Main directions of development of agro-technologies for production of spring wheat species for sustainable agriculture in the forest-steppe of the middle Volga region

Marat Amirov, *Farit* Shaikhutdinov, *Igor* Serzhanov*, and *Albina* Serzhanova

Kazan State Agrarian University, Kazan 420015, Russia

Abstract. The article presents the results of research conducted in different soil and climatic conditions of the Middle Volga region on the influence of regulated factors, as well as environmental factors on the production process of plants of various types of spring wheat. The amount of photosynthetically active radiation (PAR) is enough to obtain yields within 12–13 tons of dry biomass or 6-7 tons of grain. Natural precipitation is able to provide 3.82–4.36 t of spring wheat grain from 1 ha, and 4.5–6.3 t/ha by the total influence of solar energy, heat and moisture supply. Natural level of soil fertility without application of organic and mineral fertilizers allows to receive about 2 tons of spring wheat grain from 1 ha. Application of nitrogen in the form of ammoniac water (N-20.5 %) increased the yield in comparison with the use of nitrogen in the form of ammoniac saltpeter: the increase was 0.14 t per 1 ha. In the conditions of grey forest soil in the Predkamye region of the Republic of Tatarstan the optimal norm of sowing of spring wheat Triticum dicoccum Schuebl (spelt) depending on the feeding background was established. Growth of yield at sowing of 6 million seeds per hectare at all levels of nutrition in comparison with sowing rate of 4 million tons per hectare was 0.18 tons per hectare against the natural background, against the estimated background of NRC on 2.0 tons of grain – 0.19 tons and 2.5 tons of grain – 0.24 tons per hectare. The maximum yield increase was received at a combination of a mineral foodstuff with an optimum norm of sowing and has made on a settlement background 2 tons of grain from hectare – 0.20 tons, on 2.5 tons of grain – 0.34 tons from hectare. Thus, the aim of our research was to develop methods of growing high yielding quality grain of different types of wheat adapted to the conditions of forest-steppe in the Volga region.

1 Introduction

In order to satisfy people with food, fodder for agricultural animals and industries, obtaining high and stable yields corresponding to the standards of quality remains the main task of the crop industry [1, 2].

It is possible to increase the yield of cultivated crops by investing additional funds for the application of new effective cultivation technologies, high-yielding varieties and hybrids, machinery and equipment for cultivation of crops, fertilizers, means of weed control and protection against pests and diseases, storage and processing of agricultural products, etc., that is, an intensive way of development of the industry [3, 4].

The task of increasing crop yields with simultaneous reduction of production costs causes the need to calculate in advance the possible yield level depending on the availability of sowing factors of the environment, potential capabilities of crops, varieties, etc., that is, to have the ability to draw up an accurate program of yield formation.

This ability allows to calculate and satisfy the needs of plants (crops) in regulated factors in the most complete way, using partially regulated and unregulated factors in specific soil-climatic conditions [5–6].

At the same time, the increase in demand for energy resources has led to an increase in the cost of agricultural machinery, fertilizers, herbicides, fuel, and, consequently, the cost of manufactured products, which in connection with increasing demand leads to a constant and steady rise in prices for food products [7, 8].

The technology of cultivation of each crop has its own peculiarities in general, in each zone, farm and even on each plot. Introduction of modern technologies of separate crops is inconceivable without fruit rotation.

Cultures should be placed on the best predecessors: winter crops – on pure (sideral) pairs, spring wheat – on peas, winter crops, sown on pure pairs, fertilized tilled crops, sugar beet – after winter crops; other crops should also be placed on predecessors corresponding to their biological characteristics [9].

The conducted experiments with fertilizers and strong agricultural practices give the greatest effect only if they are applied in the appropriate link of crop rotation; their effect will be greatest only when sowing crops that are able to fully use them [10, 11].

* Corresponding author: igor.serzhanov@mail.ru

2 Materials and methods

Experiments with spring durum wheat were laid in 1984–1987 on low-power leached black earths of the Ulyanovsk region, 1990–2014 on gray forest soils of the Predkamsk zone and 2001–2003 on leached lands of the Republic of Tatarstan.

Studies on the selection and genetic potential of spring wheat varieties included in the state register in the region were carried out on gray forest soil with a content of humus – 2.8–4.3%, the sum of absorbed bases – 26.0 mg-eqv. On 100 g of soil, mobile phosphorus – 103–183, exchangeable potassium 79-149 mg per 1000 g of soil (Kirsanov), pH salt – 5.6–5.7.

Studying the norms of spring wheat spelt sowing at different levels of nutrition were carried out in 2012–2014 by the method of field and laboratory experiments. Field experiments on gray forest soils of the Predkamie of the Republic of Tatarstan were carried out on the fields of auxiliary farm of Kukmorsky Agrochemservis LLC. The soil is grey forest, granulometric composition is heavy loamy. Humus content in soil (according to Tyurin) – 3.0–3.1 %, P_2O_5 – 171–183 mg and K2O (according to Kirsanov) – 96.0–117.0 mg per 1000 g of soil. The sum of absorbed bases – 27.0 mmol, pH of salt extract – 5.1–5.3.

The object of research is spring wheat of Gremmay variety. Predecessor – winter rye after pure steam.

Experience scheme: Factor A (level of nutrition: 1. Without fertilizers (natural background; 2. Calculation of NPK for 2.0 tons of grain from 1 ha; 3. Calculation of NPK for 2.5 tons of grain from 1 ha).

Factor B (sowing rate). Four sowing rates were tested at each level of nutrition: 1 – 4 million germplasm seeds per hectare; 2 – 5 million seeds per hectare; 3 – 6 million pieces per hectare; 4 – 7 million pieces per hectare.

Nitrogen fertilizers were applied in the form of ammonium nitrate, phosphorus fertilizers – in the form of double superphosphate, potassium fertilizers – in the form of potassium chloride.

Repetition in the experiment is fourfold, placement of plots of different supply backgrounds is rented, seeding rates are sequential. The accounting area of the plot is 108 m2. The main tillage was carried out in the 3rd decade of August. To obtain the planned harvest of spring wheat spelt grain at the level of 2 tons of grain per hectare it was actually introduced: N17 P7-10 K7-10 kg/ha of active ingredient, for 2.5 tons of grain – N28 P714-16 K22-23 kg/ha of active ingredient.

During the experiments we carried out a complex of observations, counts and analyses using the "Field Experience Methodology" (Dospekhov, 1985) and "State Variety Testing of Agricultural Crops Methodology". (Moscow, 1975) and other methodical guidelines: phenological observations – according to the method of the State variety testing of agricultural crops; accounting of sprouting and density of plants standing before harvesting by counting on three permanent sites of 0.55 m^2 per each variant in three repetitions: accumulation of raw and dry biomass, growth of the leaf surface – by A.A. Nichiporovich. Determined humidity, density of arable layer formation, soil hardness. The number of weeds was calculated on the sites on 0.25 m^2 in six places of the plot on three repetitions of the experiment. Influence of spring durum wheat with diseases and pests, resistance of plants to lodging were taken into account. Nitrate nitrogen content in soil was determined by disulfenol method, alkali-hydrolysable nitrogen – by Cornfeld, mobile forms of phosphorus and potassium in extracts – by Kirsanov and Chirikov – with subsequent determination of phosphorus on photo-electric calorimeter, and potassium on flame photometer. NPK in plant samples was determined by wet ashing method: nitrogen – by Kjeldal, phosphorus – by calorimetric method, and potassium – by flame photometer. Protein in grain was calculated by multiplying the percentage of total nitrogen by a factor of 5.7; nitrogen, phosphorus and potassium utilization coefficients from soil and fertilizer were determined by the difference method according to V.A. Demin (1981). Grain yield was accounted for by the method of continuous threshing with recalculation of 14% moisture content and 100% purity; the yield structure was determined by test sheaves taken from permanent sites of each plot in three places (0.33 m^2). Technological properties of grain were determined by the methods set forth in GOST. Statistical processing of yielding data was carried out by the method of dispersion analysis according to B.A. Dospekhov: economic and energy evaluation was carried out according to the method of VNIIESH and VASHNIL (1983); correlation and regression analysis using the program Statistica ver. 5.5 A for Windows.

3 Results

At the Department of Plant Industry of Kazan State Agrarian University professor M.F. Amirov conducted research on revealing the influence of repeated sowing and alternation with other crops on the yield of spring wheat. Wheat sowing on wheat reduced grain yield by 0.8 t compared to pea sowing, barley – by 0.2 t, oats – by 0.58 t (wheat and barley are strongly affected by the same type of mushroom causing root rot, and oats suppress it). In the experiments carried out on leached chernozem of Zakamskaya experimental station peas, winter rye and pure steam were used as precursors. Despite the tendency of higher yields of pure steam and some advantage of peas over rye, all the precursors of fertilizers received programmed grain yields with quality that meets the requirements of commodity class 1 of GOST 9353-90. It means that these precursors can really be recommended for inclusion into the complex of methods of growing high quality grain crops of spring wheat in the zone. Identified advantages of the predecessors were systematically evaluated on a large number of introduced varieties. One of the main conditions for successful cultivation of spring wheat in the region is the correct selection of varieties. Varieties with relatively high resistance to drought, diseases and pests, well adapted to the soil and climatic conditions of

the region and at the same time responsive to fertilizers, were in demand. This approach is explained by the desire to reduce the cost of grain production and in the interests of rational use of natural resources, taking into account environmental constraints.

The use of natural resources and adaptive properties of cultivated varieties presupposes an in-depth assessment of not only the predecessors, but also soil and climatic conditions up to the microlevel, i.e. for each farm, field, site and careful study of the features and capabilities of the varieties themselves. Only in this case, it will be possible to reasonably zone-out varieties depending on the situation, to select even for small areas two or three suitable varieties from a fairly large number of registered in the region.

Another important question now is how realistic it is in practice, in different agro-climatic zones of the country, to receive grain of spring wheat with good baking qualities. Varieties, agricultural machinery, fertilizers, post-harvest grain processing and other factors play an important role in this process. The yield of different varieties of spring wheat placed on winter wheat, which are in pure steam, was determined by both the productivity of plants and their quantity per unit area.

Indicators of technological quality of spring wheat grain differ significantly due to the peculiarities of varieties, climatic conditions and application of fertilizers. The best indicators of wheat grain quality were characteristic of the varieties Simbirka, Priokskaya, Krasnoufimskaya 90, Prokhorovka and Amir.

The most important reserve for increasing crop yields and improving grain quality is the use of fertilizers. Fertilizer rates are set for the planned yield by the calculation method taking into account the coefficients of nutrient utilization from soil and fertilizers. In addition, the acidity of the soil is taken into account, for each crop, depending on its biological characteristics responsiveness to the elements of nutrition depends on this parameter. In fields with reduced fertility, to obtain a high yield requires a lot of nitrogen fertilizers, they are applied for grain crops in fractions, so as not to create in the soil solution of high concentrations of salts, adversely affecting the field germination and further development of young plants, not to cause excessive pinching and development of vegetative mass to the detriment of grain yields, lodging, spread of diseases, not to reduce yields. In our experiments were actually introduced in the Ulyanovsk region N62-77 R95-105 K15-65 kg in the active substance on 1 hectare, in Zakamye of Tatarstan N70-80 R57-63 K28-30, in Ancestral Kama N93-110 R48-68 K12-27. Observations on experiments have shown that the application of relatively small doses of fertilizers, also balanced in terms of elements in accordance with the requirements of the crop, did not have any negative impact on the development of plants. From the introduction of complete mineral fertilizer there were received significant increases in grain yield.

The protein and raw gluten content of durum wheat was increased when in addition to the preseeding fertilizer, wheat was also given nitrogen and liquid fertilizer-stimulating compounds with Cu + Mo in chelated form (Cu + Mo) in the flowering and milky ripeness phase. Foliar fertilizers were especially effective against the background of complete mineral fertilizer on leached chernozem of the Tatarstan Region. The maximum values of grain nature (770.3 g/l) were obtained against a fertilized background when fertilizing with nitrogen in the phase of milk ripeness (Table 4).

The economic assessment of the timing of fertilization showed the highest profitability on all the backgrounds of nutrition nutrition at milky ripeness. For Ancestors of Tajikistan, the level of profitability against a fertilized background increased from 84 to 96 %, for Zakamye – from 103 to 112 %.

In 1998-2000 Professors Shaykhutdinov F.Sh., Serzhanov I.M. and Predkamskoy Zones of the Republic of Tatarstan carried out an experiment on revealing the effectiveness of various forms of nitrogen fertilizers in combination with phosphorus-potassium fertilizers to obtain a high-quality, ecologically safe grain harvest of spring wheat. On average, over three years, the use of nitrogen in the form of ammoniac water (N – 20.5 %) increased the yield in comparison with the use of nitrogen in the form of ammonium nitrate: the increase in yield on all calculated backgrounds was – 0.14 tons per 1 hectare.

The use of ammoniac water had almost the same effect on the quality of spring wheat grain and environmental indicators as that of ammonium nitrate.

The greatest energy efficiency at cultivation of spring wheat with use of various forms of nitrogen fertilizers is received on the variant calculated on reception of 4 tons of grain from 1 hectare, at entering of ammoniac water. The energy conversion coefficient was 3.52, which is 0.25 units higher than the energy coefficient when using ammonium nitrate.

Crops should be reliably protected from weeds, diseases and pests by means of preventive and destructive measures, agrotechnical, biological and chemical control means. Development of plants, conditions of their growth and yield formation on crops should be constantly monitored in order to eliminate the obstacles that hinder the growth and maturation of plants.

In recent years, there has been an increase in demand not only for high-quality grain for bakery (durum wheat) and pasta (durum wheat), but also for spelt cereals (film wheat, double-grain). Therefore, there was a need for a comprehensive study of the low prevalence of double-grain wheat in the conditions of Tatarstan.

Professor Shaykhutdinova F.S., Professor Serzhanova I.M. carried out in 2012–2014 in the Predkamye of Tatarstan on the gray forest soil set the optimal norm of sowing spring wheat spelt of the Gremme variety depending on the background of nutrition. Studies have shown that the duration of spelt wheat vegetation was significantly affected by meteorological conditions. In the dry year of 2013, (SCC May-August 0.74) the vegetation period was the shortest – 72 days, and in the slightly dry year of 2014 (SCC – 0.79) was 77 days. In 2012 (SCC – 0.82) the vegetation period was 83 days.

At all levels of nutrition, as the sowing rate increases from 4 to 7 million germplasm seeds per 1 hectare, the number of shoots increases at a natural (no fertilizer) level of nutrition from 338 to 565 pcs/m^2, and at fertilized variants, respectively: from 370 to 580 and from 376 to 580 pcs/m^2.

The application of the calculated doses of fertilizers contributed to the increase in the value of the leaf surface. When sowing 6 million germinated seeds per hectare during the earing phase, the leaf area was formed by 5.7–9.6 thousand m2/ha more than the natural background: FS – by 253–388 thousand m2 ha, FSF – by 1.6 g/m^2 per day. With the increase in sowing rates, leaf area (except for natural background), FP and CPF values increase.

The most reliable yield in the years of research, both on natural and fertilized backgrounds was obtained by sowing 6 million germinated seeds per hectare. Average data for three years show that the increase in yield at sowing 6 million seeds at all levels of nutrition in comparison with the norm of sowing 4 million was – against a natural background – 0.18 t/ha, at the estimated level of NRC for 2 tons of grain – 0.19 and 2.5 tons of grain – 0.24 tons per hectare.

The application of calculated doses of mineral fertilizers had a significant impact on plant productivity and spelt wheat yield. Fertilizer application to the planned level of grain yield of 2 t/ha on the average on all norms of sowing provided the addition of 0.18 t/ha, against the background calculated on 2.5 t/ha – 0.3 t/ha.

However, the maximum yield increase was received at a combination of a mineral foodstuff with an optimum norm of sowing and has made on a settlement background 2 tons of grain from hectare – 0.20 tons, on 2.5 tons of grain – 0.34 tons from hectare.

The linear dependence of yield on sowing rates was established (2012 r=+0.489...0.871; 2013 r=+0.311...0.905 and 2014 r=+0.569...0.907).

4 Conclusion

The material of field experiments and laboratory tests described in the article allows to draw the following conclusions.

1) Agroclimatic resources and soil conditions of the Volga region forest-steppe in compliance with the basic methods of technology of cultivation of spring durum wheat guarantee high yields of quality grain. In our experiments in the Ulyanovsk region and Tatarstan we annually cultivated 2.5–3.5 t/ha.

2. In order to form grain with the quality that meets the requirements of GOST 9353-90, it is necessary to strictly observe the complex of methods that include the following elements: removal of the proper precursor in the crop rotation (annual and perennial legumes, fertilized winter and tilled, pure steam with fertilizer application); mineral fertilizers in accordance with the planned yield, application of appropriate microelements in case of their lack in the soil;

3. All three predecessors studied by us: peas, winter rye, pure steam – made it possible to grow first-class grain and get the planned yield.

4. At entering of mineral fertilizers on settlement productivity of grain of a spelt of 2 t/ha on the average on all norms of sowing the addition of 0.18 t/ha is received, on the lobby calculated on 2.5 t/ha – 0.3 tons. The maximum yield at all feeding levels (1.65; 1.85; 1.99 t/ha) was obtained using the sowing rate of 6 million pieces/ha of germinated seeds. The increase of yield on these variants in comparison with sowing rate was 4 million pieces per hectare against a natural background of 0.18 t/ha, with the application of NPK by 2 tons – 0.19 and 2.5 tons – 0.24 tons per hectare.

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