Bulgarian Journal of Agricultural Science, 25 (No 3) 2019, 540–545

Efficiency of windbreak forest belts for the cultivation of winter grain crops

Alexander Nikolaevich Sarychev[1*], Yuri Nikolaevich Pleskachev[2], Elena Anatolievna Ivantsova[3], Nikolay Vladimirovich Onistratenko[3]

[1]*Russian Academy of Sciences, FSC Agroecology, 400062 Volgograd, Russian Federation*
[2]*Volgograd State Agricultural University, Department of Agriculture and Agrochemistry, 400002 Volgograd, Russian Federation*
[2]*Volgograd State University, Institute of Natural Sciences, Department of Ecology and Nature Resources Management, 400062, Volgograd, Russian Federation*
E-mail: vnialmi_nir@vlpost.ru *([*]corresponding author),* agro@volgau.com, econecol@volsu.ru

Abstract

Sarychev, A., Pleskachev, Y., Ivantsova, E., & Onistratenko, N. (2019). Efficiency of windbreak forest belts for the cultivation of winter grain crops. *Bulgarian Journal of Agricultural Science*, *25*(3), 540–545

The article presents the results of studies on the complex effect of field-protecting forest plantings and technologies of the main processing of the soil on growth, development and efficiency of the main grain culture in the conditions of the southern areas of the Volgograd region. Authors established determined consistent patterns of change of some agrophysical indicators of the light brown soil and feature of formation of productivity of a winter wheat in the field with protective plantings in years, various on moisture security. Data on inspection of consequences of a dust storm in the territory of the Volgograd region are submitted. Studies have shown that the moisture content in the soil in the forestry agrolandscape varies differently in the inter-band space. The highest moisture reserves are formed in areas close to the forest band up to 15 H. This pattern can be traced both in dry and in wet years. Due to the features of the water mode the productivity of a winter wheat in the conditions of the protected field isn‘t uniform. Higher yields of wheat were obtained in those zones where additional moistening was formed. Field-protecting plantings don‘t influence soil density. This indicator varies only depending on the applied technology of tillage.

Keywords: forestry agrolandscape; winter wheat; windbreak forest belt; cultivation technology

Introduction

The Volgograd region is the agrarian region, taking the 10th place by the size of acreage in the Russian Federation (2988 thousand ha, or 3.8% of all acreage).The proportion of arable lands in the region makes 5717.3 thousand ha, from them 48% of lands are deflationally dangerous (Kulik, 2015), in which connection modern technologies of cultivation of crops have to be based on use of soil-protective technologies and the introduction of preventive measures.

It is known that one of the most effective ways of prevention of deflation of soils is creation of field-protecting forest plantings.There are more than 130 thousand ha of protective plantings by different estimates now in the territory of lands of agricultural purpose of the Volgograd region, from which more than 70 thousand ha are taken away under windbreak forest fields created in the form of linear landings on borders of fields of crop rotations. The works of Russian and foreign scientists (Skidmore, 1969; You & Ley, 2003; Voloshenkova, 2011; Abdalla & Fangama, 2015; Dafa-Alla & Naval, 2015; Kretinin, 2017) found that shelter belts favorably affect the water, temperature and food soils modes to provide protection against erosion and deflation processes.

The system of processing of the deflationally dangerous soils of agro landscapes has to be based on reduction of mechanical impact on the soil and preservation of the crop residue

remains that is possible only at application of planing plow processing of the soil or at introduction of direct no-till technologies of crops (Akgun et al., 2014). It is established that the winter period on the fields processed by planing plow 1.5-2 times more, in comparison with dump plowing and small surface treatments collects snow that is especially important for low-snow areas same as the Volgograd region. It is possible to reach small (superficial) processing only by disk tools or disk tools in combination with planing plow during the droughty postharvest period of high-quality cutting of the soil. (Sukhov et al., 1991; Goleukhin & Braliyev, 2005; Belenkov, 2006; Kiryushin, 2012)

Materials and Methods

The object of researches is located in the territory of land use of country farm of the individual entrepreneur Sarychev in Kotelnikovsky district of the Volgograd region. For carrying out researches on efficiency of field-protecting forest plantings and technologies of cultivation during 2013-2017 a series of multiple-factor field experiments in a grain-fallow-ingthree-field rotation has been put.

The studied crop is winter wheat; grade "SPARTAK", norm of sowing 3.5 million germinated seeds per 1 hectare.

All technological operations carried out during the growing season on technological cards based on dry farming system in recommendations for Volgograd region.

Scheme of experiment:

Factor A. Agrolandscape: I. Open Field (OF) (control) II. Fields protected by forest belt (FPFB) (Distance from forest belt 1.5 H, 5H, 10H, 15H, 25H, 35H)*. H is the height of the forest belt.

Factor B. Soil cultivation: I. Moldboard (Dump) plowing 0.20-0.22m II. Shallow planning loosening 0.10-0.12 m. III. Disking 0.10 – 0.12 m. IV. Combined processing 0.14 – 0.16 m.

The repetition of the experiments is threefold, with the systematic placement of options.

Protection forest belts of 3 rows Ulmuspumilain the composition of the agrolandscape; 45 years old; in 9.5-10 m of Height.

The soil of the experimental field is represented by light Kastanozems heavy loam soils, in which the humus content is 1.8%, total nitrogen – 0.15%, phosphorus – 0.10%, potassium – 0.40%.

Weather conditions in the years of research, according to the Kotelnikovskaya weather station (Fig. 1), differed sharply in the amount of precipitation. Conditionally years of researches can be divided on droughty – 2013 and 2015 when during vegetation 65.5 and 87 mm of rainfall respectively dropped out, and favorable on moistening 2014, 2016, 2017 (during vegetation 94, 198 and 117 mm of rainfall respectively dropped out).

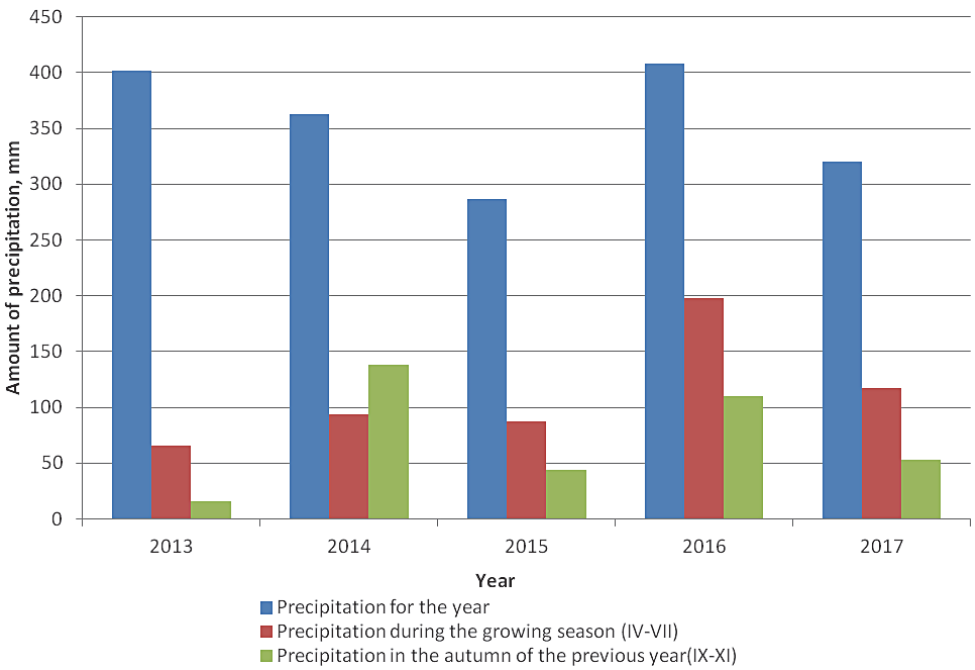


Fig. 1. The amount of precipitation during the period 2013-2017

To obtain the data, the standard methods of sampling and analysis of plant samples and soil samples were used. Determination of humidity of the soil was carried out by a thermostat-weight method, in triple frequency. Sampling was conducted by soil drill through 10 cm to a depth of 1 m. Selection was carried out in 4 periods: before sowing, in tillering phase, in the phase of entering the tube-earing, before harvesting culture. The volumetric mass of the soil was determined with the help of a cutting ring in triplicate repetition by layers 0-0.1, 0.1-0.2 and 0.2- 0.3 m at the beginning and at the end of the growing season. A study of the macroaggregate composition of the soil in the 0-0.3 m layer was conducted according to Savinov.

Sampling of plants was carried out by the method of state variety testing of crops. Sheaves of plants were selected on fixed sites using frames with an area of 0.25 m^2 (50x50 cm) in triplicates in the phase of tillering, earing and full maturity. The elements of the structure determining the yield value, the number of stems, including productive ones, the size of the ear, the number of grains in the ear, the mass of 1000 grains, the height of plants, the nature of the grain, the amount of protein in the grain were estimatedл Results were processed by methods of mathematical statistics.

Results and Discussions

Moisture during sowing and growing is the main factor in obtaining a guaranteed crop of winter crops for the soil and climatic conditions of the Volgograd region. Features of the climate in the south of the Volgograd region make this factor limiting for agricultural crops. It is known that emergence of shoots and development of a winter wheat during the autumn period requires not less than 20 mm of productive moisture in the 0-0.3 m soil layer (Balashov et al., 2016).

The water regime of the soil during the years of observations differed sharply in the content of the reserves of productive moisture, as our studies have shown. In addition, on the field with protective plantings, the amount of productive moisture in the soil changed depending on the removal from the protective forest belt and technological methods of tillage. So, in 2012 and 2014 before crops of a winter wheat, in September the content of productive moisture in a meter layer of earth was critically low both on fields with protective plantings, and without them; moisture content varied from 7.3 to 30.0 mm depending on remoteness from a forest strip and kind of soil treatment. The highest moisture reserve was on the variant with the use of the combined APK-6 plow – from 13.0 mm (35H) to 30.0 mm (5H). The lowest moisture content in the inter-band space was when using a disc harrow – from 7.3 (35H) mm up to 11.1 (10H) mm, which adversely affected on winter wheat seedlings. Shoots were obtained only in areas with optimal moisture content – 30-35 mm. The sowing of winter wheat in autumn 2013, 2015 and 2016 was carried out with the optimal content of available moisture meter layer of soil – from 44.0 to 62.1 mm. At the same time, in the field with forest protection bands observed heterogeneous water regime, as in the dry periods of 2012 and 2014. The largest moisture reserve was formed at a distance of 5 to 15 H from the forest belt. Depending on the technology of cultivation, the moisture content in the soil of the experimental field ranged from 47.4 to 62.1 mm. In the zone of the field, where the meliorative role of the forest belt weakens and on the field without protective plantations, the soil moisture reserve varied from 44.0 to 52.3 mm. For the emergence and development of autumn the amount of moisture and winter wheat are sufficient.

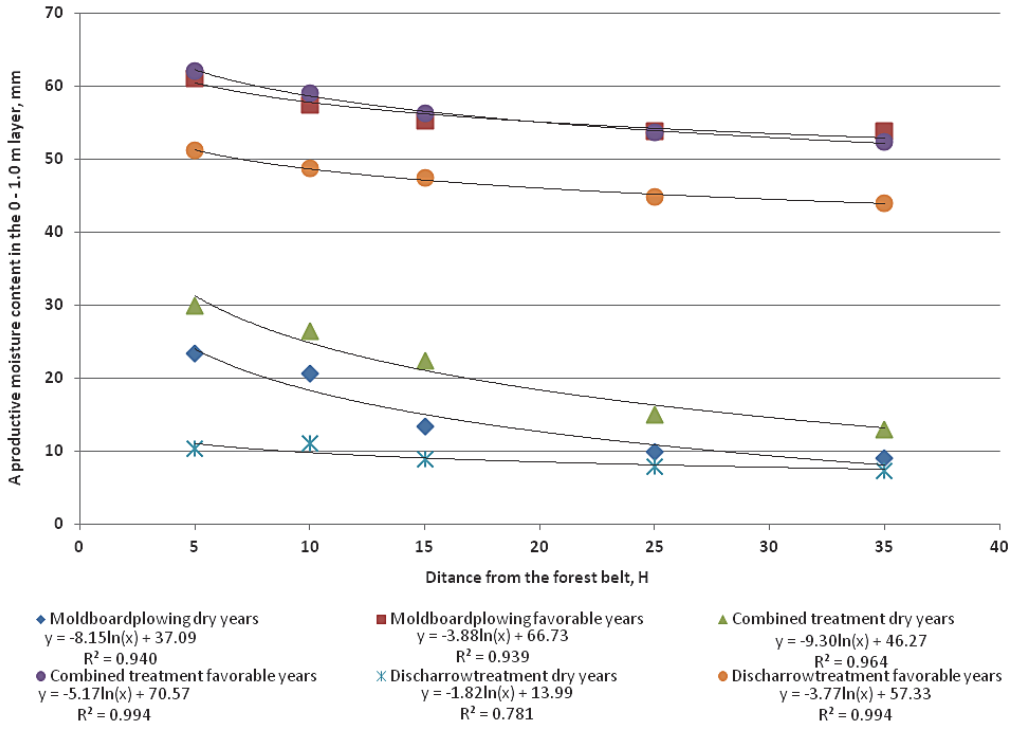
During the resumption of the growing season the soil water regime on interbelt space also differentially changed due to the specific deposition of the snow cover in winter, as the shelter forest stands are formed of snowy plumes.

It was found that the moisture content in the soil is closely related to the distance from the field of the protective band, which is described by the equation of logarithmic dependence within the studied experiment (Fig. 2).This pattern of distribution of moisture reserves on the field under the protection of forest belts was traced during the entire growing season of winter wheat.

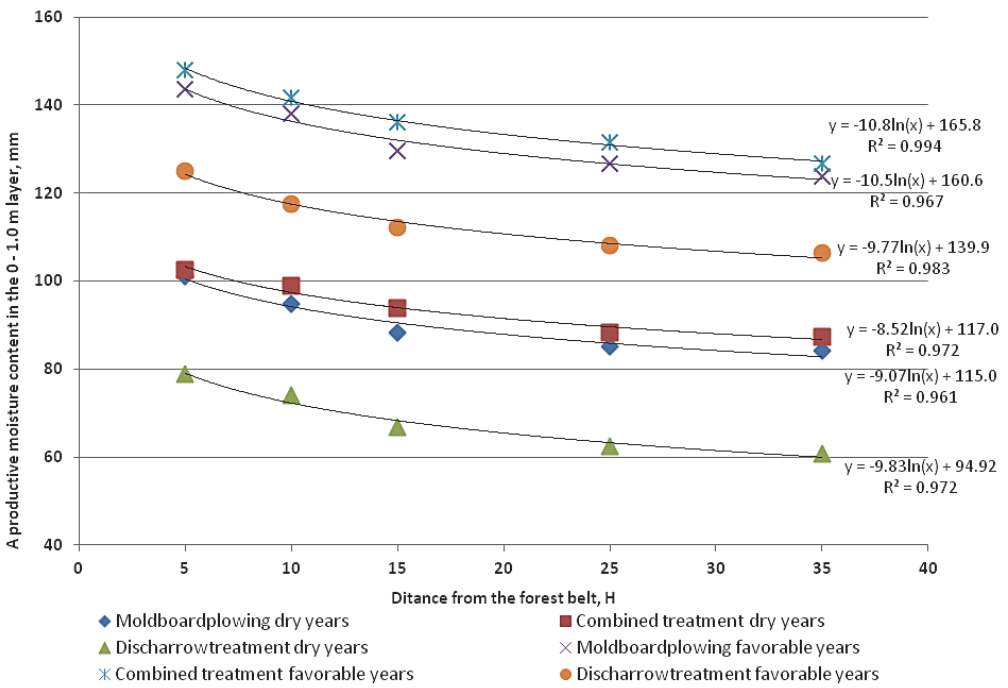
Researches have shown that when growing winter wheat in the same soil and climatic conditions total water consumption can be different depending on the distance from the forest belt and tillage systems. Thus, the value of total water consumption in dry years is lower than in wet years, and the coefficient of water consumption of culture on the contrary is higher in dry years.

In dry years (2013, 2015), the total water consumption in the field under the protection of forest belts, depending on soil cultivation, was 1213.4 m^3/ha for dumping plowing, 1247.2 m^3/ha for shallow flattening, 1070.0 for disking, and for combined processing – 1288.5 m^3/ha. In the good years (2014, 2016, 2017), the value of this indicator was 1843.4, 1794.9, 1705.8 and 1872.0 m^3/ha accordingly. The total water consumption in the field with protective plantations was on average higher than on the field without forest belts – by 76.6 m^3/ha in arid and at 128.9 m^3/ha in favorable years for humidification.

Thus, it can be concluded that forest protection strips have a direct impact on the formation of moisture reserves in the soil. There is a decrease in stocks of moisture in the soil in process of removal from protective forest strips.



A



B

Fig. 2. Dependence of the available moisture content in the inter-band space on the distance from the forest band:
A – before sowing winter wheat, *B* – during the resumption of the vegetation of winter wheat

Table 1. Harvest of winter wheat in the inter-band space, t/ha (average for 2013-2017)

Distance from forest belt	Acceptance of basic tillage, implement			
	Moldboard plowing PN-8-40	Shallow planning loosening KPSh-9	Disc harrow treatment BDT-7	Combined treatment APK-6
1.0H	0.45 1.24	0.44 1.18	0.25 0.97	0.54 1.31
5H	1.45 3.33	1.46 3.17	1.02 2.73	1.58 3.56
10H	1.37 3.12	1.35 2.99	0.95 2.57	1.49 3.24
15H	1.25 2.92	1.24 2.79	0.91 2.41	1.38 3.01
25H	1.14 2.69	1.16 2.60	0.84 2.33	1.27 2.88
35H	1.11 2.53	1.12 2.46	0.81 2.28	1.26 2.76
Average yield under the protection of forest belt	1.09 2.82	1.10 2.72	0.77 2.32	1.21 2.99
OP (control)	1.02 2.55	1.03 2.39	0.74 2.15	1.17 2.72
HCP_{05} (general); 2013 – 0.08; 2014 – 0.17, 2015 – 0.09; 2016 – 0.28, 2017 – 0.17				

Note: in the numerator, the average yield in the dry years 2013, 2015; in the denominator the average yield in the favorable years 2014, 2016, 2017

Table 2. Average height of the ground loops in forest field-protecting shelterbelts after a dust storm, m

Place of sampling	Municipal District of Volgograd Region			
	Kotelnikovsky	Octobyabrsky	Yelanskiy	Kletsky
3 m from forest belt, windward side	0.26	0.24	0.20	0.15
The middle of the belt	0.85	0.79	0.67	0.45
3 m from the forest belt, windward side	0.66	0.63	0.48	0.28

Density is a very important agrophysical soil parameter. An increase in soil density above 1.3 g/cm^3 leads to a deterioration in water availability, air exchange, nutrient regime and oppression of cultivated plants. As a result of researches it was established that the soil protective plantings did not render influence on size of density. The value of this indicator was influenced only by the technology of soil cultivation, which was applied on the inter-band space. On average, for 5 years of observations, the soil density was at the same level and was determined depending on the treatment 1.17-1.23 g/cm^3 before sowing winter wheat and 1.27-1.36 g/cm^3 before slaughter.

The productivity of cultivated culture and production quality are the main criteria for evaluating the effectiveness of agro-technology implementations. The yield indicator of winter wheat varied significantly during the years of research, which is primarily due to the prevailing weather conditions, as it can be seen from the data in Table 1. In dry years, the yield of winter wheat did not exceed 1.6 t/ha, and in humid years, productivity in individual control plots reached 3.56 t/ha. The highest yield of winter wheat was formed in zones etc. and approximations to the timber the band from 1.5 to 15 H. This is due to formation of optimum of water and food regime in these areas. It is established during the researches that in close proximity to a windbreak forest field at distance up to 1.5 H there is an oppression of cultural plants and decrease in their productivity that is caused by influence of trees which root system extends in a regional part of the field and absorbs a part of available moisture and nutrients.

The effectiveness of field shelter plantations against deflation processes was confirmed in March 2015 in a dust storm in the Volgograd region, when for 7 days the wind speed was 22-25 m/s, as a result, in fields without protective forest belts and in fields where the distance between forest belts exceeded 600 m, the upper soil layer from 5 to 11 cm was lost. Most of the fertile layer was transferred to the ravine-girder net and accumulated in field shelterbelts.

The sediment height was in some places up to 0.85 m (Table 2). In the fields, including the experimental field, with the optimal inter-band spacing between the plantations, and also using soil-processing technology based on the use of aggregates with flat-cutting working organs and leaving

stubble residues, soil was not observed on land surface and winter crops were damaged by fine soil particles.

Conclusions

In the arid climate of the southern regions of the Volgograd region, the forest shelter belts provide winter wheat with additional moisture. This in turn affects the yield of cultivated crops. The distribution of available moisture on the field with protective plantations is uneven; the largest amount of moisture accumulates in areas at a distance of 5-15 H from the forest strip.The density of the soil on the field with forest belts does not differ from the density of the soil on the field without forest strips. This agro physical indicator depends on the applied technology of tillage. Given the optimal distances between forest belts and the application of soil protection technologies, crops are not exposed to dust storms.

References

Abdalla, Y. Y. & Fangama, I. M. (2015). Effect of shelterbelts on crop yield in Al-Rahad agricultural scheme. *Sudan International journal of Current Microbiology and Applied Sciences, 4*(7), 1-4.

Akgun, N., Marakoglu, T., & Carman, K. (2014). Effect of different seedbed preparation systems on wheat yield and yield components in Middle Anatolia. *Bulgarian Journal of Agricultural Science, 20*(1), 117-121.

Balashov, V. V., Levkin, V. N., & Levkina, K. V. (2016). The maximum permissible periods for sowing winter soft and hard wheat on light Kastanozems of the Lower Volga region. *Proceedings of the Lower Volga agrouniversitetskogo complex: Science and Higher Vocational Education,* 4, 39-45. (Ru)

Belenkov, A. I. (2006). Agrotechnical principles of field crop rotation of grain specialization, basic processing and regulation of fertility of zonal soils in blackaboutterrestrial, dry-steppe and semi-desert zones of the Lower Volga region. Dissertation, Volgograd (Ru) .

Dafa-Alla, M. D. & Nawal, K. N. (2011). Al-Amin design, efficiency and influence of a multiple-row, mix-species shelterbelt on wind speed and erosion control in the arid climate of the North Sudan. *Research Journal of Environmental and Earth Sciences,* 3(6), 655-661.

Goleukhin, S. N. & Braliev, K. K. (2005). Efficiency of the main processing systems for light chestnut soils of the Volgograd Transvolga in short-rotation crop rotation. *In: And so to the development of agribusiness ualnye problems*, Proceedings of the international scientific and practical conference dedicated to the 60th anniversary of the Victory in the Great Patriotic War, Volgograd, 32-34 (Ru) .

Kiryushin, V. I. (2012). Problems of greening agriculture in Russia (Belgorod model). *Advances in science and technology AIC*, 12 (4) (Ru).

Kretinin, V. M. (2017).The fertility of forest reclaimed soil territories in the VNIALMI experimental network in the second half of the 20th century. VNIALMI, Volgograd, 122 (Ru).

Kulik, K. N. & Kulik, A. K. (2015). On the prospects of protective afforestation in the Volgograd region. *In: Strategic development of the agro-industrial complex and rural areas of the Russian Federation in modern international conditions*, Proceedings of the International Scientific and Practical Conference dedicated to the 70th anniversary of the Victory in the Great Patriotic War of 1941-1945. Volgograd, Volgograd State Technical University, 303-307 (Ru) .

Skidmore, E. L. (1969). Modifying the microclimate with wind barriers. In: *Proceedings of seminar "Modifying the Soil and Water Environment for Approaching the Agricultural Potential of The Great Plains".* Agr. Council Pub, *34* (1), 107-120.

Sukhov, A. N., Zhurbenko, A. K., & Belenkov, A. I. (1991). System of resource-saving soil cultivation as a factor of intensification of agricultural production. *In: Biologistandcal foundations of intensive technologies of cultivation of field crops in the Volgograd region.* VSHI, 119-123. (Ru)

Vasiliev, Y. I. (2003). The effectiveness of forest stripe systems in the fight against deflation of soils. VNIALMI, Vologrаd, 176 (Ru).

Voloshenkova, T. V. (2011). Efficiency of the use of moisture by grain crops in the inter-band space. Protective afforestation in the Russian Federation. VNIALMI, Volgograd, 32-35 (Ru).

Received: July, 19, 2018; *Accepted:* January, 10, 2019; *Published:* June, 30, 2019