The impact of agricultural resource-saving technologies on grain yield and quality

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Abstract. As a result of the studies it is found that applied low rates of mineral fertilizers in the fertilization system when cultivating winter wheat increased its yield to 21%, the higher rates (N64P78K78) gave yield increase to 45% (compared with the options with unapplied fertilizers), in spring barley yield increases were more significant: up to 36 and 58%, respectively. In addition to increasing yields, the use of low rates of mineral fertilizers in the cultivation of winter wheat significantly contributed to the increase in gluten content in the variants with cereal-fallow-row crop(C-F-RC) rotation and the system of combined primary tillage, the increase in gluten quality (by GDM) – only in the variants with C-F-RC rotation and plowing. The application of the increased rate of mineral fertilizers significantly raised the content of gluten and its quality in all the studied variants.

1 Introduction

Along with the measures for the gross increase in grain production in resource-saving agricultural technologies special attention should be paid to improving grain quality indicators, which are the totality of biological, physical, chemical, technological and consumer properties and features that determine the suitability of grain for the use for a specific purpose [1].

However, quite often with increasing yields there is a decrease in the quality of grain. This indicates that the applied agricultural technologies do not realize the potential of the varieties used and do not provide balanced nutrition of cultivated crops, especially with nitrogen. Scientifically-based selection of predecessors, the use of a control system to provide plants with nutrients during the growing season and other agronomical measures can radically change the developed situation and significantly increase the production of high quality grain in modern resource-saving agricultural technologies [2].

At present, the concept of "grain quality" can include more than 20 indicators depending on grain purpose and, in fact, the grain crop itself. In relation to winter wheat, main quality baking indicators, according to the interstate standard GOST 9353-2016 [3], are: gluten...
content and its quality, as well as natural weight of the grain, while for barley grain, according to GOST 28672-90 [4], they are protein content and natural weight of the grain only [5].

At the same time, the quality of grain is influenced by various factors: climatic, soil, biological and agronomical [6].

Yield and quality of cultivated crops are the resulting indicators of the efficiency of an applied agricultural technology. If we talk about resource saving in agricultural technologies, the most effective and resource-saving technology will be the one allowing to obtain a high level of yield and grain quality at the lowest cost. Along with the biological feature of the varieties used, the yield of crops depends and varies on a number of other factors (soil and climatic conditions, light regime, nutrient and water regime, field management used), by which the variation in yield over the years during the research period is conditioned.

Therefore, the purpose of the study was to determine the conditions for obtaining high quality grain in resource-saving highly productive technologies of the cultivation of winter wheat and spring barley on typical chernozem soils of Central Chernozem Region (CCR) in order to ensure quantitative and qualitative rise in the indicators of grown products, improve the efficiency and productivity of agriculture, contributing to the economic growth and food security of the country.

2 The Materials and methods

The study was conducted on the basis of the experimental field of Kursk Federal Agricultural Research Center, located in the south-eastern agro-soil area of Kursk Region, geographically belonging to the northern part of Medvensky district of Kursk region. The object of the research was resource-saving agricultural practices in adaptive technologies of winter wheat and spring barley cultivation of different intensity levels on typical chernozem soils of CCR. The subject of the research is yield and quality indicators of grown products.

For a comprehensive study of the impact of resource-saving agricultural practices on the yield and quality of grain in the cultivation technologies of winter wheat and spring barley an extensive list of available variants (276 plots in Block 1 and 8 plots in Block 2 of the experiment on the development of effective resource-saving highly productive agricultural technologies) was considered, from which 16 variants for grain-fallow-row crop (G-F-RC) rotations and cereal-grass-row crop (C-G-RC) rotations with systems of moldboard, boardless and combined primary tillage, differing from each other by applied rates of fertilizers: low - N32P39K39 for winter wheat and N26P38K38 for spring barley, as well as increased rates - N64P78K78 for winter wheat and N52P76K76 for spring barley.

The G-F-RC crop rotation of Block 1 was an alternation of clean fallow, winter wheat, maize for green fodder and spring barley. In Block 2, in the basic type technologies clean fallow was used, in intensive technologies green manure fallow was used after which in both variants winter wheat was sown, and then sugar beet was cultivated followed by buckwheat and then by spring barley. Cereal-grass-row crop (C-G-RC) rotation was an alternation of winter wheat, maize for green fodder, spring barley and perennial grasses. When moldboard primary tillage was used medium moldboard tillage was performed for barley and clean fallow, with the exception of the intensive technology variants of experimental Block 2, where medium moldboard tillage was carried out for winter wheat and surface tillage for barley. The system of combined primary tillage consisted in carrying out shallow boardless tillage for barley and clean fallow except for the intensive technology variants of Block 2, where surface tillage was performed for winter wheat, and no-till for barley. In the system of boardless primary tillage shallow boardless tillage was carried out
for barley and clean fallow. Field management was standard, the size of the record plot was 100m². The tier is twofold. The experiment used zoned varieties of winter wheat Synthetic, of spring barley Suzdalets.

3 Results and Discussion

As a result of the analysis of the data obtained, it was found that the most significant yield gains were obtained due to the application of single (basic) and double (increased) rates of mineral fertilizers in winter wheat single (basic) rates increased the yield to 21% and double rates (compared with the variants of unapplied fertilizers) up to 45%, in spring barley they were more significant: up to 36% and 58%, respectively.

For spring barley in the analysis of the influence of the factors "crop rotation" and "tillel system" it is found that the differences in the yield were insignificant and, accordingly:

1) due to the fact that the studied crop rotations differed only by the predecessors of the first crop – winter wheat, in the link of the multifactorial field experiment "winter wheat – maize for silage – barley" the effect of the use of clean fallow or annual grasses was not observed;

2) despite the multidirectional impact of the used tillage types on the structure of the spring barley yield indicators, its yield when moldboard, shallow board less tillage and even no-till was almost equal as a whole, but in numerical terms, this indicator for moldboard tillage systems exceeded the rest of the systems to 11%.

Taking into account the fact that the absolute values of the yield were higher by 4-9% on the average for the variants with C-F-RC crop rotation, it is more expedient in such crop rotations to use a system of combined tillage in when application of mineral fertilizers is planned and a moldboard system in case of refusal to apply fertilizers, whereas in C-G-RC crop rotations the use of combined tillage systems is preferable in any of the enumerated cases and does not lead to a significant decrease in the yield.

The study of the influence of crop rotations (previous crops), primary tillage systems and fertilizers in relation to the main indicators of the grain quality of winter wheat and spring barley allowed to obtain the following data (Table 1, Table 2):

Table 1 – Values of the main quality indicators of winter wheat grain depending on the used crop rotations, primary tillage systems and fertilizers (on the average, for years 2008-2016).

| Variant | Indicators of winter wheat grain quality | Gluten content, % | Gluten quality (GDM (gluten deformation meter)) | Natural weight, g/l | Tentative grain quality, by GOST 9353-2016[3] |
|---------|-----------------------------------------|-------------------|-----------------------------------------------|------------------|-----------------------------------------------|
| Extensive technology (no fertilizer applied) | | | | | |
| Block 1, C-F-RC*, plowing**, control | | 26,3 | 81 | 734 | 3rd |
| Block 1, C-F-RC*, combined tillage** | | 25,3 | 81 | 729 | 3rd |
| Block11, C-G-RC*, plowing | | 23,8 | 82 | 716 | 4th |
| Block 1, C-G-RC*, combined tillage** | | 22,9 | 81 | 711 | 4th |
Basic technology with a single (basic) rate of mineral fertilizers – \( N_{15}P_{39}K_{39} \) for primary tillage and \( N_{17} \) with crop dressing in spring tillering

| Variant | Indicators of spring barley grain quality | Protein content, % | Natural weight, g/l | Tentative grain quality class, by GOST 28672-90[4] |
|---------|-----------------------------------------|---------------------|---------------------|--------------------------------------------------|
| Block 1, C-F-RC*, plowing** | | | | |
| Block 2, C-F-RC*, plowing** | | | | |
| Block 2, C-F-RC*, boardless tillage** | | | | |
| Block 1, C-F-RC*, combined tillage** | | | | |
| Block 1, C-G-RC*, plowing** | | | | |
| Block 1, C-G-RC*, combined tillage** | | | | |

Intensive technology with a double (increased) rate of mineral fertilizers – \( N_{30}P_{78}K_{78} \) for primary tillage and \( N_{17} \) with crop dressing in spring tillering and in the phase of blossom

| Variant | Indicators of spring barley grain quality | Protein content, % | Natural weight, g/l | Tentative grain quality class, by GOST 28672-90[4] |
|---------|-----------------------------------------|---------------------|---------------------|--------------------------------------------------|
| Block 1, C-F-RC*, plowing** | | | | |
| Block 2, C-F-RC*, plowing** | | | | |
| Block 1, C-F-RC*, combined tillage** | | | | |
| Block 1, C-G-RC*, plowing** | | | | |
| Block 1, C-G-RC*, combined tillage** | | | | |

*C-F-RC – cereal-fallow-row crop rotation (in Block 1 – with clean fallow, in Block 2 – with green manure fallow);
C-G-RC – cereal-grass-row crop rotation;
**plowing – the system of moldboard primary tillage;
combined tillage – the system of combined primary tillage;
boardless tillage – the system of boardless primary tillage.

Table 2 – Values of the main quality indicators of barley grain depending on the used crop rotations, main tillage systems and fertilizers (on the average, for years 2010-2018).
| Block | **3TІ** | Efficiency  (sec) | Note |
|-------|---------|-------------------|------|
| 1     | C-G-RC*, combined tillage** | 13.4 | 601 | Second (for fodder) |
|       | C-F-RC*, plowing** | 13.6 | 602 | Second (for fodder) |

**Basic technology with a single (basic) rate of mineral fertilizers – \( N28P38K38 \)**

| Block | **C-F-RC** | Efficiency  (sec) | Note |
|-------|-----------|-------------------|------|
| 1     | C-G-RC* | 13.8 | 624 | Second (for fodder) |
|       | C-F-RC* | 13.4 | 648 | First (for food) |
| 2     | C-F-RC* | 13.2 | 653 | First (for food) |

**Intensive technology with a double (increased) rate of mineral fertilizers – \( N52P76K76 \)**

| Block | **C-F-RC** | Efficiency  (sec) | Note |
|-------|-----------|-------------------|------|
| 1     | C-G-RC* | 14.0 | 611 | Second (for fodder) |
|       | C-F-RC* | 14.0 | 610 | Second (for fodder) |

\*C-F-RC – cereal-fallow-row crop rotation (in Block 1 – with clean fallow, in Block 2 – with green manure fallow);

C-G-RC – cereal-grass-row crop rotation;

**plowing** – the system of moldboard primary tillage;

**Combined tillage** – the system of combined primary tillage;

**Board less tillage** – the system of board less primary tillage.

### 4 Conclusions

The analysis of the presented data allowed to draw the following conclusions:

- In general, the use of the studied agricultural practices did not lead to an increase in the grain quality class. As an exception one should consider only variants of intensive agricultural technologies of barley cultivation with C-F-RC rotation in Block 1, in which the application
of double (increased) rates of fertilizers providing nitrogen dressings, on the average over the years of the research (2010-2018) contributed to the increase in natural grain weight (up to 630 g/l and more) and, consequently, in the class of grain quality. The analysis of winter wheat grain showed that on the average for the years of the research (2008-2016), due to the relatively high values of GDM (gluten deformation meter) (80-85), which in most cases were limiting, according to GOST 9353-2016 [3], the harvested grain belonged to the 3rd class of quality. The variants of the extensive agricultural technology with C-G-RC rotation, in which there were low indicators of natural grain weight (on the average, less than 720 g/l) and those of gluten content (less than 24%) in grain were exceptions.

Crop rotations, basic tillage systems and fertilizers significantly influenced the considered indicators of the grain quality of the cultivated crops, and the nature of their influence was diverse, i.e. some factors had a positive impact, others a negative one. For example, the application of single (basic) fertilizer rates in the cultivation of winter wheat significantly contributed to the increase in gluten content in the grain only in the variant with C-F-RC rotation and the system of combined primary tillage, that of gluten quality (according to the GDM) only in the variant with C-F-RC rotation and the system of moldboard primary tillage, while the application of double (increased) rates of mineral fertilizers, providing nitrogen fertilization, significantly increased the content of gluten and its quality in most of the studied variants. In the course of the research it was also found that the application of single (basic) and double (increased) rates of mineral fertilizers significantly increased the natural grain weight of winter wheat on the average by 2-5%. In turn, the lowest values of protein and its quality, as well as the natural grain weight of the studied crops were observed in the variants of extensive agricultural technologies, especially when using the systems of combined primary tillage. The greatest values of the studied parameters were observed in the variants with the use of agricultural technologies of an intensive type mainly in the variants with the use of a moldboard tillage system.

Thus, according to the results of the studies, it was found that the use of the studied agricultural practices in most cases did not lead to an increase in the grain quality class, but increased individual quality indicators, as well as the yield values of the cultivated crops. The main factor affecting the increase in the yield and all the main grain quality indicators was an applied fertilizer system, the intensification of which helped to increase not only the yield, but also the protein content and its quality in the grain, as well as its natural weight. In contrast to the fertilization system, the other studied factors had an ambiguous effect on the indicators of grain yield and quality: against the background of the use of C-F-RC rotations, as well as against the background of the use of moldboard or combined systems of primary tillage, there was a significant increase in these indicators.

Therefore, proceeding from the presented considerations, in order to obtain high yields of high-quality grain, first of all it is necessary to use agricultural technologies of an intensive type with cereal-fallow-row crop rotations and the system of moldboard primary tillage. However, the introduction of clean fallows, as well as the use of a moldboard primary tillage system are quite costly measures in terms of resources, so when studying the efficiency of the used resource-saving agricultural practices, it is necessary to take into account the impact of such agricultural practices on soil fertility, yield structure and grain quality indicators, and commensurate it with the economic and energy expenditures necessary for their implementation. Our studies have been confirmed by other scientists [7-18].
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