REGULARITIES OF THE UNDERLYING PLANT BASE STASIS FACTORS FOR QUALITY CONTROL OF SOIL ON ISO 11269-1

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International Standard ISO 11269-1 gives the example of the influence of the concentration of nickel in the soil at the root length of barley.
A basic scheme of the influence of pollutants on the growth of plant roots. This is considered the entire set of statistics without the use of the arithmetic means.
Keywords: standard, an example of experiments, the hidden factors, results of simulation

The international standard ISO 11269-1 results an example of nickel concentration C (mg/kg) influence in soil on barley L (mm) [1, p.186, table 17.2]. The standard recommends to process results by statistical methods of Student or Dannet. Our methods [2, 3] have allowed to reveal biotechnical regularities of underlying factors.

Basic data

Basis of modelling in the standard is the arithmetic mean significances calculation (table 1). However same arithmetic mean significance can characterize a wide variety of statistical distributions.

Table 1. Results of the barley base test of in soil samples on the ISO 11269-1 [1, p.186, table 17.2]

Nickel concentration, mg/kg	Base length , mm									Mean base length, mm
0	98 101	99 104	105 102	100 97	100 100	101 99	102 96	103 102	97 105	101
50	96 98	104 98	99 100	101 99	102 97	97 96	102 100	100 103	97 98	99
100	85 90	91 87	93 93	92 88	88 87	84 83	90 86	84 82	89 84	88
500	17 15	9 15	8 7	11 8	16 15	13 17	11 10	12 12	9 9	12
1000	9 7	3 4	4 5	11 5	3 6	7 9	7 7	5 6	8 8	6

In table 1 each several 18 plants for same concentration of nickel are placed in a number on the principle unknown to us. Therefore it is impossible obviously to select the influencing factor. In this case we apply a technique of mediate base length ranking. In the beginning we shall show statistical models on the table 1.

Biotechnical regularities

On a table model from table 1 some formulas of nickel concentration influence on a change of barley base length, mm (fig. 1), are received:

- On the arithmetic mean base length

$$\bar{L} = 96{,}5882 \exp(-5{,}09941 \cdot 10^{-5} C^{1{,}74943}) + 5{,}66927 \; ; \qquad (1)$$

- On the typical base length

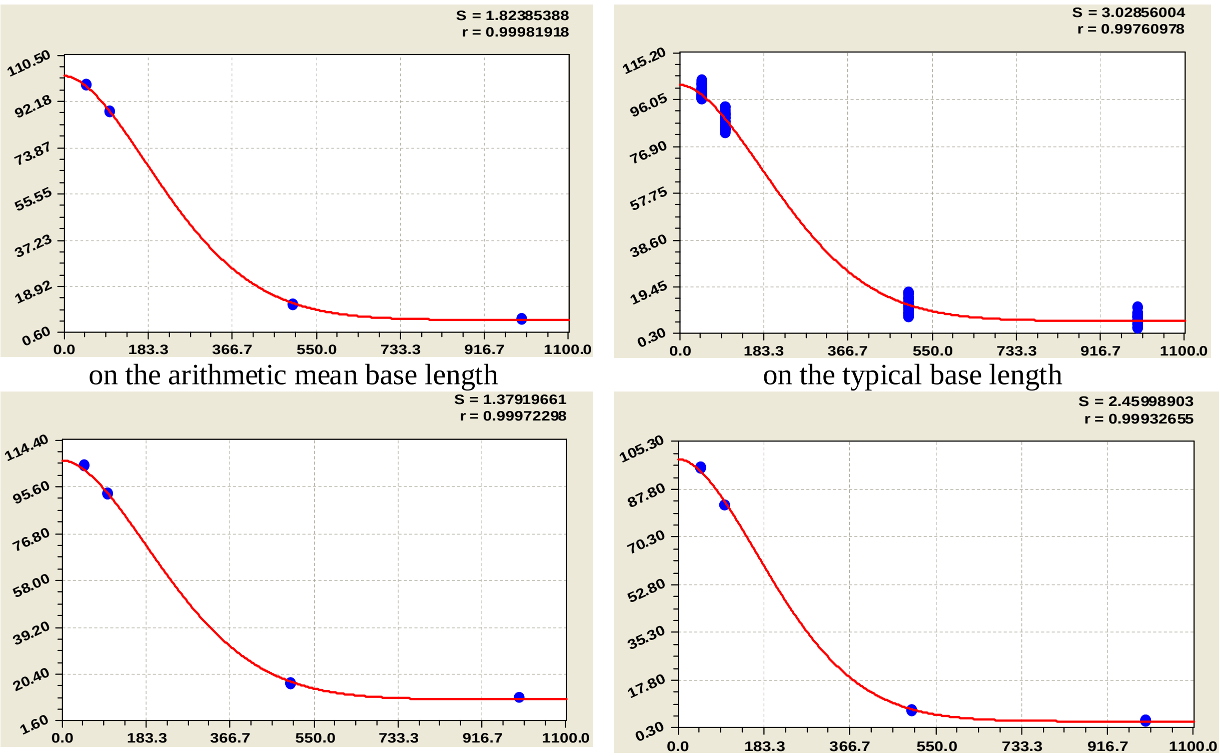
$$\tilde{L} = 96{,}4414 \exp(-4{,}77729 \cdot 10^{-5} C^{1{,}77103}) + 5{,}55494 \; ; \qquad (2)$$

- On the maximum base length (upper limit of a confidence interval)

$$L_{\max} = 95{,}9266 \exp(-4{,}3725 \cdot 10^{-5} C^{1{,}76972}) + 10{,}25557 \; ; \qquad (3)$$

- On the minimum base length (lower limit of a confidence interval)

$$L_{\min} = 96{,}2020\exp(-5{,}31762\cdot10^{-5}C^{1{,}76583}) + 2{,}75881\,. \quad (4)$$



on the arithmetic mean base length

on the typical base length

upper limit of a confidence interval

lower limit of a confidence interval

Fig. 1. Graphs of nickel concentration influence on the barley base growth

All four equations show limits of growth on condition that $C \to \infty$. But the parameters of models of means that is equations (1) and (2) within pollutant concentration change differ from each other. It proves that the statistical numbers including 18 significances of base length don't follow the Gaussian-Laplace law that is known as normal distribution law [2, 3]. Therefore arithmetic mean method gives an error on a comparison with the typical approach.

Modelling conception

In a fig. 2 the schematic diagram of pollutant influence on plant base growth is represented. With that all statistical ensemble consisting of 5 $\times$ 18 = 90 members (table 2) is considered. The greatest and least significances of base length derive a variation of plant development and growth in changing soil conditions. The transition from a level $L_{\max\max}$ in $L_{\min\min}$ occurs under the death distribution. The line of transition divides area of behaviour of a plant set on two parts:

a) from above graph in a fig. 2 is plant base stasis effect;

б) from below graph is stasis effect by plants;

All equations are obtained on a line of stasis effect by plant in growth process.

Then biotechnical regularities of stasis by plants are received under the general formula:

$$L = L_{\max\max}(-a_1 C^{a_2}) + L_{\min\min}\,, \quad (5)$$

where a_1, a_2 - required model parameter.

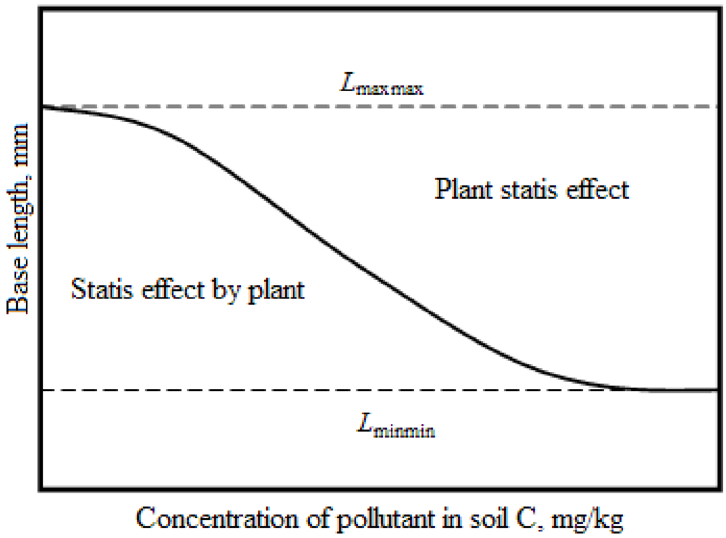


Fig. 2. The schematic diagram of pollutant influence

And the effect of plant stasis will be identified by biotechnical regularity of a kind:

$$L_s = L_{\max\max} - L. \tag{6}$$

Under the standard the longest base of a plant is measured.

Table model

The formulas (5) and (6) are applied to samplings and we shall receive table 2.

Table 2. Test result ranking

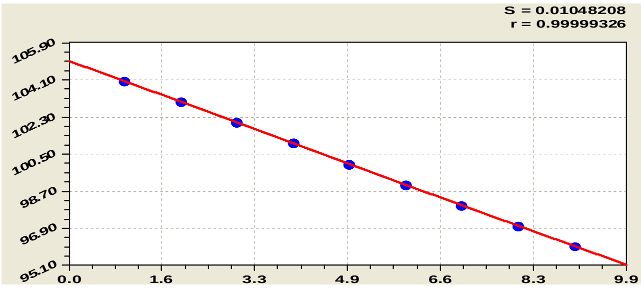
C, mg/kg	L, mm	Rank r	$L_{\max}$, mm	$L_{\max} - L$ mm	C, mg/kg	L, mm	Rank r	$L_{\max}$, mm	$L_{\max} - L$ mm	C, mg/kg	L, mm	Rank r	$L_{\max}$, mm	$L_{\max} - L$ mm
0	98	7	105	7	50	99	5	104	5	500	11	5	17	6
0	99	6	105	6	50	97	7	104	7	500	12	4	17	5
0	105	0	105	0	50	96	8	104	8	500	9	7	17	8
0	100	5	105	5	50	100	4	104	4	500	15	2	17	2
0	100	5	105	5	50	103	1	104	1	500	15	2	17	2
0	101	4	105	4	50	98	6	104	6	500	7	9	17	10
0	102	3	105	3	100	85	8	93	8	500	8	8	17	9
0	103	2	105	2	100	91	2	93	2	500	15	2	17	2
0	97	8	105	8	100	93	0	93	0	500	17	0	17	0
0	101	4	105	4	100	92	1	93	1	500	10	6	17	7
0	104	1	105	1	100	88	5	93	5	500	12	4	17	5
0	102	3	105	3	100	84	9	93	9	500	9	7	17	8
0	97	8	105	8	100	90	3	93	3	1000	9	1	11	2
0	100	5	105	5	100	84	9	93	9	1000	3	7	11	8
0	99	6	105	6	100	89	4	93	4	1000	4	6	11	7
0	96	9	105	9	100	90	3	93	3	1000	11	0	11	0
0	102	3	105	3	100	87	6	93	6	1000	3	7	11	8
0	105	0	105	0	100	93	0	93	0	1000	7	3	11	4
50	96	8	104	8	100	88	5	93	5	1000	7	3	11	4
50	104	0	104	0	100	87	6	93	6	1000	5	5	11	6
50	99	5	104	5	100	83	10	93	10	1000	8	2	11	3

C, mg/kg	L, mm	Rank r	L_{max}, mm	$L_{max}-L$, mm	C, mg/kg	L, mm	Rank r	L_{max}, mm	$L_{max}-L$, mm	C, mg/kg	L, mm	Rank r	L_{max}, mm	$L_{max}-L$, mm
50	101	3	104	3	100	86	7	93	7	1000	7	3	11	4
50	102	2	104	2	100	82	11	93	11	1000	4	6	11	7
50	97	7	104	7	100	84	9	93	9	1000	5	5	11	6
50	102	2	104	2	500	17	0	17	0	1000	5	5	11	6
50	100	4	104	4	500	9	7	17	8	1000	6	4	11	5
50	97	7	104	7	500	8	8	17	9	1000	9	1	11	2
50	98	6	104	6	500	11	5	17	6	1000	7	3	11	4
50	98	6	104	6	500	16	1	17	1	1000	6	4	11	5
50	100	4	104	4	500	13	3	17	4	1000	8	2	11	3

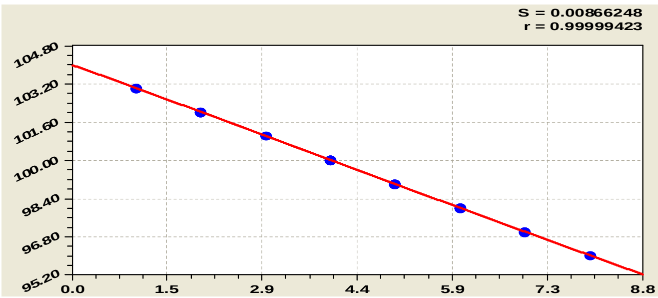
Here L_{max} means a maximum of base length in each sampling for same significance of an explanatory variable.

Number ranking

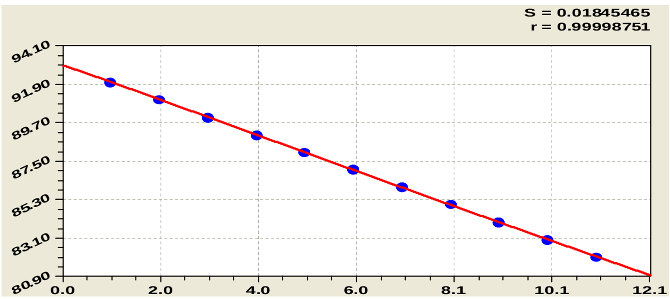
On vectorial orientation «it is better → worse» we shall give ranks $r = 0,1,2,...$ to each significance of length in five samplings. After death distribution identification the biotechnical regularities (fig. 3) were obtained.



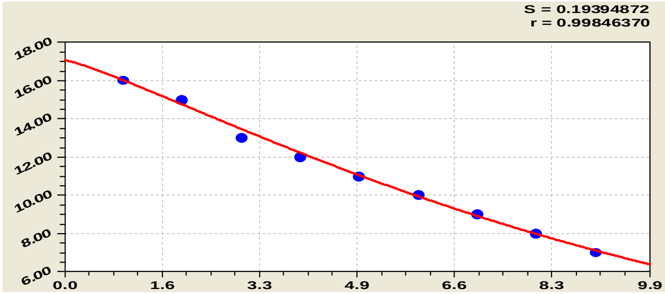
$$L_0 = 104,9907 \exp(-0,0093102 r^{1,02913})$$



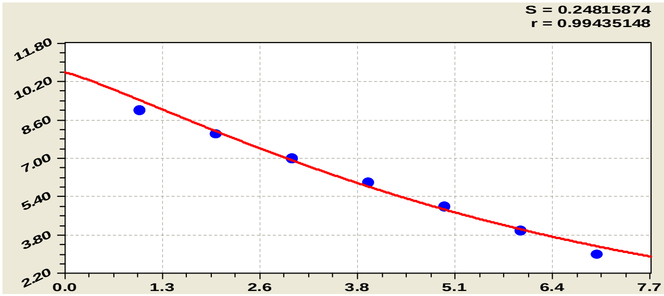
$$L_{50} = 103,9857 \exp(-0,0094009 r^{1,02843})$$



$$L_{100} = 92,9821 \exp(-0,010339 r^{1,04029})$$



$$L_{500} = 17{,}0766 \exp(-0{,}064813 r^{1{,}18556})$$



$$L_{1000} = 10{,}5721 \exp(-0{,}11780 r^{1{,}17277})$$

Fig. 3. Graphs of unknown factor influence

The high equation correlation coefficients (in a right upper graph angle) show availability of underlying factor or even groups of underlying factors in experiment results.

The residuals after the equations in a fig. 3 equal to less than 0,5 mm, that is there are below measuring precision of length of the longest plant base.

The two-factor image is shown in a fig. 4.

The unknown factor exerts noticeable influence for significant concentration of pollutant.

On rank length, that is on a maximum rank r_{max}, it is possible to judge about attempts of a plant to resist to harmful pollutant influence.

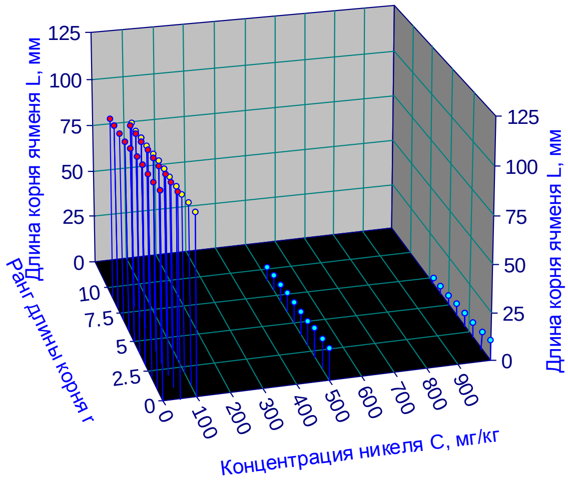


Fig. 4. Disposition of base length

Confidence interval

It is determined more precisely on data of table 3, when curculating members of general statistical sampling consisting from 90 members as the formulas (fig. 5) come into account:

- on the upper limit of confidence interval of base length

$$L_{max} = 105{,}0076 \exp(-4{,}38223 \cdot 10^{-5} C^{1{,}84524}) + \\ + 0{,}20528 C^{0{,}84335} \exp(-0{,}0018467 C^{0{,}99989}); \quad (7)$$

- on the under limit of confidence interval of base length

$$L_{\min} = 96{,}0000\exp(-0{,}21378C^{0{,}40327}) + \\ + 0{,}12512C^{1{,}94994}\exp(-0{,}028479C)\,. \quad (8)$$

Table 3. Limits of confidence interval

upper		under	
0	105	0	96
0	105	50	96
50	104	50	96
100	93	100	82
100	93	500	7
500	17	1000	3
500	17	1000	3
1000	11		

These binomial equations contain two stable distribution laws. First component is the death distribution offered by us [2, 3], in which in difference from the Laplace law intensity of death (degree of an explanatory variable) is entered. Second component indicating high-stress excitation of test plants from pollutant effect is the biotechnical law of prof. P.M. Mazurkin. Besides first component is a special case of the biotechnical law. Therefore all regularities are received from one formula.

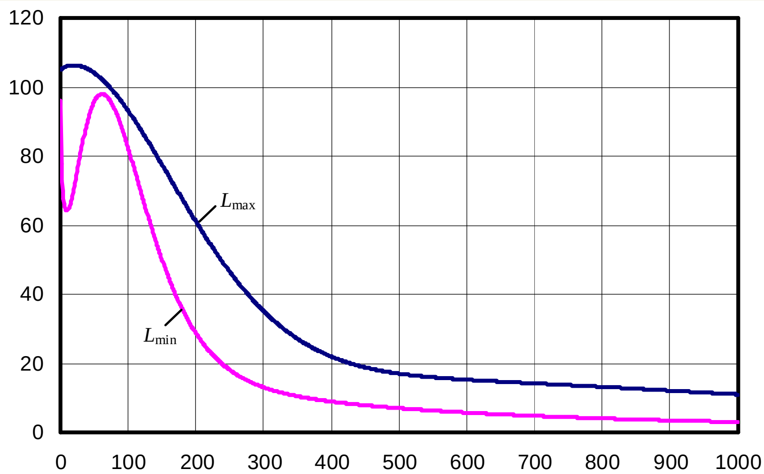


Fig. 5. Limits of confidence plant behaviour interval on the length of longest base in each plant (axis of ordinates) depending on pollutant concentration (abscissa)

Table 4. Scatter of length and stasis of plant base, mm

C, mg/kg	Maximum		Minimum		Scatter	Stasis	
	rank $r_{\min}$	$L_{\max}$	rank $r_{\max}$	$L_{\min}$	ΔL	$L_{C\max}$	$L_{C\min}$
0	0	105	9	96	9	0	0
50	0	104	8	96	8	1	0
100	0	93	11	82	11	12	14
500	0	17	9	7	10	87	89
1000	0	11	7	3	8	94	93

Small nickel concentrations up to 30 … 40 mg/kg exert positive influence to robust plant development and growth. And depauperate plants fast reduce their growth, but according to increase of nickel concentration in an interval 10 … 250 мг/kg depauperate plants receive death high-stress excitation. These conclusions are preliminary, as the scale of explanatory variable, accepted in the standard, is small. The additional researches by the rules of developmental experiments are necessary.

Scatter of length of base and stasis

The composite indexes obtained on the basis of table 1 data disregarding recurrings of the members of statistical sampling, are represented in table 4.

The interval between lines of the upper and under limits of confidence interval shows scatter of length of plant base ΔL. This parameter is equal to $\Delta L = L_{\max} - L_{\min}$. Stasis L_C will be defined on a difference of a variable length L from greatest base length L_0 for zero concentration of pollutant in soil that is from expression $L_C = L_0 - L$.

The change of a maximum rank will be defined under the biotechnical formula (fig. 6)

$$r_{\max} = 9\exp(-0{,}068416C^{0{,}18838}) + 6{,}61267 \cdot 10^{-11} C^{5{,}90256} \exp(-0{,}025330C)\,. \quad (9)$$

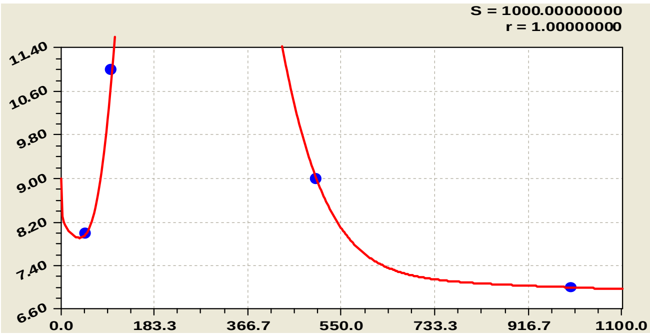


Fig. 6. Graph of maximum rank of base length (axis of ordinates) from pollutant concentration (abscissa)

The disposition of points concerning contour shows insufficiency of observations in an interval 100 … 500 mg/kg.

Scatter of base length (fig. 7) shows even more intuitive intense sparsity of nickel concentration significances:

$$\Delta L = 8{,}52730\exp(-6{,}71576 \cdot 10^{-5} C) + $$
$$+ 1{,}93804 \cdot 10^{-31} C^{17{,}06904} \exp(-0{,}069594C)\,. \quad (10)$$

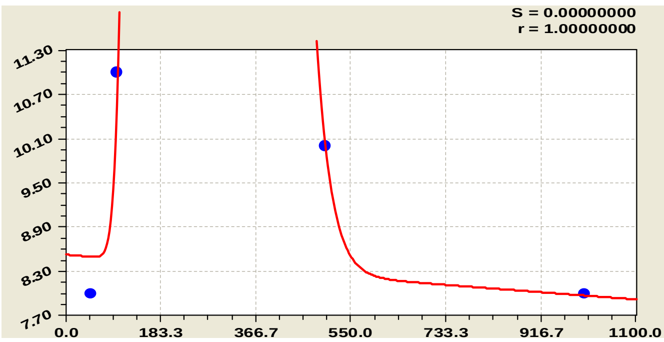


Fig. 7. Graph of scatter of base length (axis of ordinates) from pollutant concentration (abscissa)

The residuals after the formula (10) are capable to give wave component (fig. 8) because of that they is significant more error of measurements in ± 0,5 mm.

$$\Delta L_3 = 1{,}25505\exp(-0{,}018019C^{1{,}00055})\times$$
$$\times\cos(\pi C/(89{,}13295-0{,}0011380C^{1{,}02453})+1{,}18463) \qquad (11)$$

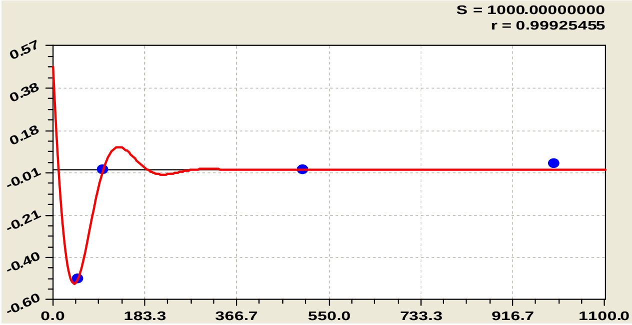


Fig. 8. Wave component graph of model of base length scatter (axis of ordinates) from pollutant concentration (abscissa)

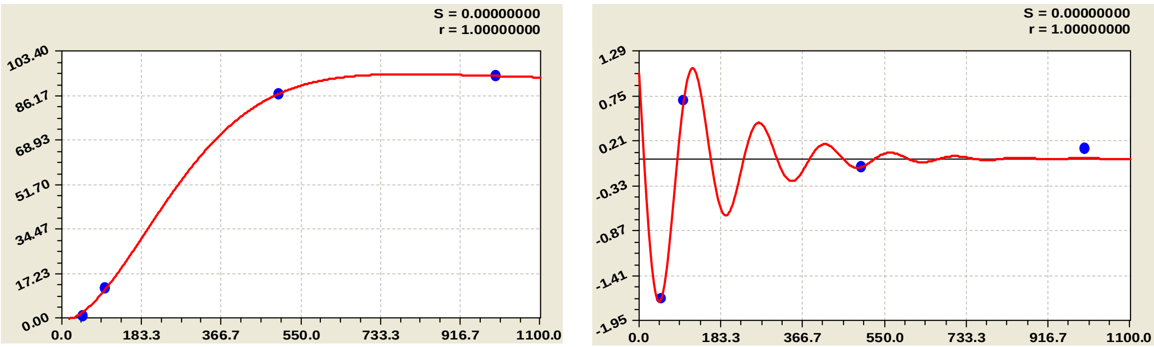
Thus, for small concentrations pollutant offers vibrational perturbation in plant behavior. Therefore influencing on development and growth of barley base can be both positive, and negative depending on a soil nickel concentration change scale, accepted in experiments.

Then the general model of barley base length scatter change, depending on nickel concentration in soil, after repeated parametric identification in a software envelope CurveExpert-1.3 will be defined by the trinomial equation of kind:

$$\Delta L = 8{,}53098\exp(-6{,}42631\cdot 10^{-5}C)+1{,}93473\cdot 10^{-31}C^{17{,}06865}\exp(-0{,}069603C)+$$
$$+1{,}25404\exp(-0{,}017927C^{0{,}99926})\cos(\pi C/(89{,}09648-0{,}0020767C^{1{,}24037})+1{,}18747)\,. \qquad (12)$$

Stasis of robust species

They are present in each subgroup (fig. 9) and are determined by the tendency (trend) of difference kind and wave component on formula:



a) b)

Fig. 9. Behavior of robust barley species for stasis: a – on a trend with first two not wave components; b – on third wave component

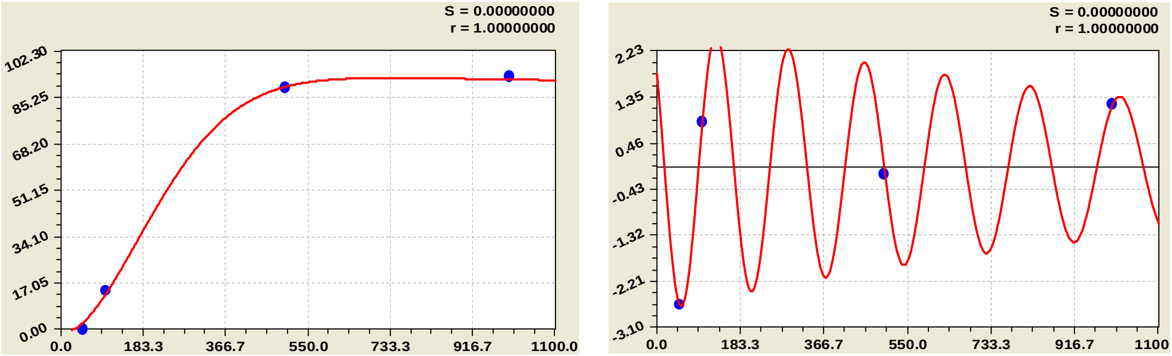
$$L_{C\max} = 99{,}82401\exp(-5{,}97800\cdot 10^{-5}C) - 100{,}83128\exp(-4{,}10906\cdot 10^{-5}C^{1{,}76153}) +$$
$$+2{,}28550\exp(-0{,}0060152C)\cos(\pi C/(75{,}23778 - 0{,}0011263C) + 1{,}11439)\,. \quad (13)$$

Dynamic factor is significant on a model (13) in an interval 0 … 500 mg/ kg.

Stasis of depauperate species

With even greater dynamism perturbation influence of nickel concentration in soil (fig. 10) on growth depauperate barley species is exhibited:

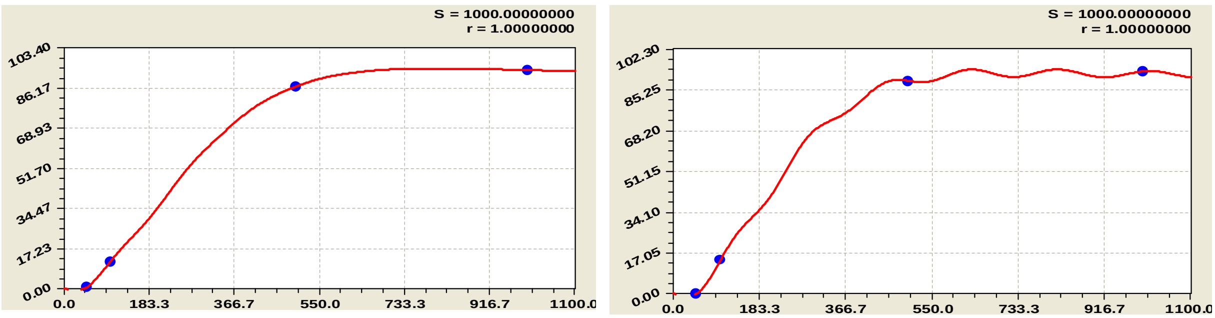
$$L_{C\min} = 94{,}39225\exp(-2{,}80992\cdot 10^{-5}C) - 96{,}18219\exp(-4{,}00000\cdot 10^{-5}C^{1{,}81633}) +$$
$$+2{,}78417\exp(-0{,}00070954C)\cos(\pi C/(73{,}77210 + 0{,}012625C) + 0{,}87252)\,. \quad (14)$$



a) b)

Fig. 10. Behavior of depauperate species for stasis on two and three components

Comparison of the graphs in a fig. 9b and the fig. 10b shows that depauperate species confront own death longer, than robust barley plant species. But behavior dynamism of robust species is greater. It is visible for comparison of the graphs under both full formulas (13) and (14) in a fig. 11.



a) b)

Fig. 11. Adaptation of robust (a) and depauperate (b) plants to polluted soil

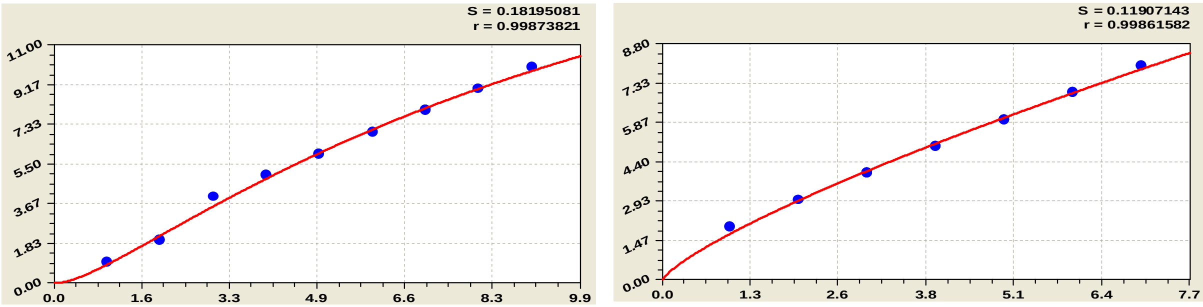
Stasis in plant subgroups

The subgroups from 18 plants conduct itself variously. The makers of an example from ISO 11269-1 have arranged results of monitoring so, that on significances of soil nickel concentration regularities were obtained by us for each plant subgroup under the formula (6), that is under the expression $L_s = L_{\max} - L$.

For first three significances of nickel concentration in soil 0, 50 and 100 mg/kg under the formulas of biotechnical regularities in a fig. 3 functional accuracy $L_s = L_{\max} - L = r$, where r - rank of distribution $r = 0,1,2,...$ was received.

The concentration levels in 500 (fig. 12a) and 1000 (fig. 12b) mg/kg have changed proportionality of small levels of the nickel contents in soil under the formulas:

$$L_{s500} = 742{,}1466 r^{2{,}77434} \exp(-6{,}75035 r^{0{,}19763}); \; L_{s1000} = 1{,}72778 r^{0{,}77620} . \quad (16)$$



a) b)

Fig. 12. Stasis for nickel concentration 500 (a) и 1000 (b) mg/kg in soil

The plants for $C = 500$ confront and change growth under the biotechnical law, and at a level $C = 1000$ mg/kg the aggravation of base growth occurs under the exponential law.

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