from a harvesting area of 3 million hectares and a yield of 1.43 t/ha. Soy remains a fairly profitable crop, and the development of its production has become a state priority.

In comparison with the world's leading producers (USA, Brazil, Argentina, China, Paraguay, India), domestic indicators are not up to par, especially in terms of yield.

In the southern regions of our country, yield growth is constrained by a lack of precipitation, both during the entire growing season of soybeans, and in its second half during the period of greatest water consumption, especially in the Lower Volga region. A significant increase in the sown area in the regions of Central Russia is not accompanied by a significant increase in the average yield, since the
promotion of such a heat-loving crop as soybeans above 51-52 °C of North latitude limits the use of medium-ripening potentially most productive varieties. The significant distribution of less adapted than domestic varieties of foreign selection (up to 50%) does not contribute to the profitability of domestic soybean production.

In the main soybean producing countries, this crop has a high export potential. A number of Russian researchers predict such a future for domestic variety production. [1, 4, 6] the most Important reserve for a significant increase in soybean production is the intensification of the introduction of irrigated land into agricultural circulation and its cultivation in the Lower Volga region, where this crop provides from 3 to 5 tons of grain per 1 ha [7, 8, 9] with the use of adapted, responsive to a high agricultural background varieties and improving the technology of their cultivation.

The aim of the research is to study the productivity of a new (in the State Register of varieties - from 2020) [2] medium-ripening soybean variety Volgogradka 2 under different irrigation regimes.

2. Materials and methods
Long-term (2013-2015) studies were carried out in the Federal state unitary enterprise "Irrigated" of All-Russian Research Institute of Irrigated Agriculture on zonal light chestnut soils. The content of nitrogen (36-44 mg/kg of soil) is low, mobile phosphorus (27-51 mg/kg) is average, and potassium (265-327 mg/kg) is high. This type of soil is characterized by high density, low zones of productive moisture and low water permeability in the root layer (Table 1).

| Indicators | Depth of soil sampling, m | 0-0.1 | 0.1-0.2 | 0.2-0.3 | 0.4-0.4 | 0.4-0.5 |
|------------|--------------------------|-------|---------|---------|---------|---------|
| Density of the soil, t/m³ | 1.25 | 1.29 | 1.31 | 1.34 | 1.39 |
| Soil porosity, % | 51.7 | 51 | 49.4 | 47.9 | 46.3 |
| Least moisture capacity (LMC), % | 25.5 | 25.2 | 24.7 | 25 | 24.3 |
| Wilting humidity, % | 8.35 | 8.97 | 9.8 | 10.9 | 11.8 |

Meteorological conditions were characterized by contrast in the manifestation of hydrothermal conditions. In 2013, weather conditions were more favorable for the growth and development of soybeans. The atmospheric drought limiting the yield of this crop in irrigated crops [4, 5, 7] was less pronounced - 85 days with a relative humidity of less than 30% than that in other (2014, 2015) studied years (114 days). This contributed to a deeper study of the water consumption of plants of the new variety.

The irrigation regime for the pre-watering humidity threshold included options for maintaining at the level of V1 70-80-70% of LMC (70% - at the stage of "sowing-end of budding", 80% - "mass flowering-filling of beans", 70% - "beginning of ripening-full ripeness"), at the level of V2 80-80-70% of LMC and V3 – 80-80-80% of LMC is control. The accounting area of plots is 120 m². The experience is repeated 4 times.

Seeds were sown at a rate of 500 thousand pieces/ha based on 100% germination, using a wide-row method (0.70 m) and fertilizing based on the planned yield of 3.5 t/ha of grain (N₉₀ P₉₀ K₉₀ kg of active substance/g). The counts and observations of plants and soil were carried out in accordance with the methodology of B. A. Dospekhov.
3. Results and discussion

For the formation of a crop, a new variety from sowing to full ripeness needs from 113 (2014) to 120 days (2015) with a total provision of temperatures above 10 °C during this period of 2660...2863, which is typical of varieties of the medium-ripening group.

Soybeans is one of the unique crops that can form more than half of organic matter in a fairly short time of the growing season [8]. The results of our research confirm this statement (Table 2).

Intensification of water consumption of plants increases the processes of photosynthesis, as the basis for crop formation under irrigation conditions. Limiting the flow of irrigation water to 70-80-70% of LMC significantly (by 22.9%) activates the productivity of leaf photosynthesis, compared to other more water-rich irrigation regimes (V2, V3). The increase in the leaf surface area of this variety to 56.6 thousand m²/ha leads to an increase in biomass up to 6.5 t/ha and for a shorter time – 61.9% of the total during the growing season, than in the variants with limited irrigation water supply to plants (V1 and V2) – 63.4-64.8%, so it is important not to be late with irrigation in crops of this variety.

To carry out the planned irrigation regimes in the crops of the studied variety, it is necessary to carry out from 3 to 6 (during the 2013 growing season) and from 5 to 9 in more arid years (2014, 2015) of irrigation with norms from 378 to 630 m³/ha, taking into account the stage of plant development at the time of irrigation (Table 3).

Table 2. Indicators of the intensification of organic matter formation (for 54 days) during the period of flowering-filling of beans (average data for 2013-2015)

| Characteristics and properties | Irrigation regime, % of LMC | Indicators | Indicators |
|--------------------------------|----------------------------|------------|------------|
|                                |                           | Absolute value of the time | Deviation from control, % | Share of total (106 days) during the growing season, % | Deviation from control, % |
| Water consumption of plants, m³/ha · day | V1 70-80-70 | 58.7 | 2.3 | 63.5 | 12.2 |
|                                 | V2 80-80-70 | 55.9 | 2.6 | 70.4 | 2.6 |
|                                 | V3 80-80-80 | 57.4 | - | 72.3 | - |
| Area of the assimilation surface of the crop, thousand m²/ha | V1 70-80-70 | 50.4 | 11 | 58 | 2.1 |
|                                 | V2 80-80-70 | 47.4 | 16.3 | 52.4 | 7.7 |
|                                 | V3 80-80-80 | 56.6 | - | 56.8 | - |
| Net productivity of photosynthesis, g/m² · day | V1 70-80-70 | 5.9 | 22.9 | 51.3 | 25.1 |
|                                 | V2 80-80-70 | 4.9 | 2.1 | 40 | 2.4 |
|                                 | V3 80-80-80 | 4.8 | - | 41 | - |
| Growth of phytomass, t/ha | V1 70-80-70 | 6.2 | 4.6 | 64.8 | 4.7 |
|                                 | V2 80-80-70 | 6.5 | - | 63.4 | 2.4 |
|                                 | V3 80-80-80 | 6.5 | - | 61.9 | - |

Under irrigation conditions, the most intensive water consumption was observed in plants under irrigation regimes V1 and V3, and the longest with a share of time – 72.3% of the total for the growing season – in the control variant. The leaf surface area of the largest size of 56.6 thousand m²/ha is reached in the variant 80-80-80% of LMC.
The registered variety is able to increase the biomass without irrigation at the rate of 70-80-70% of LMC in the years favorable for the stage development of plants in the first half of the growing season (before flowering) (2013). In the future, during the period of reproductive development, it is important to provide plants with irrigation water from 4 to 5 watering sessions.

**Table 3.** The relationship of irrigation regime, number of irrigation, stages of plant development and year of cultivation of the soybean variety Volgogradka 2

| Stages of plant development                  | Irrigation regime, % of LMC | Years of observation |
|----------------------------------------------|----------------------------|----------------------|
|                                              |                            | 2013 | 2014 | 2015 |
| Mass shoots – flowering                      | V1 70-80-70                | 0    | 1    | 1    |
|                                              | V2 80-80-70                | 1    | 2    | 2    |
|                                              | V3 80-80-80                | 1    | 3    | 2    |
| Mass flowering – beginning of seed filling   | V1 70-80-70                | 1    | 2    | 2    |
|                                              | V2 80-80-70                | 2    | 2    | 3    |
|                                              | V3 80-80-80                | 2    | 2    | 3    |
| Mass filling of beans – beginning of ripening| V1 70-80-70                | 2    | 2    | 2    |
|                                              | V2 80-80-70                | 2    | 2    | 2    |
|                                              | V3 80-80-80                | 2    | 2    | 2    |
| Mass ripening – full ripeness                | V1 70-80-70                | 0    | 0    | 0    |
|                                              | V2 80-80-70                | 0    | 1    | 0    |
|                                              | V3 80-80-80                | 1    | 2    | 2    |
| Total for the period: mass shoots – full ripeness | V1 70-80-70            | 3    | 5    | 5    |
|                                              | V2 80-80-70                | 5    | 7    | 7    |
|                                              | V3 80-80-80                | 6    | 9    | 9    |

Due to the finished type (with mass flowering), the variety proposed for production effectively uses soil moisture from atmospheric precipitation in early autumn. The ripening of plants of this variety and the formation of large seeds characteristic of the variety can take place without irrigation at this time (except for the 80-80-80% of LMC variant). In dry years, it is necessary to carry out 1-2 watering.

The development of irrigation reclamation techniques is closely related to the assessment of quantitative indicators of water balance receipts and identification of the share of irrigation water, precipitation and moisture accumulation in the soil. The results of our research have shown that irrigation and precipitation play a significant role in the structure of total water consumption during cultivating the Volgogradka 2 variety (Table 4).

**Table 4.** Structure of total water consumption (average data for 2013-2015)

| Water balance items: | Irrigation regime, % of LMC | 70-80-70 | 80-80-70 | 80-80-80 |
|----------------------|------------------------------|----------|----------|----------|
| Water balance items: | m³/ha | %     | 4185 | 4442 | 4689 |
| Irrigation water:    | m³/ha | %     | 2600 | 2900 | 3200 |
| Precipitation:       | m³/ha | %     | 1214 | 1214 | 1214 |
| Moisture in soil (before vegetation – 1391 m³/ha) at | 1020 | 1063 | 1116 |
the end of vegetation | 371 | 328 | 275  
| m^3/ha | % |   |

In more water-rich years (2013), the share of irrigation water varies from 44.7 to 56.2%, approaching the level of precipitation - 37.6-44.3%. In dry and arid years, the water supply with irrigation increases to 60.9-70.9% with a decrease in atmospheric precipitation to 23.4-27.9%.

Analyzing the spectrum of the irrigation regime, it was found that with a decrease in the flow of irrigation water, its share in the structure of total water consumption decreases. However, the share of soil moisture consumption by plants increases significantly – from 5.9 to 8.9%, which contributes to significant savings in irrigation water.

A highly profitable increase in yields when cultivating soybeans on fairly costly irrigated land can be achieved using a variety that is responsive to irrigation water and optimization of the irrigation regime.

As a result of our research, it was found that crops of the variety recommended for irrigation conditions form higher levels – by 10.8-12.5% of the yield of 3.18-3.23 t/ha of grain under differentiated (V1 and V3) irrigation regimes than in the control variant (Table 5).

**Table 5.** Influence of crop moisture conditions on the yield of the soybean variety Volgogradka 2, t/ha

| Indicators by year | Irrigation regime, % of LMC | V1 70-80-70 | V2 80-80-70 | V3 80-80-80 |
|--------------------|-----------------------------|-------------|-------------|-------------|
| 2013 (LSD05 t/ha – 0.16) | 3.48 | 3.52 | 3.01 |
| 2014 (LSD05 t/ha – 0.04) | 3.22 | 3.28 | 2.84 |
| 2015 (LSD05 t/ha – 0.06) | 2.84 | 2.89 | 2.75 |
| Average LSD05 t/ha | 3.18 | 3.23 | 2.87 |
| Deviation from control: t/ha | 0.31 | 0.36 | - |
| % | 10.8 | 12.5 | - |

**Table 6.** Relationship of protein and fat content in seeds and their gross yield with the regime of irrigation of the Volgogradka 2 variety

| Indicators | Irrigation regime, % of LMC | Proteins, % | Years | Deviation from control, % |
|------------|-------------------------------|-------------|-------|---------------------------|
| Protein content in seeds | 70-80-70 | 40.2 | 2013 | -1.7 |
| | 80-80-70 | 39.6 | 2014 | -2.1 |
| | 80-80-80 | 41.3 | 2015 | - |
| Fat content in seeds | 70-80-70 | 15.2 | Average | 0.4 |
| | 80-80-70 | 14.7 | | 0.9 |
| | 80-80-80 | 16.6 | | - |
| Gross harvest of protein, t/ha | 70-80-70 | 1.2 | 2013 | 5.8 |
| | 80-80-70 | 1.2 | 2014 | 6.7 |
| | 80-80-80 | 1.07 | 2015 | - |
| Gross harvest of fat, t/ha | 70-80-70 | 0.45 | 2013 | 7.3 |
| | 80-80-70 | 0.44 | 2014 | 7.3 |
| | 80-80-80 | 0.43 | 2015 | - |
The constant irrigation regime in crops of this variety does not contribute to a significant increase in yield, even in relatively favorable precipitation years (2013) - 3.01 t/ha.

For protein-oilseed soybean culture, it is important to study changes in the quality indicators of the economically valuable part of the crop [4, 7]. However, this area of research is not sufficiently covered in scientific publications. The results of our research have shown (Table 6) that the fluctuations of these indicators are influenced by the meteorological conditions of the years of crop formation and water regimes of the soil.

The highest protein content in seeds of the studied variety was observed in 2014 – 40.6...43.9% of the dry grain weight, the lowest - in 2015 (37.7...39.7%). The highest concentration of crude protein in seeds was observed with the pre-irrigation regime of 80-80-80% of LMC – 39.7-43.9%, and the lowest - with differentiated irrigation regimes.

The process of fat accumulation in seeds was less subject to variability in the years of research than the protein content. The irrigation regime also did not significantly affect the variability of this trait.

Economically more valuable indicators of the quality of the crop harvested from the field are the gross yield (collection) of crude protein and fat per unit area. A similar analysis of the results of our research showed that the gross yield of protein was 1.03...1.10 t/ha, fat - 0.41...0.44 t/ha, and in the sum of these indicators it reached 1.44...1.54 t/ha. Differentiation of the water regime of the soil led to an increase in these values by 5.8...7.3% compared to the constant irrigation regime during the vegetation period.

4. Conclusion
A long-term (2013-2015) study of the productivity of a new variety of soybeans Volgogradka 2 (since 2020 - in the State Register of soybean varieties approved for use) under various irrigation regimes is associated with the phases of plant development of 70-80-70% of LMC, 80-70-70% of LMC and constant - 80-80-80% of LMC during the growing season (control).

Plants of the variety reach ripeness during the periods of sowing – full ripeness within 113 days (2014) and 120 days (2015) are typical of varieties of the middle-ripening group with a need for a total of the temperatures above 10 °C – 2660...2863.

It was found that the differentiation of the irrigation regime (70-80-70% of LMC) increased the net productivity of leaf photosynthesis by 22.9% compared to the control. In optimal meteorological conditions years (2013) crops need from 3 to 6 and in dry years (2014, 2015) – from 5 to 9 irrigations with rates from 378 to 630 m³/ha, taking into account the stage of plant development. Due to the determinant of the development of a new variety in the favorable years (2013) is able to do without irrigation before flowering, effectively use of soil moisture and to complete the vegetation due to precipitation at the end of the summer period and the beginning of autumn. In the structure of the total water consumption of this variety (4185...4689 m³/ha), the irrigation rate is 62.1...68.2%, precipitation is 25.9...29% and soil moisture is 5.9...8.9% on average over the years of research and depending on the irrigation regime. In favorable years, the share of irrigation water increases (44.7...56.2%), approaching precipitation (37.6..44.3%), in dry years, on the contrary, it increases significantly (60.9...70.9%) in proportion to the decrease in the level of natural moisture supply (23.4...27.9%).

Higher yield (3.18-3.23 t/ha) was observed in this variety in crops with a differentiated irrigation regime, compared to the control (2.87 t/ha), and especially in favorable (2013) years (3.48-3.52 t/ha).

The level of protein content in seeds increased (40.6...43.9%) in 2014 and decreased (37.7...39.7%) in the growing season of 2015. The concentration of fat in seeds was slightly variable (14.6...19.5%) over the years of research. The irrigation regime also did not significantly affect the variability of this trait. The gross yield of protein and fat, as well as their total indicators, significantly increased in the variants of differentiated irrigation regimes (5.8...7.3%) compared to the control.

| Total gross yield  | 70-80-70 | 1.65 | 1.56 | 1.41 | 1.54 | 6.9 |
|-------------------|----------|------|------|------|------|-----|
| - protein + fat t/ha | 80-80-70 | 1.64 | 1.57 | 1.41 | 1.54 | 6.9 |
|                   | 80-80-80 | 1.5  | 1.46 | 1.36 | 1.44 | -   |
The productivity potential of the new soybean variety Volgogradka 2 has been significantly realized. Water management in the agrocenosis of this variety will significantly increase the yield, grain quality and expand the area of sowing.

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