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Applying analysis of variance to determine stability of morphological and value for cultivation and use characteristics of *Lactuca sativa* var. *longifolia* L. variety of lettuce 'Skarb'

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Purpose. Providing a scientific rationale for the practical application of analysis of variance elements to determine the range of morphological and value for cultivation and use (VCU) characteristics of Romaine lettuce 'Skarb' variety. **Results.** The Romaine lettuce 'Skarb' variety was identified by the type of display of quantitative (QN) identification characteristics. VCU characteristics of the var. *longifolia* L. varieties were determined and statistically processed. The author focused on practical application of histogram and variation curve of phenotype morphological characteristics when performing the uniformity test. The correlation between quantitative characteristics of lettuce leaf and head was observed when plant productivity was developing. Romaine lettuce yield value was verified statistically. Thresholds were established for the indices under study, confidence intervals were defined over the years of study. **Conclusions.** The use of Lewis stability factor (S.F. = X_{max}/X_{min}) allowed to establish the stability of each characteristic display. Practical application of the histogram and variation curve for determining code of display of quantitative morphological characters and the range of VCU characteristics of the Romaine lettuce 'Skarb' variety was scientifically grounded.

Keywords: Romaine lettuce, variety, identification, variation series, deviation, thresholds, characteristic stability.

Introduction. Identifying the cutting lettuce varieties by way of morphologically describing qualitative, quantitative and pseudo-qualitative characteristics enables obtaining a morphological coding for a phenotype, establishing correlation [thereof] with VCU characteristics of the plant generative organs. These are the quantitative characteristics of Romaine lettuce leaves and heads, in particular, leaf length and width, head height and diameter, the number of leaves, which require further improvement in terms of searching for confidence intervals and variation range thresholds for the purpose of histogramming and tracing the curve of morphological and VCU characteristics expression.

Studies of foreign and domestic scientists have been monitored as regards the identification of cutting lettuce varieties identification and cultivation for marketing and seed production purposes. That reveals a range of the technological measures and the enhanced techniques of manufacturing marketable commodities and seed, targeting chiefly leaf lettuce and head lettuce. Ukraine has Romaine lettuce among its minor vegetables. That limits its cultivation [1]. Such foreign breeding varieties as 'Veradarts', 'Paryzkyi zelenyi', Ballon are well-known in Ukraine. The above varieties of Romaine lettuce are only spread among private households, most of them without official listing. So far, a domestic breeding Romaine lettuce 'Sovskyi' variety is the only one to represent *var. longifolia* L.

An extremely narrow assortment of Romaine lettuce currently provides no option for implementing the selection of high-performance adapted varieties for the conveying (ongoing) production meeting the demand for fresh vegetables grown in open field throughout early spring to autumn and winter season for all the ecological gradients. Examining distinctness of Romaine lettuce varieties breeding material as followed by further actual use of the analysis of variance to determine the range of Romaine lettuce candidate varieties morphological and VCU Characteristics, underpins *Relevance* of the study.

Aims and objectives of the study seek a validation for morphological description of quantitative characteristics as the Romaine lettuce 'Skarb' variety is being identified, disclosing actuals use for the histogram and variable curve of phenotype morphological characteristics as the uniformity test is being conducted, and displaying a correlation of phenotype with VCU indices of plant productivity.

Materials and methods. The field examination of distinctness of *Lactuca sativa* var. *longifolia* L. varieties was being conducted at the plots of Maiak Testing Station under the Horticulture and Melon Cultivation Institute, NAAS (village of Kruty, Nizhyn district, Chernigiv region) during 2005 to 2007. The design of field trials cultivating the cutting (Romaine) lettuce complies with 'Metodyka doslidnoi spravy v ovochivnytstvi i bashtannytstvi' (The Rules of

Procedure for Arranging Vegetable and Melon Growing Trials) [3] and 'Metodika polevogo opyta' (Rules of Procedure for Field Trial) [4]. The trials include phrenology observations and biometric examinations [5, 6]. Analysis of the variance in a sample of 20 plants indicates leaf length and width, head height and diameter. The mean value (n_{mean}) and mean square deviation (σ) have been found, which enables establishing the thresholds (*min−max*) for the range of quantitative characteristic expressions, where $n_{mean} \pm$ σ [7].

The study subject targets the workflow of vegetative and generative organs development with the view of implementing Lactuca sativa var. *longifolia* L. Romaine lettuce plants potential productivity in the course of growth and development thereof. The scope of the study covers the identification of 'Skarb' Romaine lettuce variety.

'Skarb'. The variety is of domestic breeding. Its development has engaged the author thereof. It is a mid-season cultivar (48 days from mass sporting to marketable maturity). The seed colouration is brown; the seedling displays no anthocyanin colouration. The attitude of elliptic, thick leaves (external) at harvesting maturity is erect. Leaf apex shape is obtuse. The leaves are dark green without any expression of anthocyanin colouration. The leaf upper side glossiness is moderate. Leaf blade blister is moderate, blisters are of average size. Undulation and lobbing of leaf blade margin are absent. Leaf blade venation pattern is not fan-like. Axil branching is absent. Seed stem is free of fasciation. The head is large by diameter, dense, narrow elliptic by longitudinal shape. The average weight of a head is 0.5 kg.

The seed is ripening within 100 to 110 days. Marketable yield of heads is 32 tons per ha.

The ranges of leaf and head quantitative characteristics, numeric values of measurements and calculations have established the variation series. The latter are presented as a model diagram displaying the differing frequency values by columns of appropriate height.

In order to plot up the variation curve of the histogram, the relevant quantitative ranges of leaf length and head height have been processed mathematically.

Arithmetic mean value refers to the principal index of average quality of the items to be examined and is computed as follows:

$$a = \frac{\sum_{i=1}^{n} a_i}{n} \,.$$

Allocating the sample among the frequencies enables computing the arithmetic mean value with more convenient equation, where *n = 20*, *k = 5*, while the arithmetic mean:

$a = (a_1 m_1 + a_2 m_2 + ... + a_k m_k) / 20$.

The other variable descriptive of the population is a *mean square deviation*. That index is of exceptional value for math statistics.

It applies as an absolute measure of diversity. Besides, it underpins nearly all characteristics of variability, distribution, correlation, regression, dispersion analyses, etc. The principal equation to compute the mean square deviation follows:

$$\sigma = \sqrt{\frac{\sum (a_i - a)^2}{\nu}} = \sqrt{\frac{\sum (a_i - a)^2}{n-1}}$$

(the sample is not grouped by frequencies),

$$\sigma = \sqrt{\frac{\sum (a_i - a)^2 m_i}{n-1}}$$

(grouped),

where s (sigma) − *mean square deviation* (name of the symbol also attributes to the index itself, so that the mean square deviation is commonly referred to simply as 'stigma'); $(a_i − a) − mean (central) deviation$, that is, the difference between each variance and the arithmetic mean; *v* − number of degrees of freedom; the computations assume the number of degrees of freedom equals to the number of variances minus one, that is *v = n − 1*.

The key advantage of mean square deviation is the complete quantitative characteristic of the variability of the index being examined. However, the index does not enable comparing the variability of two groups of different mean value of the characteristic being examined and the variability of different characteristics. To remedy the situation, one would apply the following variability index: the variability or variation ratio. The ratio of mean square deviation to arithmetic mean of the sample, expressed as a percentage, is a variation ratio.

$$V = \frac{\sigma}{a} 100\% \,.$$

The variation ratio enables comparing the variability degree inherent in different characteristics. The higher is the ratio, the higher is the overall variability inherent in the characteristic. Low variability ratio $V = \leq 10\%$ indicates general uniformity of a variety by that characteristics, whereas a high ratio would suggest a lack of uniformity.

The range of length quantitative values variability, i. e. the difference between the highest

and the lowest value in the range of variables, is to be calculated. The finding is to be used for histogramming.

$$R = a_{max} - a_{min}$$

where R − range of variation

a_{max} − maximum value of the sample

a_{min} − minimum value of the sample.

Stability of each characteristic has been examined. Lewis Stability Factor applies for that purpose (S.F. = X_{max}/X_{min}). Its value varies from unity and on. The closer the factor approaches unity, the more stability the characteristic is acquiring.

Results and discussion. The morphological description method has been applied to identify vegetative and generative organs of Skarb Romaine lettuce variety plants. The biometric examinations are completed for the following characteristics: external leaf: by length, external leaf: by width, external leaf: number of leaves, head: diameter, head: height, head: weight: Table 1 displays the statistical data for the external leaf.

Table 1

Statistical data of variation series for internal leaf length

m_i	a_j	$a_j m_j$	$(a_j - a)$	$(a_j - a) \cdot m_i$	$(a_i - a)^2$	$(a_i - a)^2 \cdot m_i$
3	18.5	55.5	-0.98	-2.94	0.96	2.88
5	19.0	95.0	-0.48	-2.40	0.23	1.15
5	19.5	97.5	0.02	0.10	0	0
4	2.00	80.0	0.52	2.08	0.27	1.08
3	20.5	61.5	1.02	3.06	1.04	3.12
Arithmetic mean a = 19,48			The total of all deviations = 0 or very close to 0		Sum of squares $\sum_i (a_j - a) \cdot m_i$ = 8.23	

Upper and lower limits have been found for each subgroup of equally measured values. The measured results get grouped, their frequency arrays with sub-group intervals and the number of measured results within those intervals, i.e. the frequency, provided.

Interval	18.5-18.8	18.9-19.2	19.3-19.6	19.7-20.0	20.1-20.5
Frequency	3	5	5	4	3

This case resolves to **19.48±1.96×0.15**, so that the confidence range is **19.19 to 19.77**. Table 2 indicates the findings as processed according to the Variation Series program.

In order to find the note of expression of 'External leaf: by length' as a relevant morphological characteristic the mean value a = 19.48 and the mean square deviation s = ±0.65 are to apply. It is the a ± s that would enable finding the thresholds for min and max of the ear length quantitative values, with follow-up determination of relevant characteristic note of expression. That is to say, the note and state of expression thereof are subject to compulsory assessment as the uniformity is examined. The relevant computations workflow would look as follows:

a_{min} = 19.48 − 0.65 = 18.83 cm;

a_{max} = 19.48 + 0.65 = 20.13 cm.

The length of a standard internal leaf of the Romaine lettuce is ranging within 18.83 to 20.13 cm. The quantitative variables of the Romaine lettuce internal leaves length have resulted in rather high values of the characteristic expression. The general sample of the characteristics to be examined includes 60 plants of Skarb Romaine lettuce variety. 25 plants have been marked to analyze the variation. These are their measured values that actually set up the variation series for relevant characteristics of the external and internal leaves and the head (Fig. 1).

The trial includes biometric examinations of five morphological traits and two VCU characteristics. The input data enters seven variation series, each containing 25 items of data. Searching for the thresholds has returned notes of expression for the leaf and the head QN-characteristics (Table 3).

Finding the thresholds of quantitative characteristics of leaf and head and identifying the note of characteristic expression are outlined below in relevant succession:

Leaf width:

a_{min} = 7.84 − 1.24 = 6.6 cm; a_{max} = 7.84 + 1.24 = 9.1 cm.

The numerical values of leaf width range within 6.6 to 9.1 cm. The expression thus meets the note of 7 (large). Lewis Stability Factor is as follows: S.F. = 1.4.

Table 2

Searching up the thresholds for internal leaf length of Romaine lettuce applying the Variation Series program

Mean value	Dispersion	Mean square deviation	Error of mean	Variation ratio	Accuracy
a = 19.48	D = 0.42	s = ±0.65	Δ = m_a ≈ ± 0,15	V = 3.4%	$m_V = \dfrac{\Delta}{a}$ = 0,8

*The table-derived t-criteria at the level of significance of 5% for all the var. row = 2.1.

Leaf length:

$a_{min} = 25.89 - 4.91 = 20.91$ cm;

$a_{max} = 25.89 + 4.91 = 30.80$ cm.

The numerical values of leaf length range within 20.91 to 30.80 cm. The expression thus meets the note of 7 (large). The characteristic stability: S.F. = 1.5.

Number of leaves:

$a_{min} = 27.04 - 2.11 = 24.93$ pcs;

$a_{max} = 27.04 + 2.11 = 29.15$ pcs.

The number of leaves shaping the head range within 24 to 29 pcs. Note of expression is 7 (large). The characteristic is relatively stable: S.F. = 1.2.

Head diameter:

$a_{min} = 17.21 - 1.30 = 15.91$ cm;

$a_{max} = 17.21 + 1.30 = 18.51$ cm.

The numerical values of leaf diameter range within 15.91 to 18.51 cm. The expression thus meets the note of 9 (very big). The characteristic stability: S.F. = 1.1.

Head height:

$a_{min} = 26.86 - 2.00 = 24.86$ cm;

$a_{max} = 26.86 + 2.00 = 28.86$ cm.

Such thresholds have returned 7 (large) as a note for characteristic expression. The quantitative characteristic stability: S.F. = 1.1.

The techniques of variance analyses have had a particular application aimed at VCU characteristics: weight of head and yield of Skarb variety.

Head weight:

$a_{min} = 409.00 - 89.88 = 319.12$ g;

$a_{max} = 409 + 89.88 = 498.88$ g.

The head weight thresholds of 319 to 499 g have returned 5 as a note of expression (medium). The index numerical value wide range of variation causes instability of the head weight quantitative characteristic: S.F. = 1.6.

The yield of marketable products of the lettuce range within

$a_{min} = 28.81 - 2.29 = 26.52$ mt per ha;

$a_{max} = 28.81 + 2.29 = 31.10$ mt per ha.

The yield ranging within 26.52 to 31.10 mt per ha secures the stability of essential VCU characteristic expression as certified by the S.F. = 1.2. Stability of each characteristic is examined. The Lewis Stability Factor (S.F. = X_{max}/X_{min}) acquires its specific values for each characteristic. Its value amounting to ≥ 1 is to be noted. The closer the S.F. value is approaching unity, the more stable the relevant characteristic is becoming, its expression flattening. The expression of such characteristics as the number of leaves, diameter and height of the head, the yield is quite stable (the S.F. value is closest to unity).

Conclusions. The Romaine lettuce internal leaves length secures the note of 5 (medium) assigned to the characteristic expression. The relevant thresholds range within 18.83 to 20.13 cm, which is 2.08 to 10.86 cm less than the length of external leaves. The thresholds of external leaves length range within 6.6 to 9.1 cm meeting the note of 5. The head characteristic of the leaves number, its thresholds ranging within 24.93 to 29.15 pcs, proves to be stable. Skarb Romaine lettuce variety is found to have a medium diameter of the head (15.90 to 18.51 cm). The height of Romaine lettuce variety varies within the range of 24.86 to 28.86 cm. That secures the stability S.F= 1.1 of the characteristic expression. The VCU index of head value is quite stable, S.F.= 1.6, with minimum and maximum values equal to 319 g and 488 g, respectively. The threshold values of Skarb Romaine lettuce variety yield (26.5 to 31.1 mt per ha) secure the value of S.F = 1.2.

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Table 3

Findings resulted from statistical treatment aimed at detecting the thresholds of expression note for quantitative characteristics describing Skarb Romaine lettuce variety leaf and head

Characteristic	Mean	Error of mean	Dispersion	T.S.D.	Dev. ratio	Accuracy	t.
Leaf:							
width, cm	7.84	0.25	1.53	1.24	15.8	3.2	31.7
length, cm	25.89	0.98	24.09	4.91	19.0	3.8	26.4
Head:							
number of leaves, pcs	27.04	0.42	4.46	2.11	7.8	1.6	64.0
diameter, cm	17.21	0.26	1.68	1.30	7.5	1.1	66.4
height, cm	26.86	0.49	4.00	2.00	7.4	1.5	67.2
weight, g	409.00	17.98	8079.25	89.88	22.00	4.4	22.8
Yield , mt per ha	28.81	0.46	5.24	2.29	7.9	1.6	62.29

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Н. В. Лещук. Застосування варіаційної статистики для встановлення стабільності морфологічних та господарсько-цінних характеристик сорту *Lactuca sativa* var. *longifolia* L. 'Скарб'

Мета. Науково обґрунтувати практичне застосування елементів варіаційної статистики для визначення параметрів морфологічних та господарсько-цінних ознак сорту салату ромен. **Методи.** Польовий, лабораторний, аналітичний та статистичний. **Результати.** Ідентифіковано сорт салату ромен 'Скарб' за типом прояву кількісних (QN) ідентифікаційних ознак. Визначено та статистично опрацьовано результати господарсько-цінних характеристик сортів var. *longifolia* L. Розкрито практичне застосування гістограми та варіаційної кривої морфологічних ознак фенотипу під час тесту на однорідність. Виявлено кореляційний зв'язок кількісних ознак листка та головки салату ромен під час формування продуктивності рослин. Статистично підтверджено достовірність результатів показника врожайності салату ромен, встановлено граничні межі досліджуваних показників та визначено довірчі інтервали за роки досліджень. **Висновки.** Застосування коефіцієнта стабільності Левіса (S.F. = X_{max}/X_{min}) дало можливість встановити стабільність прояву кожної ознаки. Науково обґрунтовано практичне застосування гістограми та варіаційної кривої для визначення кодів прояву кількісних морфологічних ознак та параметрів господарсько-цінних характеристик сортів салату ромен 'Скарб'.

Ключові слова: салат ромен, сорт, ідентифікація, варіаційний ряд, відхилення, граничні межі, стабільність ознаки.

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Н. В. Лещук. Применение вариационной статистики для определения стабильности морфологических и хозяйственно-ценных характеристик сорта *Lactuca sativa* var. *longifolia* L. 'Скарб'

Цель. Научно обосновать практическое применение элементов вариационной статистики для определения параметров морфологических и хозяйственно-ценных признаков сорта салата ромэн 'Скарб'. **Методы.** Полевой, лабораторный, аналитический и статистический. **Результаты.** Идентифицирован сорт салата ромэн 'Скарб' по типу проявления количественных (QN) идентификационных признаков. Определены и статистически обработаны результаты хозяйственно-ценных характеристик сортов var. *longifolia* L. Раскрыто практическое применение гистограммы и вариационной кривой морфологических признаков фенотипа салата во время теста на однородность. Показано корреляционная связь количественных признаков листа и кочана салата ромэн, при формировании продуктивности растений. Статистически подтверждена достоверность результатов показателя урожайности салата ромэн, установлены предельные границы исследуемых показателей и определены доверительные интервалы за годы исследований. **Выводы.** Применение коэффициента стабильности Левиса (S.F. = X_{max}/X_{min}) позволило установить стабильность проявления каждого признака. Научно обоснованное практическое применение гистраммы и вариационной кривой для определения кодов проявления количественных морфологических признаков и параметров хозяйственно-ценных характеристик сорта салата ромэн 'Скарб'.

Ключевые слова: салат ромэн, сорт, идентификация, вариационный ряд, отклонение, предельные границы, стабильность признака.