Managed Grain Production as an Element of Rational Environmental Management for Grain Production with a Minimum Level of Hidden Damage

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Abstract. The aim of the work is to evaluate the possibilities of X-ray quality control of seed and grain batches to identify hidden ecogenic and technogenic damage, to assess their impact on the economic suitability of grain and the possibility of its selection for precision studies of individual samples and mass analysis of grain batches. X-ray signs of hidden damage to the grain of a biogenic and technogenic nature were revealed, which significantly affect the economic suitability of grain batches (fracturing, internal germination, enzyme-mycotic depletion,damage and infestation of the grain with insects, non-fulfillment of the grain. It is shown that in production conditions there are grain defects that are absent in field small-scale experiments. The results obtained are the basis for improving agricultural technologies in order to produce economically valuable grain with a minimum level of hidden damage, as well as to ensure the competitiveness of domestic grain production in the world grain market.

Keywords: Microfocus radiography, hidden damage to the grain structure, operational quality control of grain and seeds, economic suitability of grain batches.

1 Introduction

In the process of grain production for various purposes, both in Russia and abroad, various agricultural technologies are used for growing, harvesting, drying and post-harvest part-time grain. The impact on the resulting grain during the implementation of these technologies leads, to varying degrees, to hidden damage to the grain, which negatively affects its sowing and technological characteristics. The task of managed grain production, as an element of rational nature management, is to identify various types of hidden defects, assess the level of hidden damage to grain batches, the degree of its influence on the economic suitability of grain and the possibility of adjusting its production modes to minimize the level of hidden injury to economic grain batches. This approach allows you to monitor the quality of grain immediately after harvesting, select the best batches of grain for seed, food or feed purposes, while optimizing the cost of agricultural resources necessary to obtain an optimal crop (seeds, mordants, fertilizers, etc.)

This approach, developed by Russian scientists since the 80s of the last century, continues to be a priority in the world seed science and seed production [1]. It should be noted that seeds with hidden defects cannot be separated on existing sorting machines. Their share, when using various types of seed agricultural technologies, reaches 80% and more, so they are a constant component reflecting the internal damage to seeds of all production batches of grain. In this connection, the development of methods for X-ray assessment of economically significant hidden damage to the weevil will allow for an effective selection of the most conditioned (with a minimum level of hidden injury) grain batches, as well as develop effective methods for X-ray separation [1].

It should be emphasized that systemic studies carried out by seed growers on agronomic seeds and studying the indicators of the integrity of the internal structures of the weevil and significantly affecting the biological usefulness and economic suitability of grain batches in available foreign sources are still lacking.

2 Materials and research methods

The object of the study was the seeds of barley and wheat obtained under conditions of small-scale and industrial crops in various soil and climatic zones of the country. The grain was X-rayed using the PRDU-2 X-ray machine [1]. Seed germination was determined according to GOST 12038-84. Statistical processing of the results was carried out according to B. A. Dospekhov [2].

3 Research results

Solving the problem of ensuring grain production with a minimum level of hidden trauma required identifying the degree of integrity of the internal structures of the weevil and the reasons causing the occurrence of natural and man-made defects. It was shown that these defects arise when the following factors are applied to the grain [3-7]:

- abiotic, associated with unfavorable soil and climatic conditions, leading to a decrease in the technological qualities of grain, as well as causing violations of the structural integrity of the grain, affecting its economic suitability;
- biotic, caused by violations of the structural integrity and economic suitability of the grain, such as damage by the bug-harmful turtle and other sucking pests, enzymomycosis depletion and damage to the embryo of biogenic origin;
- anthropogenic (technogenic), caused by the violation of technological modes of cultivation, post-harvest processing and storage of grain, such as fracturing, mechanical and thermal injuries of the embryo, hidden germination in the heap, etc.

Among the detected hidden defects detected by "soft-beam" microfocus radiography with direct (projection) X-ray image magnification, the most significant signs that significantly affect the economic suitability of grain were identified, namely:

- severe fracturing of the endosperm associated with thermomechanical injury of the grain during harvesting or drying. This sign can be an indirect indicator of increased protein content of the grain;
- internal germination of grain, especially its early stages. This sign reflects, to a certain extent, the partial depletion of the embryo and endosperm, and X-ray analysis is optimal in this case;
- enzyme mycosis depletion reflects the hydrolytic effect of fungal enzymes and the seed's own enzymes on its surface layers;
- damage to the grain by the bug-harmful turtle reflects the hydrolytic effect of its enzymes on the inner and surface layers of the grain;
- damage to the grain by sucking pests of the stock reflects the loss of the endosperm substance, changes in its quality and is characterized by the additional presence of toxins - products of the vital activity of insects;
- the defect of the embryo is manifested in various degrees of shading of its X-ray images, which is a reflection of the damage to the embryo by fungi and its accelerated aging, due, in particular, to suboptimal modes of drying the grain mass;
- mechanical injuries of the embryo are a reflection of the impact of the working bodies of harvesting machines on the embryo of the grain (the embryo is knocked out, its mechanical crushing, etc.);
- the failure of the grain reflects the violation of grain growing technologies, as well as long-term storage modes.

It is important to note that the results obtained during the X-ray analysis of the grain batch for the quantitative characteristics of hidden defects will significantly complement the traditional methods. Such an analysis is necessary for a more accurate assessment of the sowing and technological characteristics of grain batches, which have not yet been systematically studied in industrial grain production. This approach makes it possible to determine whether the grain belongs to different classes in terms of quality, taking into account the proportion of hidden defects, and to make optimal decisions on mixing batches of the same class or not significantly reducing the class of newly formed batches, on the storage modes of batches of different classes and on the priority of using certain batches of grain in the event of an emergency replacement [8].

The most economically significant defects of the grain are shown in Figures 1-4.

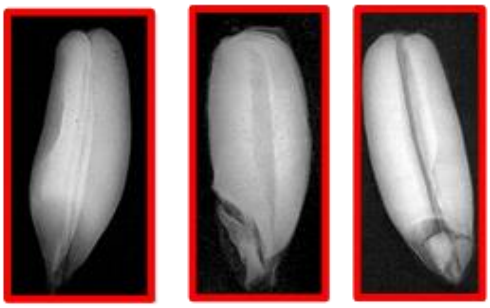

Figure 1. X-ray images of grain and seeds with missing or damaged embryo

Figure 2. X-ray images of seeds with the indicator of latent germination

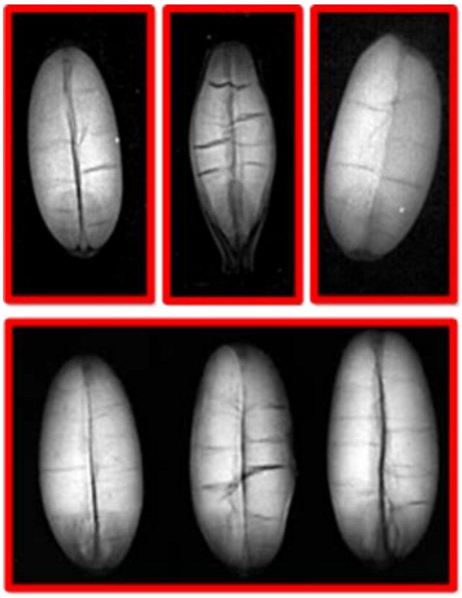

Figure 3 X-ray images of grain with endosperm fracturing

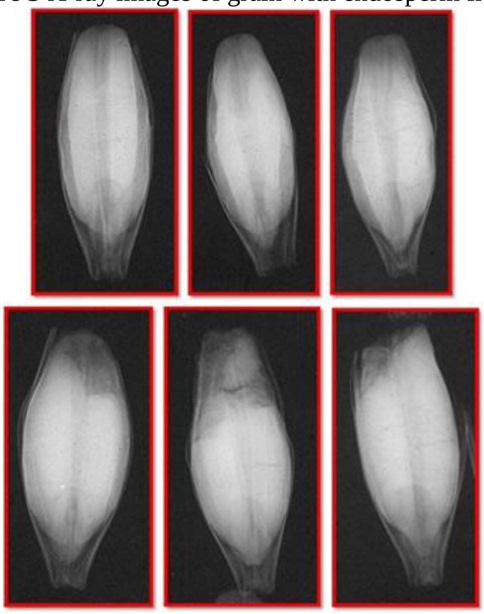

Figure 4 X-ray images of grain and seeds with enzymomycosis depletion

Figure 5 X-ray image of grain and seeds damaged by a bug - harmful turtle

Figure 6 X-ray image of grain and seeds damaged by insect pests of the stock

As a result of many years of experiments, it was found that the revealed hidden defects depend on the modes of obtaining grain in the conditions of small-scale or industrial experiments. [9-14].

An analysis of the results presented in Table 1 for seeds formed in the Leningrad region under conditions of fine-grained precision experiment shows that two types of hidden defects are revealed in the structure of the grain-the initial stage of internal germination and enzyme mycosis depletion. A high proportion of latent germination (up to 66%) and enzyme mycosis depletion (up to 17%) in seed batches.

Table 1. Radiographic analysis of barley seed samples obtained from the small-scale farming experiment, %

Sample number	Hidden germination	Enzyme mycosis depletion
Sample 1	31±3	17±3
Sample 2	43±4	8±2
Sample 3	66±3	3±1

It is important to note that in the barley samples obtained under the conditions of the small-scale experiment, the X-ray index of fracturing, in contrast to the seeds obtained under production conditions (Table 2), is absent.

Table 2. Radiographic analysis of barley seed samples obtained from the small-scale farming experiment, %

Sample number	Fracturing	Damage to the embryo	Enzyme mycosis depletion
Sample 1	79±3	27±3	14±2
Sample 2	51±4	23±3	30±3
Sample 3	50±4	10±2	24±3

Indeed, in the conditions of production experience, three types of defects are detected: fracturing (up to 79%), enzyme mycosis depletion (up to 33%) and damage to the embryo (up to 27%). The analysis of the results presented in Table 2 showed that during the post-harvest part-time work of the seed pile, the most traumatic is the drying mode, which is manifested in the occurrence of such a defect as hidden fracturing in grain batches. As it was established, the weak link in the process of post-harvest processing of seeds is precisely the thermal drying mode [5]. It should be noted that the conducted experiments on growing seeds of different degrees of fracturing have shown that this feature can have a significant impact on the germination of production batches of seeds and their economic suitability. In this connection, there is a need to normalize the latent fracture index to solve the question of the practical use of seed batches in determining the optimal seeding rate and predicting potential field germination. It is important that the practical use of the method of radiography is quite real and appropriate, since this method is included in the domestic and foreign grain quality standards. Currently, this standard is being improved and presented in digital format [1].

Of particular interest are the results on the use of the X-ray method to assess the latent damage of the grain when growing in different soil and climatic zones, as well as to assess its impact on the germination rate (see Table 3 and Table 4).

Table 3. X-ray analysis of the content of wheat grain fractions with different types of hidden defects obtained in different soil and climatic zones of the country

Origin of grain shipments	Underperformance of the grain, %	Granule fracture, %
Saratov region Sample 1	2	3
Saratov region Sample 2	22	3
Saratov region Sample 3	24	4
Omsk Region Sample 1	2	25
Omsk Region Sample 2	12	1
Rostov region Sample 1	5	18

The results obtained indicate that the batches of wheat grain intended for long-term storage have a low level of fracturing (up to 25%) and under-filling (up to 24%) of the grain. Such grain turned out to be the most suitable for responsible storage in the Rosrezerv system.

Special experiments to assess the relationship between the total indicator of hidden defects in batches of malting barley seeds and their germination are presented in Table 4.

Table 4. Results of X-ray analysis of seeds of different batches of barley and their germination rate

Sample batch of barley	Content of seeds with identified types of internal defects, %			Seed germination rate, %
	fracturing	enzyme mycosis depletion	Hidden germination	
Sample 1	41	21	8	90
Sample 2	19	8	2	97
Sample 3	68	46	6	85

These results indicate that sample 2, which has a lower total level of hidden defects (29%), also has a higher germination rate (97%) compared to other samples, in which the total level of hidden defects was higher than 70%.

4 Conclusion

The materials presented in the article give reason to believe that the improvement of methods for detailed analysis of the structural features of grain and seeds, primarily latent defects and anomalies, is a scientific and methodological base that allows you to develop a new type of technology with a minimum level of latent damage to grain and thus obtain a unique product - economically suitable high-quality lots of seeds and grain, which has no analogues in the world. The resulting grain will have the best sowing and technological characteristics and will be quite competitive in the world grain market. This approach is based on:

- conducting a comprehensive monitoring of the assessment of quality and safety indicators of grain and seeds, including freshly harvested ones, which cannot be carried out on the basis of traditional methods;
- making optimal decisions on the movement of grain and seed lots during their harvesting, part-time work, acceptance and placement for safe storage;
- improvement of standards for quality control of grain for various purposes and development of new regulatory indicators for the permissible degree of its hidden damage;
- creation of federal insurance reserves of seed grain on a new methodological basis, as an addition to the existing system of funds for strategic and interventional grain reserves;
- creation of new algorithms for agricultural insurance of grain stocks for different purposes, taking into account the minimization of sanitary risks.

To implement these tasks, it is necessary to create a domestic control network and carry out digital certification of grain and seeds within the framework of the targeted program "Grain Informationalysis" developed jointly with the Russian Agricultural Center. To do this, it is necessary to ensure a decrease in the level of dependence of the domestic market on foreign genetic and breeding material and stimulate scientific research in the agro-industrial complex to develop progressive invasive technologies for controlling the economic suitability of grain.

The introscopic approach in scientific developments to ensure seed control and improve on its basis the physical, technical and information basis of non-destructive assessment of the quality of seed material will be the basis of a new direction in precision farming, namely controlled seed production. This will allow in the near future to develop unique seed (sparing) agricultural technologies within the framework of "smart" agriculture.

As a result, this will enable domestic seed and grain producers to reduce technological risks associated with latent injury and ensure high competitiveness of Russian grain in the world grain and seed markets.

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