Photosynthetic activity of spring barley crops in the zone of forest belts influence in the Volgograd region

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Abstract. Protective afforestation has a significant impact on the morphometric parameters of spring barley. It increases the number of grains per spikelet and the number of spikelets per spike. As the grain crops approach the field-protective forest belt, the length of the stem and the mass of 1000 grains increase. In fact, the yield increase at a distance from the protective belt is 3.0 c / ha. The influence of forest shelter belts is traced throughout the growing season on the development of Medicum 139 barley and is reflected in such indicators as leaf area, photosynthetic activity of crops, the amount of dry phytomass and net productivity of photosynthesis. The results of the study indicate the important role of forest belts. The area of application of the developments is the zone of soils of the Lower Volga region.

1. Introduction

Russian scientists pay due attention to the influence of trees and shrubs in order to protect agricultural land from droughts, dry winds, dust storms and water erosion since the 18th century. They noted the beneficial effect of protective afforestation on soil properties, growth, condition and productivity of agricultural crops. The role of protective afforestation in the stabilization of agricultural production in the arid regions of Russia is well known. Forest belts create a microclimate favorable for cultivated crops and improve the water regime of soils [3,9,12].

Forest belts with a certain impact on the ecology of fields, increase the ameliorative effect (accumulation and preservation of productive moisture) and the preservation of soil fertility, thereby increasing the economic significance of protective forest plantations [4,29].

Today in order to increase the productivity of agricultural crops, depending on soil and climatic resources, various technologies and agrotechnical methods are used to control the photosynthetic activity of crops [2,11,17,22].

The interrelation of plants in the agrocenosis is of a immediate nature and depends on many factors. The main task for obtaining high yields is to create such a crop, which would maximize the potential of the photosynthetic activity of plants in the agrocenosis. This can be achieved through the creation of favorable conditions for the growth and development of plants [1,5,28]. Z.I. Usanova notes that the regulation of the density of the productive stalk, and, consequently, the structure of the agrocenosis, is much more difficult than the density of planting, especially in barley, due to the greater dependence of the degree of tillering on meteorological conditions [11,12]. The overwetting has the greatest negative effect on the number of productive shoots for harvesting. Drought causes more damage to the value of productive tillering in comparison with the productivity of spikes [14, 16, 23].

According to P.I. Polityko [22], in the Non-Chernozem zone of the Russian Federation, favorable conditions for the sprouting of barley seedlings are formed in 38% of years. In these years, field...
germination reaches 80% and more, in the remaining 62% of the years it decreases due to low temperatures and overwatering. N.V. Voitovich [5] also believes that during the use of seeds grown under similar conditions, the survival rate is influenced to a greater extent by meteorological conditions than by the quality of the seeds. The experiments carried out by a number of authors indicate that seed treatment prevents possible seed losses by 50%.

Fertilizers and the concentration of soil solution have a great influence on field germination rate and plant safety [18, 19, 25]. The harvest of any agricultural crop, including barley, is formed in the process of photosynthesis as a result of the use of solar radiation. Leaves are the main part that absorb solar energy [6,10,13].

I.S.Shatilov noted that in crops of barley during the growing season, the share of leaves accounts for about 50% of the absorbed acid. Spikes absorb about 24% in the control, in intensive crop rotation they absorb about 14% of the total, while the bulk of it is assimilated by leaf sheaths and green parts of the stem. Therefore, one of the main conditions for the maximum use of photosynthetic active radiation (PAR) is the creation of crops with an optimal leaf area, capable of being in active state for a long time [15,30]. It is believed that with a surface index of 4-5 m / m, sowing as an optical photosynthetic system works in an optimal mode, absorbing the greatest amount of PAR. With a smaller leaf area, part of the PAR is not absorbed by the leaves.

If the leaf area exceeds 50 thousand m / ha, then the lower leaves are shaded by the upper ones and their share in photosynthesis is significantly reduced. There unproductive costs of photosynthesis products to the detriment of the quality of valuable reproductive and storage organs occur [20, 24]. The assimilating surface of cultivated cereals increases to heading, then decreases. During the life of plants, it changes, so the efficiency of photosynthesis depends not only on the size of the leaf surface, but also on the duration of its activity [20, 21]. The study of the dynamics of the formation of assimilating surface in crops and the creation of conditions for its optimal size is of great practical importance, since the parameters of photosynthesis associated with them play a significant role in the yield of agricultural crops. Growth processes, reflecting general functional and metabolic changes in plants, most closely correlate with the course of their accumulation of biomass and air-dry matter [26, 27].

Growth, development of plants occurs and yield is formed as a result of photosynthesis. A. Hoyle points out that high yields are formed under the condition when the area of the sown leaf surface quickly grows to the optimum size and remains at this level for a long time [28].

Therefore, the study of the photosynthetic activity of spring barley crops under the influence of forest belts is relevant in the modern conditions of the development of the Russian economy.

The purpose of the research is to study the indicators of photosynthetic productivity of spring barley during the growing season (germination, tillering, stemming, heading, flowering), to carry out a comparative analysis of the photosynthetic activity of spring barley crops by development phases. In order to achieve this purpose, we determined and calculated the area of leaf surface; photosynthetic activity of crops, crop structure, the amount of dry phytomass, net productivity of photosynthesis during the growing season.

2. Materials and methods
We performed the research in the Land Use “Gorodishchenskoye” (cadastral number 34: 03: 000000: 6) in the zone of influence of forest belts on the experimental field of Lower Volga Research Institute of Agriculture. The site is located in the light chestnut subzone of the dry steppe zone of chestnut soils in the Lower Volga region. The territory of the household is presented by undulating plain. The climate is extreme continental climate, hydrothermal index = 0.5-0.6. The sum of the average daily positive air temperatures is 3400-3500 ° C. Average annual precipitation is 300-350 mm. The amplitude of the minimum and maximum temperatures is 7.8 ° C (from + 43 ° C to -35 ° C). Forest strip is 5 meters high with 4 rows.

It includes Norway maple (Acer platanoides), European white elm (Ulmus laevis) and golden currants (Ribes aureum). The soils are low in nitrogen, medium in phosphorus, and high in potassium. The humus content is 1.2-2.0%, pH = 7-8. The experiment was performed according to the methods of the dry steppe zone of the Lower Volga region. The main cultivation of autumn fallow includes stubble plowing with a disc harrow BDT-3 to a depth of 8-10 cm, after 10-15 days plowing with a moldboard
tool to a depth of 25-27 cm. In spring, harrowing is carried out in 2 rows. Before sowing winter wheat, autumn fallow is cultivated by the KPS-4 cultivator to a depth of 6-8 cm.

Spring barley Medicum 139 was sown, the seeding rate was 3.8 million pcs / ha.

Table 1. Meteorological conditions over the years of the study

| Indicator                                     | Harvest year |
|-----------------------------------------------|--------------|
|                                               | 2016-2017    | 2017-2018    | 2018-2019    |
| Annual precipitation, mm                      | 374.9        | 393.0        | 387.3        |
| Average temperature during the growing season, °C | 18.5         | 21.9         | 20.5         |
| Precipitation during the growing season, mm   | 62.4         | 87.8         | 126.1        |
| Hydrothermal index during vegetation          | 0.6          | 0.4          | 0.5          |

The amount of precipitation for 2016-2017; 2017-2018 and 2018-2019 harvest years (table 1) respectively amounted to 374.9; 393.0 and 387.3 mm. The hydrothermal index for the growing season of spring barley was for 2016-2017; 2017-2018 and 2018-2019 harvest years - 0.6; 0.4 and 0.5, respectively.

During the growing season, the observations were carried out and samples were taken to study morphophysiological parameters in the phases of tillering, stemming, heading and flowering.

Crop monitoring was carried out according to the following algorithm. On the indicated dates, the mass of plants from an area of 0.25 m² together with the root system was taken from plots at a distance from FOREST BELT. Morphometric measurements and calculation of such indicators as wet and dry biomass, leaf area and net productivity of photosynthesis (NPP) was carried out. The measurement of leaf area was carried out according to O.S. Reshetsky, NPP - according to B.A. Dospekhov, structural analysis of barley harvest was carried out according to the method of the South-East. Sheaves were selected from an area of 0.25 m on each inter-lane cell on continuous row crops. The numbers of plants before harvesting, the number of common and productive stems, grain weight, sheaf weight, 1000 grain weight were determined per 1 m². Biometric analysis of plants was carried out according to the method of M.S. Savitsky From the selected sheaves, 30 plants were chosen and the height of the plants, the length of the spike, the number of spikelets (total and including developed), the number of grains and the weight of grain per spike were determined. Mathematical and statistical processing of crop data was carried out using Microsoft Excel and Statistica programs.

3. Results and discussion

Agrometeorological conditions for the growing seasons of spring barley of 2017-2019 were quite favorably for the growth and development of spring barley. Field germination and survival of plants for harvesting had a great influence on the formation of grain yields.

Table 2. The stock of productive soil moisture in crops of spring barley, depending on the previous crop and methods of biologization (average for 2017–2019)

| Previous crop | Soil layer | Sowing | Harvesting |
|---------------|------------|--------|------------|
| Chickpea      | 0…0.3 m   | 28.0   | 9.8        |
|               | 0…1.0 m   | 74.2   | 26.0       |
| Chickpea      | 0…0.3 m   | 28.7   | 10.3       |
|               | 0…1.0 m   | 76.4   | 26.2       |
| Safflower     | 0…0.3 m   | 31.4   | 10.3       |
|               | 0…1.0 m   | 78.2   | 27.7       |
| Grain sorghum | 0…0.3 m   | 35.3   | 10.7       |
|               | 0…1.0 m   | 81.9   | 27.7       |
| HCP₀₅         | 0…0.3 m   | 1.54   | 0.51       |
|               | 0…1.0 m   | 3.9    | 1.34       |
At the time of sowing spring barley (Table 2) in the arable soil layer of 0 ... 0.3 m, the reserves of productive moisture ranged from 28.0 mm for the previous chickpea in a four-field crop rotation to 35.3 mm for the previous grain sorghum in a seven-field crop rotation. The same pattern was traced in the meter layer of soil.

The main role in the accumulation of the reproductive organs of spring barley belongs to the upper leaves. In this regard, it is necessary to promote the extension of their life. The lifespan of leaves is affected by soil and air moisture, varietal characteristics and the presence of nutrients. The size of the area of leaf blades, their lifespan and the productivity of the leaf surface have a significant impact on the formation of dry mass of plants and grain yield. The unit of leaf area in potentially high yielding and less yielding varieties has different productivity.

According to the obtained results presented in Figure 1.2, the greatest correlation dependence on such an indicator as the moisture reserve in the productive soil layer of 0-30 cm has spring barley crops at a distance of 5H from forest belt at the time of sowing with a determination coefficient of 0.921. Spring barley is less dependent on the moisture reserve in the productive soil layer at a distance of 15H from forest belt and further with a determination coefficient of 0.710.

![Figure 1](attachment:figure1.png)

**Figure 1.** Correlation dependence of spring barley yield on moisture reserves in the productive soil layer of 0-30 cm at a distance of 5H from the planting zone at the time of sowing.

![Figure 2](attachment:figure2.png)

**Figure 2.** Correlation dependence of spring barley yield on moisture reserves in the productive soil layer of 0-30 cm at a distance of 15H from forest belt and further at the time of sowing.

The growing season of spring barley in the “sprouting – heading” phase with sufficient precipitation had a good growth effect. The assimilating surface was 12 ... 22.8 in the sprouting phase and 30 ... 32.2 thousand m² per hectare in heading phase. The growth of the leaf surface continued until the heading phase, and the minimum leaf area was in milky phase.

On average, over the years of research, the highest photosynthetic potential of spring barley was at a distance of 10H - 1272.4 thousand m²/ha, the lowest value of PAR during the growing season was at a distance of 5H - 1019.4.
Table 3. Indicators of photosynthetic activity of spring barley crops (average for 2017-2019)

| Distance from FOREST BELT, H | S average, thousand m²/ha | PAR, thousand m²/ha, day/ha | NPP, g/m² per day |
|-----------------------------|---------------------------|-----------------------------|-------------------|
| 5H                          | 23.6                      | 1019.4                      | 0.43              |
| 10H                         | 25.9                      | 1272.4                      | 0.56              |
| 15H                         | 25.45                     | 1162.8                      | 0.41              |
| 20H                         | 26.00                     | 1184.4                      | 0.62              |
| 25H                         | 26.60                     | 1233.2                      | 0.41              |
| 25H                         | 28.00                     | 1330.0                      | 0.55              |

Net productivity of photosynthesis (NPP) is the increase in dry biomass in grams per day per 1 m². During the years of research, the NPP value largely depended on weather conditions. On average, PAR indices for spring barley crops were as follows: the smallest - 0.41 g / m² per day at a distance of 15H and 25H from FOREST BELT, the highest at a distance of 20H - 0.62 g / m² per day (Table 1). However, it is impossible to give decisive answer about the photosynthetic activity of plants at different distances from FOREST BELT, since the formation of the leaf area during the growing season is influenced by the agrophone (the amount of fertilizers by the phases of development, the moisture content of crops (the years differed in moisture), the variegation of soil differences in the experimental field, which affected the performance of PAR and NPP.

In order to determine the features of the formation of the productivity of spring barley under the influence of forest belt, it is necessary to study the dynamics of the accumulation of the mass of absolutely dry matter by plants. The studies showed that the active accumulation of absolutely dry matter by spring barley plants occurs in the phase of stem elongation and ranges from 600 to 889 g / m², depending on the safety of the plants for harvesting and the distance from the plant leaf, then these indicators decrease due to the loss of a part of the leaves and the consumption of plastic substances for air (table 4).

Table 4. Dynamics of the accumulation of dry matter in spring barley crops (average for 2017-2019)

| Distance from forest belt, H | Interphase period                  |               |               |               |
|-----------------------------|------------------------------------|---------------|---------------|---------------|
|                             | Stooling-stem elongation           | Stem elongation - heading | Heading-milky phase | Heading-milky phase |
| 5H                          | 169                                | 600           | 132           | 901           |
| 10H                         | 192                                | 889           | 99            | 1178          |
| 15H                         | 156                                | 842           | 126           | 1124          |
| 20H                         | 148                                | 854           | 103           | 1105          |
| 25H                         | 114                                | 855           | 114           | 1083          |
| 30H                         | 177                                | 790           | 99            | 1066          |

The dynamics of the accumulation of dry matter mass by spring barley plants depends on agricultural technologies, weather and climatic conditions, etc. The influence of the seeding rate of seeds and the sowing density of spring barley on the accumulation of dry matter leads to a decrease in the dry matter weight per unit of sown area. This is clearly expressed in the tillering-milk phase.

The grain yield of spring barley depended on the influence of forest belt and weather conditions of the year in the initial phases of plant development, especially in the heading phase. On average, the highest yield was obtained at a distance of 5-10H from forest belt and amounted to 1.8 t / ha, the smallest - 1.05t / ha at a distance of 15H from forest belt.

Under the influence of forest belt, the elements of the structure of the spring barley yield change significantly (table 5).
Table 5. Structure of spring barley yield (average for 2017-2019)

| Distance from forest belt, H | Productive stems, pcs/m² | Grains per head, pcs | Weight of 1000 grains, g | Weight of grains in head, g | Average yield (2017-2019) |
|-----------------------------|---------------------------|----------------------|-------------------------|-----------------------------|---------------------------|
| 5H                          | 396                       | 17                   | 31,8                    | 0,6                         | 1,8                       |
| 10H                         | 452                       | 18                   | 34,8                    | 0,7                         | 1,8                       |
| 15H                         | 258                       | 16                   | 30,4                    | 0,5                         | 1,05                      |
| 20H                         | 396                       | 18                   | 32,8                    | 0,6                         | 1,4                       |
| 25H                         | 312                       | 18                   | 30,4                    | 0,6                         | 1,5                       |
| 25H                         | 402                       | 17                   | 30,9                    | 0,5                         | 1,6                       |

The number of productive stems of spring barley by the stage of grain ripening for three years of research was 258-452 pcs / m². The number of grains in head of spring barley varied from 16 to 18 pcs / m² at different distances from forest belt. The same pattern was traced for the mass of 1000 grains.

The leaf area significantly influenced the formation of the mass of 1000 grains and the number of productive stems calculated in heading phase depending on the influence of forest belt. Data processing using a software package (Microsoft Excel and Statistica) revealed a correlation between forest belts and the development of the leaf surface by development phases. In heading phase, the correlation coefficient in 2018 was R = 0.7, in 2019, R = 0.6, respectively. Such a coefficient showed a sufficient relation, despite the fact that the wind factor was not taken into account, but only the influence of the forest belt. In milky phase, a reliable correlation was established between the leaf surface area and the mass of grains in the main spike in 2017, 2018 and 2019 (R = 0.7, 0.5, 0.6, respectively).

On the basis of the obtained harvest of spring barley, laboratory analysis of grain quality on FDM was carried out.

Table 6. Fiber content in barley grain, %

| Distance from forest belt, H | Fiber on dry matter, % |
|-----------------------------|------------------------|
| 5H                          | 17,22                  |
| 10H                         | 21,00                  |
| 15H                         | 22,01                  |
| 20H                         | 21,00                  |
| 25H                         | 22,12                  |
| 30H                         | 22,10                  |

According to the analysis of the grain quality of spring barley, the high fiber content was at a distance of 15H and more meters from forest belt, and vice versa, in the immediate vicinity of forest belt, the fiber content decreases. This is due to the fact that forest belt shades plants, and also there is competition from forest belt for nutrients and soil moisture.

We revealed correlation between the yield in heading phase with the leaf surface area from the influence of forest belt (from 5N to 30N) (R = 0.4 .. 0.6), productive stems (R = 0.8), 1000 grain weight (R = 0 , 5 .. 0.6), weight of grains from the main spike (R = 0.6 .. 0.7); yield with leaf surface area in milky phase (R = 0.5..0.7), productive stems (R = 0.6 .. 0.8), 1000 grain weight (R = 0.6 .. 0.7) and the mass of grains from the main spike (R = 0.6 .. 0.7). Over the years the density and the size are influenced by the conditions of the vegetation of plants.

4. Conclusion

The increase of grain production requires new ways to increase crop yields. The study of plants in the zone of influence of forest belts is currently of particular relevance, since it makes it possible to increase the yield of grain crops due to the reserve of additional moisture. The studies showed that in the conditions of the dry steppe zone of light chestnut soils of the Lower Volga region, it is advisable to create field-protective forest plantations. They contribute to the improvement of indicators that...
determine the activity of agricultural crops during the growing season, such as the assimilation of surface of leaf mass, indicators of its photosynthetic activity, net productivity of photosynthesis, structure and its yield.

The regression and dispersion studies of the data set were carried out and proved the correctness of the conclusions. Thus, the cultivation of barley under the influence of forest belt promotes the increase in yield, plants safety to harvest, productive bushiness, grain weight per plant, 1000 grains regardless of the meteorological characteristics of the years, which ultimately contributes to the increase in its biological yield by 8.6%.

References
[1] Enver K and Yusuf D 2019 Yield stability and adaptation of four spring barley (Hordeum vulgare L.) cultivars under rainfed conditions Research on Crops 20 (1) 10
[2] Borrego-Benjumea A, Carter A, Glenn A J and Badea A 2019 Impact of excess moisture due to precipitation on barley grain yield in the Canadian prairies Canadian Journal of Plant Science 99 (1) 93-96
[3] Balakay N I 2013 Protective forest belts Ways to improve the efficiency of irrigated agriculture 50 17-24
[4] Verin A Yu, Medvedev I F, Gubarev D I, Derevyagin S S and Grafov V P 2018 Influence of the forest belt on the formation of ecological factors of the agricultural landscape Agrarian scientific journal 12 12-15
[5] Voitovich N V and Eroshenko N A 2010 Productivity and quality of malting barley Agriculture Cultivation technology 6 28-29
[6] Vušetić M, Marček T and Španić V 2019 Photosynthetic and antioxidative strategies of flag leaf maturation and its impact to grain yield of two field-grown wheat varieties Theoretical and Experimental Plant Physiology 31 (3) 387-399
[7] Zamyatin S A, Izmostiev V M, Vinogradov G M, Lapshin Yu A and Vinogradova I A 2010 Trends in climate change, impact on agriculture Agriculture 4 13-14
[8] Zivcak M, Olsovska K and Brestic M 2017 Photosynthetic responses under harmful and changing environment: Practical aspects in crop research Photosynthesis: Structures, Mechanisms, and Applications 16 203-248
[9] Usanova Z I and Gulyaev M V 2011 Influence of the background of mineral nutrition and seeding rates on the productivity of spring grain crops in the conditions of the Upper Volga region Achievements of science and technology of the agro-industrial complex 11 24-27
[10] Cammarano D 2019 Rainfall and temperature impacts on barley (Hordeum vulgare L.) yield and malting quality in Scotland Field Crops Research 241 (1) 107559
[11] Klem K, Gargallo-Garriga A, Rattanapichai W, Oravec M, Holub P, Veselá B, Sardans J, Peñuelas J and Urban O 2019 Distinct Morphological, Physiological, and Biochemical Responses to Light Quality in Barley Leaves and Roots Frontiers in Plant Science 10 (14) 1026
[12] Sarychev A 2018 Peculiarities of Ecological Conditions for the Formation of Spring Barley Bioproductivity in the Arid Zone of Volgograd Oblast on Lands Exposed to Deflation Arid Ecosystems 8 (2) 129-134
[13] Kadyrov M A, Senchenko V G and Baturo F N 2006 Barley: how, where, when and always with a profit Belarusian Agriculture 1 21-23
[14] Li C-S, Wu X-L, Tang Y-L, Li J, Ma X-L, Li S-Z, Huang M-B and Liu M 2019 Response of yield and associated physiological characteristics for different wheat cultivars to nitrogen stress at mid-late growth stage Acta Agronomica Sinica (China) 45 (8) 1260-1269
[15] Lu W, Adamowicz W, Jeffrey S R, Goss G G, Faramarzi M 2018 Crop Yield Response to Climate Variables on Dryland versus Irrigated Lands Canadian Journal of Agricultural Economics 66 (2) 283-303
[16] Mukhina M Yu 2005 Differentiated Approach to Grain Seed Treatment Plant Protection and Quarantine 38 19-20
[17] Mirenkov Yu A, Saskevich P A and Soroka S V 2006 Chemicals for plant protection (Minsk: “Trioleta”)
[18] Ojuederie O B, Olanrewaju O S, Babalola O O 2019 Plant growth promoting rhizobacterial mitigation of drought stress in crop plants: Implications for sustainable agriculture Agronomy 9 (11) 19
[19] Pavlovskaya N E, Timakov A G, Yakovleva I Ya, Mameev V V and Pavlovskaya N E 2019 Study of morphophysiological parameters and net productivity of spring barley photosynthesis Scientific journal of the Russian Research Institute of Land Reclamation Problems 1 2-15 DOI: 10.31774/2222-1816-2019-1-153-167
[20] Polityko P M, Kuzmin V N, Kisilev E F, Eroshenko N A et al. 2010 Technologies for the cultivation of spring crops in the Central Non-Black Earth Region (Recommendations) (Moscow: MosNIISH)
[21] Ruleva O V and Ovechka N N 2018 Dynamics of wind speed in irrigated agroforestry landscapes Meteorology and Hydrology 9 97-103
[22] Rogers C W, Dari B, Hu G and Mikkelsen R 2019 Dry matter production, nutrient accumulation, and nutrient partitioning of barley Journal of Plant Nutrition and Soil Science 182 (3) 367-373
[23] Soroka S V and Yakimovich E A 2014 The use of plant protection products in Belarus Plant protection and quarantine 4 8-10
[24] Sarychev A N 2018 Peculiarities of Ecological Conditions for the Formation of Spring Barley Bioproductivity in the Arid Zone of Volgograd Oblast on Lands Exposed to Deflation Arid Ecosystems. 8 (2) 129-134
[25] Tanyukevich V V 2013 Aboveground phytomass of forest belts, their influence on the wind regime and moisture accumulation of agricultural landscapes Polythematic network electronic scientific journal of the Kuban State Agrarian University 91 986-1003
[26] Hoyle A, Brennan M, Jackson G and Hoad S 2019 Increased grain density of spring barley (Hordeum vulgare L.) is associated with an increase in grain nitrogen Journal of Cereal Science 89 102797
[27] Handlířová M, Lukas V and Smutný V 2017 Yield and soil coverage of catch crops and their impact on the yield of spring barley Plant. Soil and Environment 63 (5) 195-200
[28] Shatilov I S and Kayumov M K 1978 Scientific basis for programming crop yields (Moscow: Kolos).
[29] Shetvsoy V M, Malyuga N G, Pikushova E A and Lobach I A 2009 Disease resistance of winter barley Proceedings of the Kuban State Agrarian University 16 77-83.
[30] Shtyrkhunov V D, Ostanina A V, Eroshenko N A et al. 2010 Spring barley. Cultivation technology in the Central Region of the Non-Black Earth Zone of the Russian Federation. Moscow: Publishing house of the Timiryazev Russian State Agricultural University-Moscow Agricultural Academy)