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Methodological Aspects of Assessing the Competence of Laboratory Personnel Determining the Quality of Seed Potatoes

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Abstract. Most of the quality indicators regulated by the standard for seed potato certification are determined by the subjective component, that is, the competence of the personnel. However, the regulatory framework does not establish criteria for assessing competence, which poses uncontrolled risks in the laboratory. The purpose of the study is to develop and investigate the methodology for assessing the competence of laboratory personnel involved in the testing of seed potatoes and determine the extent of application of the methodology. The methods of probability theory and mathematical statistics are used for the tasks of selection and research of statistical criteria that correspond to the law of distribution of the obtained data and provide the necessary reliability for the available sample volumes. The statistics and the method of determining the threshold value, which mathematically describes the decision-making on competence, are provided for the binomial distribution law. The properties of the proposed statistical method for assessing the competence of personnel in terms of finding the maximum differences in the results of the analysis, at which the personnel are recognised as competent, are investigated. The study demonstrates the dependence of the method capacity on the data volume. It is determined that to obtain a confidence probability of 0.95 for quality indicators, the content of which in the average sample according to the technical conditions is minimal, the sample size should be 600-1000 tubers. At the same time, up to 100 tubers are sufficient for indicators whose content is under 5%. The method proposed by the authors showed that the average sample of 250 tubers recommended by the standard is entirely justified in terms of attracting resources during certification but must be adjusted during competence monitoring in a testing laboratory that confirms its competence by the requirements of DSTU ISO IEC 17025:2019. The findings presented can be used by the personnel in the seed testing laboratories as a measure to minimise the risks caused by the impact of personnel incompetence

Keywords: seed potato, certification, potato quality indicators, statistical criterion, reliability of decision-making, seed testing laboratory

Introduction

Industrial potato growing is a separate important branch of agriculture, as Ukraine is one of the four leading countries in the world in terms of gross potato production, in 2021, 20.8 thousand tons of potatoes were produced [1]. In 2020, the Cabinet of Ministers of Ukraine (CMU) adopted an order “On approval of the concept of the State target programme for the development of industrial potato growing for the

period up to 2025” [2]. The programme aims, among other things, to increase the production of high-added-value products and strengthen Ukraine’s presence on the world market of agricultural products and food. The production of seed potatoes belongs to the state-regulated sphere and is regulated by the resolution of the Cabinet of Ministers of Ukraine No. 97 of February 21, 2017 [3]. Each batch of potato

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seed material or part of it sold must be accompanied by a sowing certificate. The resolution defines the certification, issuance, and cancellation procedure of seed potato sowing certificates and certificate forms. During the certification process, the certification body authorised by the Ministry of Agrarian Policy and Food of Ukraine sends the samples selected by the authorised certification auditors (agronomist-inspector) to the testing laboratory (TL) accredited for compliance with the DSTU ISO IEC 17025:2019 Standard [4]. The certification body decides to certify/not certify the batch based on the results of tests of seed quality indicators. At the same time, the competence of TL personnel is crucial, and any inconsistencies in the work of personnel lead to erroneous decisions on batch certification. Thus, the assessment of the competence of TL personnel by accurate and reliable methods is an urgent task.

The requirements for the competence of TL personnel who evaluate seed potatoes at the request of the certification body are established in the national standard of Ukraine DSTU ISO IEC 17025:2019 [4]. In addition to the general requirements of overhead lines, it is necessary to have a procedure and keep records on the selection, training, supervision, authorization, and monitoring of personnel competence. This article will discuss methods for monitoring personnel competence using statistical criteria. There are no clear instructions on the choice of statistical criteria but the bibliography for the standard [4] contains standards of the DSTU GOST ISO 5725 series, accuracy (correctness and precision) of measurement methods, and results. Part 2. The main method of determining the repeatability and reproducibility of the standard measurement method [5]. Part 3. Intermediate indicators of precision of the standard method of measurement [6]. Part 4. Basic methods for determining the correctness of the standard measurement method [7]. Part 5. Alternative methods for determining the precision of the standard method of measurement [8]. Part 6. Using accuracy values in practice [9]. The standards do not provide methods for assessing and monitoring personnel competence for test results obtained for determining the quality indicators of seed potatoes.

The study [10] analysed the requirements for the competence of laboratory personnel and methods of evaluation, but the proposed methods do not consider the specifics of seed laboratories and do not contain decision-making criteria. The work [11] considers the competence of personnel as a component of service quality when comparing laboratories accredited following ISO/IEC 17025:2017 without providing methodological aspects of competence assessment. Articles [12; 13] compare best practices in accredited laboratories using critical factors, including personnel competence. However, they do not provide methods for assessing competence.

The study [14] identifies the needs and areas of personnel training to meet the requirements of accredited laboratories without practical methods for assessing their competence. In [15] the object of study is the assessment of total uncertainty during calibration in terms of assessing the component due to the competence of the personnel. However, the study does not examine the specifics of evaluating personnel competence for discrete distribution laws depending on the sample size.

The investigation [16] allows for measuring the readiness of the laboratory to meet the requirements of

ISO/IEC 17025: 2017. Descriptive statistics were used to create radar charts and empirical research methods, including personnel competence, but quantitative estimation methods were not considered.

The article reveals [17] the process of determining the compliance of quality characteristics of TL specialists, using the approach “People Development Tools”, which focuses on the human factor in the implementation and maintenance of quality systems [17; 18]. However, given the requirements of the Standard regarding the reliability of the results, the TL should document the data to identify trends and, if possible, apply statistical methods to analyse the findings. Common recommendations on the process of personnel competence management, such as the Eurolab Federation do not contain quantitative criteria for evaluating competence but give generalised recommendations [17; 19].

Thus, the assessment of personnel competence is an integral component in the confirmation of the TL competence. However, the assessment of personnel competence for seed labs was not investigated. The scientific novelty of the study consists in the development of a method for reliable determination of personnel competence based on statistical processing and establishing the limits of its application.

Given that the full description of the competence of overhead line personnel, which declares and confirms its competence, should contain both a qualitative and quantitative component, *the purpose of this study* is to develop and analyse a methodology for assessing the competence of overhead line personnel using statistical criteria and establish the boundaries of the application of the methodology following the tasks faced in practice.

Materials and Methods

The research was conducted on the basis of an accredited potato seed laboratories LLC AROSERT in 2019-2022. The object of research was samples of original, elite, and reproductive seed material of potato varieties included in the State Register of plant varieties suitable for distribution in Ukraine [20]. Samples were taken from batches of seed potatoes for certification purposes. Testing of samples was carried out by the personnel of overhead lines accredited according to the methods for determining seed qualities set out in DSTU 4014-2001 [21]. Quality indicators certifying the sowing qualities of seed potatoes are selected following the content of the certificate [3, Appendix 2], in which, in addition to the indicators of sowing qualities indicating information about the origin of seeds, the results of evaluation according to the acts of crop assessment, acceptance of basic crops by the commission, analysis of tubers, quarantine inspection, site, and laboratory varietal control.

Requirements for the sowing qualities of potato seed material are taken from DSTU 4013-2001 [22]. The research methods used the mathematical apparatus of probability theory and mathematical statistics about solving problems of assessing the competence of personnel.

As is known from the general theory of measurements, the uncertainty of the measurement result generally contains three components: instrumental, due to the use of measuring equipment (ME), methodological, due to the method, and subjective, due to the competence of personnel. Determination of the sowing qualities of seed potatoes is conducted by methods that can be divided into

two groups depending on their contribution to the total uncertainty of the test result: the first – method using ME, and the second – method based on the competence of personnel. Methods that involve the use of ME provide for the organisation and improvement of metrological support and will not be considered in this paper. Methods of the second group will be subjected to detailed analysis, which determines the following indicators of seed sowing qualities (as a percentage) [2, Appendix 2]: 1) the presence of tubers of other varieties; 2) the presence of tubers affected by diseases: 2.1) wet rot, 2.2) late blight, 2.3) black leg, 2.4) dry rot (fomosis, *Fusarium*), 2.5) rhizoctoniosis, 2.6) common and silver scab, 2.7) powdery scab; 3) the presence of damaged tubers, of which: 3.1) affected stem nematode, 3.2) damaged by wireworm, 3.3) damaged by rodents, may beetle, scoops 3.4) with mechanical damage (more than 10 millimetres deep); 4) the presence of tubers damaged by chemicals, with signs of burns, freezing, deformation, with root nodules, crushed, cut, peeled.

The determination of these indicators depends entirely on the competence of the personnel and can be used as a basis for monitoring competence. In addition, the use of these methods allows us to implement the requirements regarding the monitoring of reliability in terms of duplication of testing using the same methods as testing blind samples [4].

250 potato tubers ($N=250$) selected were analysed. The assessment is conducted in pairs with two specialists [21]. A tuber that belongs to the same sample is examined sequentially and independently of each other by each of the specialists.

Considering the method of representation (the number of detected facts out of the total number), the analysis results are presented in a discrete distribution. From a wide class of discrete distributions (binomial, Poisson, negative binomial, Pascal, geometric, hypergeometric), the binomial distribution law was chosen for the problem of monitoring the competence of seed potato test results.

In the language of mathematical statistics, the task of monitoring competence the following: the first specialist analyses a sample with a volume of $N1$ tests and identifies $m1$ defective cases, the second specialist analyses a sample with a volume of $N2$ tests and identifies $m2$ defective cases. Under the defective case, we mean a potato tuber in which lesions and inconsistencies are detected according to the selected list of quality indicators [22].

Samples $N1$ and $N2$ are distributed according to the binomial distribution law. We set the problem of statistical comparison of two perimeters of binomial distributions. We put forward zero hypothesis $H0$: the difference between the fate of defective cases is insignificant (the results of analysing potato tubers do not differ statistically, and the competence of the personnel is confirmed).

Alternative hypothesis $H1$: the difference between

the fate of defective cases is significant (the results of analysing potato tubers are statistically different; the competence of personnel is not confirmed).

You can solve the problem set in this way if you apply the appropriate statistics. With a normal approximation of the binomial distribution law the statistics for testing the $H0$ hypothesis have the form [23]:

$$z = \frac{\frac{m_1}{N_1} + \frac{1}{2N_1} - \frac{m_2}{N_2} - \frac{1}{2N_2}}{\sqrt{\frac{m_1+m_2}{N_1+N_2} \frac{1}{N_1+N_2} \left(\frac{1}{N_1} + \frac{1}{N_2} \right)}} \quad (1)$$

The resulting value of z-statistics is compared with the limit value of U. As the limit value, we choose the quantile of the Gaussian distribution law for the selected confidence probability α . For laboratory tests $\alpha = 0.95$, $U = 1.96$.

If we use the normal approximation using the arcsine transformation, formula (1) for clarification can be replaced with the following:

$$z = \sqrt{\frac{1}{N_1} + \frac{1}{N_2}} \left(2 \arcsin \frac{m_2}{N_1} - 2 \arcsin \frac{m_2}{N_2} \right) \quad (2)$$

However, in it is shown that the results of determining z according to (1) and (2) give the same result. Based on this, in the practice of TL, the value of z-statistics should be calculated using Formula (1).

For simplicity, given that the same sample is analysed during competence monitoring, we assume $N1=N2=N$. Formula (1) will take the form:

$$z = \frac{\frac{m_1-m_2}{N}}{\sqrt{\frac{(m_1+m_2)(2Nm_1-m_2)z}{4N^3}}} \quad (3)$$

The statistical method proposed by the authors for assessing the competence of personnel is tested in the practical activities of accredited overhead lines during the planned monitoring of the competence of personnel authorised to determine the sowing qualities of seed potatoes. According to the weaning method, the average sample for analysis contains 250 tubers ($N = 250$). [21]. To determine the competence of specialists to identify affected and unsuitable tubers, an average sample from a standard batch was selected to check their competence.

Results and Discussion

The results of the assessment of personnel competence using the selected z-statistics with the proposed simplification (3) are presented in Table 1. The results were obtained experimentally in an accredited TL. It should be noted slight differences between specialists in the number of detected tubers with signs of disease. The calculated values of z-statistics allowed to make a statistically sound conclusion about the sufficient competence of the first and second specialists when comparing their results with each other.

Table 1. Personnel competence analysis

Indicator of sowing qualities	Specialist 1 m1	Specialist 2 m2	z	Are specialists competent?
(1)	1	2	0.579	Yes
(2)	8	10	1,016	Yes
(2.1)	0	0	0	Yes
(2.2)	1	0	1,001	Yes

Table 1, Continued

Indicator of sowing qualities	Specialist 1 m1	Specialist 2 m2	z	Are specialists competent?
(2.3)	2	3	0.449	Yes
(2.4)	2	2	0	Yes
(2.5)	0	0	0	Yes
(2.6)	0	0	0	Yes
(2.7)	3	5	0.713	Yes
(3)	8	7	0	Yes
(3.1)	1	1	0	Yes
(3.2)	1	2	0.579	Yes
(3.3)	2	1	0.579	Yes
(3.4)	4	3	0.381	Yes
(4)	1	1	0	Yes

Based on the results of statistical processing, the specialists were recognised as competent. A special feature of this method is the possibility of mutual verification of only two specialists, which is a limitation when applying the proposed method. One specialist, usually with more experience and without recorded inconsistencies in the results of testing seed potatoes, is accepted as a reference. Its results are compared in pairs with the results of other authorised personnel.

To determine the maximum differences between

the selected quality indicators, which confirm the competence of personnel for sample size $N = 250$ the authors conducted the following simulation. The difference between the number of detected tubers was calculated using the selection method.

Table 2 shows that a feature of z-statistics is an increase in permissible deviations between the readings of specialists with an increase in the total number of detected discrepancies, which should be considered in the TL when planning competence monitoring.

Table 2. Maximum differences between certain quality indicators

Detection range	Specialist 1 m1	Specialist 2 m2	z	Are specialists competent?
Smallest	1	6	1,903	Yes
	1	7	2,139	no
Medium	10	20	1,883	Yes
	10	21	2,040	no
Largest	20	33	1,889	Yes
	20	34	2,017	no

That is, a maximum difference of 6 tubers is suitable at in the smallest detection range. In the medium detection range a difference of 9 tubers is permissible. The largest detection range allows a difference of 12 potatoes. These results are explained by the binomial distribution law and can be used by the quality department during competency monitoring. An important issue in assessing competence is the reliability of decisions made. As is known the power of statistical criteria depends on the volume of the studied samples [24].

TL can always use samples that have been submitted for testing to monitor reliability. The average sample for analysis always contains 250 tubers, but for analysis, elite, original, or reproductive seed material is usually passed, which does not contain a large number of disease lesions, and damage and does not contain tubers of other varieties. The use of such material will not test the ability of personnel to detect and correctly identify diseases or injuries.

There is a need to create your tuber sample, in which the person authorised to create samples for intra-laboratory

control introduces sick and damaged tubers found in the batch. To answer the question of what the minimum volume of the average sample (the number of tubers) should be and what is the number of damaged tubers in it, the authors suggest using the expression (4) given in [23]:

$$N_{min} = \frac{\ln(1-\alpha)}{\ln(1-p_0)} \quad (4)$$

where p_0 – a value of the binomial distribution parameter.

The authors carried out simulation modelling using an expression (4). In the Table 3 showed calculated recommended sample sizes N_{min} so the number of damaged/affected tubers m (total N_{min}) to ensure a confidence level of 0.95 assessment of personnel competence for the original seed and potato elite (4), and norms (in percent) of sowing qualities of seed potatoes, which are given in [22], were used for calculation. Volumes were calculated for the next categories of seed material established by the standard [22].

Table 3. Sample sizes of original and elite potato seed material to ensure a confidence level of 0.95

Indicator of sowing qualities	Polissia and forest-steppe		Steppe	
	OH, N_{min}/m	EH, N_{min}/m	OH, N_{min}/m	EH, N_{min}/m
(1)	300/3	300/3	300/3	300/3
(2.1)	300/3	300/3	300/3	300/3
(2.2)	600/3	200/3	600/3	200/3
(2.3)	300/3	1000/3	300/3	1000/3
(2.4)	600/3	600/3	300/3	300/3
(2.5) from 1/8 to 1/4	300/3	200/3	600/3	300/3
(2.5) over 1/4	300/3	300/3	300/3	300/3
(2.6)	100/3	100/3	60/3	60/3
(2.7)	300/3	300/3	300/3	300/3
(3.1)	300/3	300/3	300/3	300/3
(3.2)	300/3	300/3	600/3	600/3
(3.3)	300/3	300/3	300/3	300/3
(3.4)	86/3	86/3	53/3	53/3
(4)	300/3	300/3	300/3	300/3

Note: OH – original seed material, EN – the elite seed material for climatic zones of Ukraine “Polissya” and “forest steppe” and “steppe”

Table 4 shows calculated by the simulation modelling recommended sample size N_{min} and the number of damaged/affected tubers m (in total N_{min}) to ensure a confidence level of 0.95 assessment of personnel competence.

Table 4. Recommended sample sizes to ensure the reliability of personnel Competence assessment for potato seed reproduction

Indicator of sowing qualities	PH-1-2 N_{min}/m	PH-3-4 N_{min}/m
(1)	600/3	300/3
(2.1)	300/3	300/3
(2.2)	150/3	75/3
(2.3)	1000/3	600/3
(2.4)	300/3	200/3
(2.5) from 1/8 to 1/4	200/3	150/3
(2.5) over 1/4	300/3	300/3
(2.6)	100/3	60/3
(2.7)	300/3	300/3
(3.1)	600/3	300/1
(3.2)	150/3	150/3
(3.3)	300/1	300/1
(3.4)	67/3	45/3
(4)	300/3	300/3

Note: RN-1 – reproductive seed (RN) of the first reproduction; RN-2 – the second reproduction; RN-3 – the third reproduction; RN-4 – the fourth reproduction

As can be seen from Tables 3 and 4, a low percentage of crop quality standards and features of the binomial distribution law showed the need to study 10,000 tubers in some cases. For cases where the standard [22] does not allow the presence of any affected/damaged tuber, the authors took 1% availability as an example (demonstrating

that personnel can detect the affected/damaged tuber), such cells are highlighted in grey.

In practice, this means that such results raise questions about the actual reliability of estimates obtained for the volume of an average sample of 250 tubers, as regulated in, if the calculations show a different minimum volume.

On the other hand, selecting and analysing 1,000 tubers will require significant resources, which would be impractical. Therefore, the specialists who developed the standard most likely chose the average volume of the average sample.

Secondly, given that valid for a long period, tested, there is no notification of its cancellation, the question of the reliability of assessing the sowing qualities of potatoes by the seed personnel of the overhead line can be assigned to the management of the TL using Table 3,4, allocating time and human resources in such a way as to minimize the unnecessary burden on personnel, the management of TL plans and ensures the implementation of monitoring of personnel competence in the presence of the required number of tubers and the content of damaged/affected tubers in the average sample.

The results obtained in Table 1 are the results of a unique test of the examined batch of seed potatoes. The results obtained in Tables 2-3 can be reproduced by the method of simulation modelling and do not contain restrictions on reproduction.

Studies similar to the ones cited have not been conducted by Ukrainian or foreign scientists. In works [25; 26] the competence of personnel in agro-industrial laboratories was considered. However, the maximum differences are not determined for which personnel are recognised as competent (similarly to those obtained in Table 1). In works [27; 28], the issue of determining the varietal affiliation of potatoes was considered, however, not defined sample sizes of original and elite potato seed material to ensure a confidence level of 0.95, as done by the authors. In the works of foreign authors [29; 30], issues of quality and reliability of assessments obtained in laboratories

are considered. However, no recommendations have been made for sample sizes as in Table 4. Similar studies performed in accordance with the recommendations [31; 32] can be considered a continuation of this study.

Conclusions

Determination of the sowing qualities of seed potatoes belongs to the legally regulated sphere and largely depends on the competence of personnel. The organisation of reliable monitoring of personnel competence in testing laboratories allows for avoiding erroneous decisions during the certification of a batch of seed material.

The method proposed by the authors for assessing the competence of personnel using statistical processing makes it possible to avoid subjectivity in decision-making. The research of the method conducted by the authors allows for determining the maximum differences between certain potato quality indicators for different volumes of identified unsuitable tubers, which confirms the competence of the personnel.

Recommended sample sizes to ensure the reliability of personnel competence assessment for potato reproduction seed material allow TL management to plan and organise competence monitoring that considers the required number of tubers studied, and the minimum content of tubers with damage and diseases to obtain monitoring results. The findings obtained can be used in the development of new regulatory documents that contain both guidelines for assessing the competence of personnel, and updated requirements that will minimise the volume of average samples for determining individual quality indicators of potato reproduction seed material.

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Методологічні аспекти оцінювання компетентності персоналу лабораторій визначення якості картоплі насінневої

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Анотація. Більшість регламентованих стандартом показників якості для сертифікації насінневої картоплі визначаються суб'єктивною складовою – компетентністю персоналу, однак нормативними документами не встановлено критеріїв оцінювання компетентності, що спричиняє неконтрольовані ризики в лабораторії. Метою роботи є розроблення та дослідження методики оцінювання компетентності персоналу лабораторії, яка здійснює випробування насінневої картоплі та встановлення меж застосування методики. Використано методи теорії ймовірності та математичної статистики для задач вибору та дослідження статистичних критеріїв, які відповідають закону розподілу отримуваних даних та забезпечують необхідну достовірність за наявних обсягів вибірки. Для біноміального закону розподілу наведено статистику та спосіб визначення граничного значення, який математично описує прийняття рішення про компетентність. Досліджено властивості запропонованого статистичного методу оцінювання компетентності персоналу в частині знаходження максимальних різниць в результатах аналізування, за яких персонал визнають компетентним. Показана залежність потужності методу від обсягів даних. Визначено, що для отримання довірчої ймовірності 0,95 для показників якості, вміст яких у середній вибірці згідно з технічних умов мінімальний, обсяг вибірки повинен бути 600-1000 шт. Водночас для показників, вміст яких допускається до 5 % достатньо до 100 шт. Запропонований авторами метод показав, що рекомендована стандартом середня проба об'ємом 250 шт цілком виправдана з точки зору залучення ресурсів під час сертифікації, однак повинна бути скоригована під час моніторингу компетентності у випробувальній лабораторії, яка підтверджує свою компетентність відповідно до вимог ДСТУ ISO IEC 17025:2019. Отримані результати можна використовувати персоналом з якості у насінневих випробувальних лабораторіях як захід для мінімізації ризиків, спричинених впливом некомпетентності персоналу

Ключові слова: сертифікація насінневої картоплі, показники якості картоплі, статистичний критерій, достовірність прийняття рішень, насіннева випробувальна лабораторія