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To cite this article: F Musaev *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **395** 012083

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Economic justification for applying instrumental methods of seed quality control

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Abstract. The basis of food independence of any country is a reliable seed system, and seed control is a concern of the state in many developed countries. The standard methods used for analyzing the quality of seeds do not meet today's requirements for seed production, they are laborious, time-consuming, and also uninformative. The contemporary level of scientific knowledge requires the use of new instrumental methods that are highly informative. We have developed an instrumental X-ray method for assessing the quality of vegetable seeds. It is highly informative, quick and easy to perform, and preserves the material being analyzed. The article compares and economically analyzes the widely used standard morphometric method and the implemented instrumental method of X-ray analysis of seeds. It turned out that the use of instrumental methods for seed quality analysis is economically and energetically justified. The method of X-ray analysis of seeds favorably differs in energy efficiency and the period of performance from the standard method. Introduced instrumental method for visual analysis of radiographs is slightly inferior to the standard in labor costs, but the process is significantly accelerated with automatic analysis. The method is automated, which allows to avoid errors in assessing the quality of seeds associated with the operator's subjectivity. The article calculates the benefit from introducing the X-ray method in the seed control case. It is shown that over a ten-year lifetime of the X-ray diagnostic unit, all the costs of organizing the laboratory pay off even with a relatively small workload and begin to make a profit.

1. Introduction

A reliable seed system is the basis of any country's food independence. In most developed countries, including the Russian Federation, seed control is the responsibility of the state. Unfavorable soil and climatic conditions in most regions of our country do not contribute to the widespread industrial seed production of heat-acceptable crops. The main problem of the industry is the quality of the produced seeds, which do not meet the requirements of contemporary agriculture. Therefore, a constant search for favorable backgrounds for seed production is necessary [1].

Seed production of vegetable crops has a special specificity associated with the huge species diversity, the increased heat demand of most crops, the biennial and long-term development cycle of a number of species. The quality requirements of vegetable seeds, due to their high productivity, is also increased.



The traditional, standard methods of analyzing the quality of seeds do not meet today's requirements for seed production, because they are laborious, time-consuming, and also uninformative. The modern level of development of agricultural technologies, as well as the expansion of scientific knowledge requires the use of new instrumental methods in seed control, characterized by high information content and speed of execution [2].

The seed quality analysis is a rather laborious process and requires highly skilled operator. It is necessary to minimize the share of manual labor in this process through the use of instrumental methods. It will also increase the objectivity of the assessment being conducted.

There are many instrumental methods for influencing seeds to improve their sowing qualities [3], [4], [5], [6], [7], [8], [9], [10]. However, only a few are engaged in studying the internal structure of seeds in connection with their economic and biological significance [11], [12], [13], [14].

In the long-term (2016-2018), a joint work of employees of the Federal Scientific Center for Vegetable Growing, the Agrophysical Research Institute, St. Petersburg State Electrotechnical University and the Scientific Research Institute of Storage Problems of the Federal Agency of State Reserves was carried out with the purpose of developing a new instrumental biophysical method for analyzing the quality of vegetable seeds.

2. Materials and Method

The object of research was various methods of analyzing the quality of seeds, namely standard (morphometric) and instrumental (biophysical). The material for research was the different-quality seeds of various 25 types of vegetable crops.

Morphometric analysis of seed quality was carried out by the standard method GOST 12038-84 (Interstate Standard-Methods for Determining the Germination of Agricultural Crops Seeds) [15].

An instrumental analysis on the quality of seeds was carried out by a new biophysical X-ray method of vegetable seeds [16].

We have conducted a comparative economic analysis of various methods for assessing the quality of seeds.

The standard laboratory method for determining seed germination GOST 12038-84 adopted as the traditional method of analyzing the quality of seeds.

The method of X-ray analysis of seeds was considered in the following two versions: (1) visual analysis of radiographs; (2) automatic analysis of radiographs. The following works were taken into account as an example: (1) for a standard technique, we used a certified seed testing laboratory of the Federal Scientific Center for Vegetable Growing; (2) for the X-ray method, works conducted in the laboratory of X-ray analysis of seeds of the Department of Electronic Devices of the Saint Petersburg Electrotechnical University "LETI."

3. Results and Discussion

The X-ray analysis of vegetable seeds is still carried out for research purposes, and the cost of work can only be calculated. The entire analysis process consists of the following three stages: (1) sample preparation; (2) setting, shooting, recognizing images; and (3) visual analysis of radiographs on a computer monitor.

Table 1. The cost of analyzing seeds of vegetables and melons in the Testing Laboratory of the Federal Scientific Center for Vegetable Growing, March 2018.

Type of work	Standard	Cost, rub.
Complete analysis	-	1841
Clean and waste seed	GOST 12037-84	779
Germination	GOST 12038-84	814
Viability	GOST 12038-84	336
Humidity	GOST 12041-82	142
Weight of 1000 seeds	GOST 12042-80	106
Pest population	GOST 12045-97	142

The process of sample preparation is the most time-consuming technique in the whole process of seed analysis. At the same time it does not require special qualifications of the worker and can be performed by a laboratory assistant, trainee, etc. It is a method of regularly applying seeds on a thin sticky tape. Depending on the type, size of seeds, the preparation of one sample (100 seeds x 4 times) takes 20 minutes.

A radiographic survey of seeds is carried out by an electrical engineer. Shooting one sample (4 or 8 pictures) takes 10-20 minutes, and an image recognition on the scanner is also included here. More time is spent on setting up a plant, which depends on the size of the seeds being analyzed. If seeds of one size group are removed, then the need for reconfiguration disappears, accelerating the process.

The X-ray analysis is the final stage and is carried out by a qualified x-ray operator. The visual analysis is carried out on a computer monitor, the results are plotted in a worksheet. An experienced specialist will need about 30 minutes to analyze one sample.

Total, the visual X-ray analysis of one seed sample, together with sample preparation and shooting, takes 60-70 minutes (Table 2).

With automatic analysis, a computer performs the work of a radiobiologist in a few seconds. Therefore, the time for sample preparation and filming is taken into account, which totals 30-40 minutes.

In the X-ray analysis of seeds, labor costs and analysis duration almost coincide (Table 2). With the standard method of analysis, regardless the amount of labor, the analysis duration is associated with the type of seed and can be 7-14 days, even up to 21 days for individual species (GOST 12038-84).

So, the X-ray analysis differs from the standard method of less energy and speed of execution. The method for visual analysis of radiographs is inferior to the standard in labor costs, but with an automatic analysis, the process is significantly accelerated.

Table 2. Economic and energy comparison of standard and instrumental methods.

Methods	Labor costs, man / hour	Energy consumption, kW / h	Duration of analysis
<i>Standard method</i>			
GOST 12038-84	0.8 – 1.0	4 – 7	7-14 days
<i>Instrumental (radiographic) method</i>			
Visual radiography	1.0 – 1.2	0,5	1 - 1.2 hours
Automatic radiography	0.5 – 0.7	0,3	Less than 1 hour

We considered the economic effect of the use of the X-ray method of the current version in the current laboratory, taking into account current costs. Now, we will calculate the benefits in organizing a new laboratory of seeds radiography, taking into account the payback of equipment. The cost of analyzing a seed sample on a radiograph is calculated using the following formula:

$$C = (P_{eq}/XT) + P_{em} + S$$

where C is the cost of analyzing a single sample; P_{eq} is the cost of equipment; X is the workload of the laboratory (a number of analyzes per year); T is the estimated service life of the equipment; P_{em} is the cost of consumable materials and electricity; S is the remuneration of employees, taking into account the complexity and complexity of work.

Now, we will enter our data into the formula: P_{eq} is 3.8 million rubles, (when purchasing several X-ray complexes; T is 10 years; P_{em} is 15 rub.; S – [0.5 man / hour technician (rate 15000 rub / month) = 90 rub.] + [0.25 man / hour engineer (rate 30,000 rub / month) = 90 rub.] = 180 rub.; X – it depends on the number of seeds received for analysis and the frequency of their quality control, ranges from 50 (in low-loaded research laboratories) to 2000 (in laboratories that carry out commercial orders) analyzes per year.

We give an example of calculating the cost of X-ray analysis of a single seed sample, when the laboratory is loaded at 50 analyzes per year:

$$C = [3\,800\,000 / (50 \times 10)] + 15 + 180 = 7795 \text{ rubles.}$$

The cost of determining the seed germination of a seed according to the standard method GOST 12038-84 is 814 rubles (Table 1). Obviously, with a low frequency of analysis, the laboratory of X-ray analysis of seeds cannot benefit. It is necessary to increase the number of tests for the payback of expensive equipment. Analysis of the data in Table 3 shows that with an increase in the “load” of the laboratory (100 ... 200 ... 300 ... 500 tests / year), the cost of each analysis decreases, and already when conducting 700 tests a year for 10 years, the cost of each analysis is 738 rubles. This is slightly lower than the cost of determining seed germination by the standard method. Therefore, in order to pay off laboratory equipment with a 10-year service life, it is necessary to carry out at least 700 X-ray analyzes of seeds per year or 2-3 analyzes per day, which is technically easy to do. When the laboratory has 1500-2000 tasks in a year, we can not only pay back the equipment, but also achieve tremendous savings and work with profits (Fig. 1).

Table 3. Comparative economic analysis of instrumental and standard techniques, RUB.

Number of tests per year	Expenses (for 10 years)		Costs, X-ray analysis of one sample	Annual savings
	Radiography $P_{eq} + [XTx (P_{em} + S)]$	GOST 12038-84 $XT \times 814$		
50	3 897 500	407 000	7795	- 3 490 500
100	3 995 000	814 000	3995	- 3 181 000
200	4 190 000	1 628 000	2095	- 2 562 000
300	3 858 000	2 442 000	1286	- 1 416 000
500	4 775 000	4 070 000	955	- 705 000
700	5 165 000	5 698 000	738	533 000
1000	5750 000	8 140 000	575	2 390 000
1500	6 725 000	12 210 000	448	5 485 000
2000	7 700 000	16 280 000	385	8 580 000

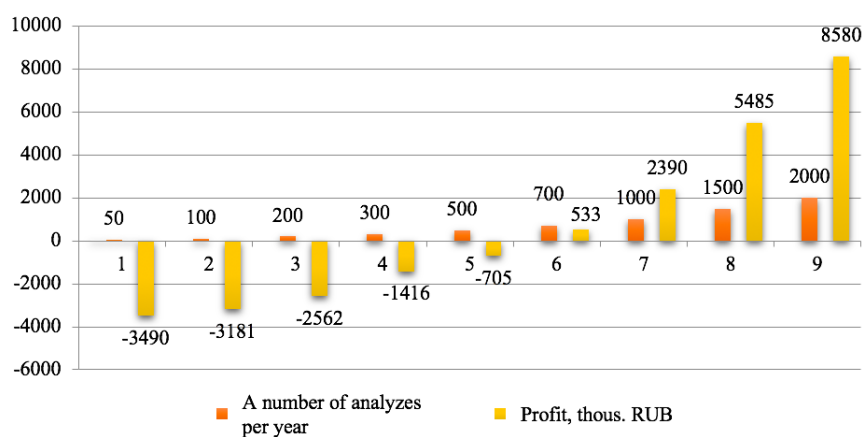


Fig. 1. Economic benefits from using instrumental methods for analyzing the quality of seeds.

Despite the higher cost of X-ray diagnostic equipment, the costs pay off with its rational use, and for a 10-year service life of the plant, the method makes a huge profit.

4. Conclusion

Obviously, the use of instrumental methods for analyzing seed quality is economically feasible both by reducing manual labor and speeding up the analysis process. When applying the instrumental analysis in the automatic mode, the reliability of such assessment is also increased due to the exclusion of the subjective factor associated with the qualification or operability of the operator.

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