CORRELATION BETWEEN SOIL PH MEASURED IN TWO ELUENTS IN THE CASE OF AGRICULTURAL LAND: CONCLUSIONS REGARDING SOIL REACTION CLASSES

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Abstract. Soil pH is one of the most important measured soil parameters. It is an indicator of soil quality, establishes the reaction class, fertilizer recommendations, liming necessity and also an index of the soil biological processes. In Romania, the most common measurement of soil pH is carried out in H_2O or KCl as eluents in 1:2.5 ratio. The novelty of this research is that a large number of soil samples (911) were investigated from Romanian farmland territories with different soil types and different chemical properties. In order to integrate the results of soil pH in international soil databases, it is necessary to establish and validate a relationship between pH_{H2O} and pH_{KCl}. The obtained value of the correlation coefficient r = 0.983 indicates a strong correlation between the two sets of values. The linear and polynomial functions have a high coefficient of determination $R^2 = 0.96$. The investigated soils of this study are classified in reaction classes from strongly acidic to slightly alkaline. The models proposed by this study can be used in laboratories for intern quality control and for converting pH values in different eluents.
Keywords: *sampling, eluents, average differences, equations, acidification, alkalinisation*

Introduction

One of the most routine soil analyses is soil pH, which is used mostly to interpret the soil reaction, the availability of soil nutrients and the intensity of biological processes in soils (Miller et al., 2010; Sadovski, 2019). In a research study by Wu et al. (2019), soil pH is defined as the key parameter in order to understand the relationships between nutrient availability for plants and environmental factors. From the perspective of soil water content, soil pH values are strongly correlated with the soil water balance, more precisely, average annual precipitation and average annual potential evapotranspiration. International specialists recommend soil pH to be measured either in H_2O or in other electrolytes with different ionic strength such as KCl. The influence of salt solution on soil pH measurement is called the suspension effect on pH. If the pH is measured in water, it may be compared with measurements in other kinds of electrolytes. But, as it is well known, if the soil is diluted with H_2O, the most part of soil protons tend to remain fixed to the soil particles and they are not released into the soil solution (Ahern et al., 1995; Brinton, 2019). Some researchers, as Gavriloaiei (2012), recommends the measurement of soil pH in a dilute KCl solution, because it will provide more accurate results than the measurement of pH in H_2O. By adding a salt solution, the soil cations are released and they replace some protons from the soil particles. These processes force the hydrogen ions to pass into the solution and make their concentration in the bulk solution closer to the pH value that can be found in the field. Soil pH is defined as the critical soil

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quality parameter, because it controls the soil microbial activity, the soil nutrient availability and the development and growth of plant roots. In most of the cases, slightly acidic soils are optimal for the macronutrients and micronutrients availability for plants. Also, it is a critical element in order to understand the soil nutrient availability and weathering as well as the relationship between soil and biota. In the study made by Kabala et al. (2016), soil pH is characterized as the indicator which influences directly plant growth and yield quality and which may indirectly influence soil food production, forestry, water soil management, waste and wastewater disposal, and biodiversity protection. The human activities from agriculture have an impact on changes of soil pH, both as acidification and alkalinisation processes. Soil pH is such an important indicator because it is one of the defining parameter in all soil studies, inventories, soil databases and environmental monitoring programs. The importance of a correct determination of soil pH is required because this indicator influences all the biological, chemical and physical properties and processes that can affect the plant growth and biomass yield. In the early stages of a study, soil pH is the indicator which gives us a clue about the soil condition and the expected direction of many of the soil processes, and it is controlled by the leaching of basic cations, mainly: Ca, Mg, K, Na. Also, soil pH influences the biochemical processes, such as: substance translocation, trace elements mobility, soil organic fractions mobility, microbial ecophysiological indicators, soil enzymes activity, mineralization and biodegradation of soil organic matter, the processes of nitrification and denitrification, ammonia volatilization (Neina, 2019; Edmeades et al., 1990; Thiele-Bruhn et al., 2015). Soil chemists often refer to soil pH as the master variable because it controls ion exchanges, dissolution-precipitation, reduction-oxidation processes, and adsorption and complexation reactions (Kome et al., 2018; Lauchli et al., 2012). From the agricultural point of view, the importance of knowing the soil pH is related to the liming and fertilizer requirements and the efficiency of herbicides. From another perspective, soil pH serves as an index of soil weathering and mineral transformation and it constitutes an important parameter in establishing the pedotransfer functions (Bravo et al., 2017; Zapko et al., 2014). The aim of this study was to compare the soil pH measured in H_2O and KCl at the most commonly used ratio 1:2.5 and to establish a correct correlation between the values of those two eluents. Also, our goal was to classify all agricultural soils of Romania in reaction classes, especially in the actual context of climate changes worldwide and particularly in South-Eastern Europe (Smuleac et al., 2020). The limit of this study is the fact that the sampling was confined to surface soil layer.

Materials and methods

The decision to choose a specific eluent or a soil: eluent ratio for soil pH determination, is generally decided by the national scientific authorities and must be justified by the local soil properties, particular climate conditions and soil management practices. That is why, different measurement methods in different countries worldwide lead to incompatibility of data disturbing data integration at the international level and is necessary to find a common point in order to find an easier interpretation of the obtained data (Jonsson et al., 2002; Summer, 2008). In Romania soil pH is measured according to the ASRO standard SR 7184-13 (2001), which recommends a 1:2.5 soil-to-water ratio and also for KCl 0.1 mol L^{-1} solution. The intern laboratory code of the procedure is PS-03-which represent the code of standard laboratory procedure method approved by RENAR (National Certification Institution in Romania). A total of 911

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samples were collected from the arable agricultural soils of Romania. The study did not involve protected land, endangered or protected areas. Surface soil samples at 0-20 cm depth were collected, using a soil auger and being stored in polythene bags and labelled with indelible markers (Webster et al., 2013, 2018; FAO, 2021; Grant, 2009). These soil samples represented a diverse range of chemical and physical properties, including planes and hilly areas, from the relief point of view (Wang et al., 2018; Smuleac et al., 2020). The pertinent soil properties were highly variable. Standard measurements were performed on the soil sampling. Prior to laboratory analysis, samples were air dried and passed through a 2 mm soil sieve, to separate the fine soil fraction lower than 2 mm from the coarse fraction (FAO, 2021). The common extracts are distilled water in 1:2.5 soil-suspension ratio and KCl 0.1 mol L^{-1}. The role of KCl solution is to test for the presence of exchangeable Al. The absolute value of pH in KCl solution bears a strong correlation with Al saturation. This higher concentrated salt solution displaces H^+ and Al^{3+} ions completely from the exchange complex. Al displaced by K^+ on the exchange complex, consumes OH^- ions and increases H^+ concentration, as a result the pH of the solution is lowered. Exchangeable Al is present if the pH in KCl is lower or equal with 5.2, and if the value is higher, Al becomes non-exchangeable due to processes of hydrolysis, polymerization and precipitation (Grant, 2009; Hendershot et al., 2008; Smith et al., 1997). For the measurements a Mettler Toledo Seven Easy digital pH-meter was used, bearing a combine glass electrode, which had been previously calibrated with buffer solutions of pH = 4, pH = 7, pH = 10, the used reagents were of analytical grade. All measurements were carried out at room temperature varying between 20.0 °C and 25.0 °C, and after 2 h of stirring, as it is recommended in standard for soil pH. The soil reaction classes were established according to the Romanian applied methodology for pedological studies, as it is presented in *Table 1*.

Table 1. *Soil reaction classes, data interpreted according to Romanian National Research Institute for Pedology and Agrochemistry (1986)*

Soil reaction class	Values of pH in H_2O 1:2.5	Values of pH in KCl 0.1 M 1:2.5
Strongly acid	4.40-5.09	≤ 4.29
Moderately acid	5.10-5.89	4.30-5.09
Slightly acid	5.90-6.80	5.10-6.09
Neutral	6.81-7.20	6.10-6.59
Slightly alkaline[1]	7.21-8.49	≥ 6.60

[*]For pH in KCl reaction is alkaline ≥ 6.60 pH units

The choice of the functional model was made based on the values of the coefficient of determination R^2. The statistical significance of the model is given by the F-test and the sig. value, at the $\alpha = 0.01$ level. High values of R^2, as close as possible to 1, were followed, which indicate us the fit of the chosen model to our experimental data. The types of functions tested are linear, quadratic, cubic and logistic. We applied Paired Samples t Test because the statistical series values consist of paired items obtained by measuring the same statistical individuals by two methods. In the same context, we also applied the nonparametric Sign Test. Statistical analysis and graphical representation of the collected data were executed using IBM SPSS Statistics Version 23.

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Results

As many researchers explained in previous studies (Wang et al., 2019), the difference between soil pH in water and pH in KCl, is that the first refers to the acidity of the soil solution, but the second one refers to the acidity of the soil solution together with the reserve acidity in the colloids and therefore it is always more acidic than the pH in water.

Regression between the pH in the two eluents mentioned before, is important because it gives the possibility to researchers to compare in direct way their own obtained values with the data that are already existing in literature of other countries.

The soils used for this experiment represent a range of soil reactions founded in South-Eastern Europe, from strongly acid to a slightly alkaline.

The pH in water is ranged from 4.42 to 8.49, mean 6.98. In case of pH in KCl, the values are increasing from a minimum of 3.65 to a maximum of 8.07, mean 6.08 (Toth et al., 2008).

Mean value of pH_{KCl} was lower than the mean in water by 0.90 pH units, which is due to potassium/hydrogen exchange in the salt-soil suspension and to the release of hydrogen ions into the solution, situation founded and explained also by Kabala et al. (2016).

In strongly acidic reaction class 7 soil samples were determinated, representing 0.76%, the obtained values in H_2O ranged from 4.42 pH units to 5.03 pH units, and in KCl ranged from 3.65 to 4.11 pH units. The results of pH values measured in KCl were on average 0.97 units lower than those measured in water (*Fig. 1*).

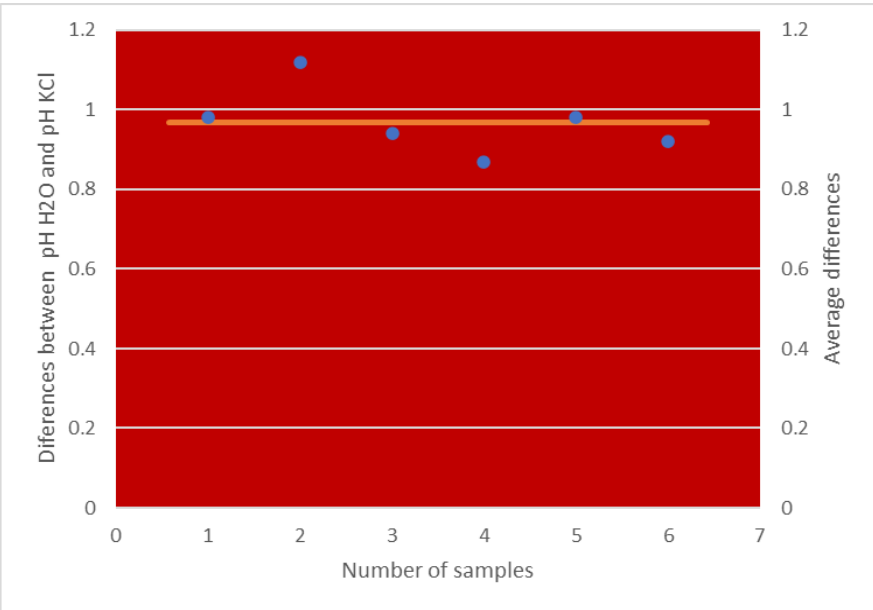

Figure 1. *Soil pH in strongly acid reaction class*

Analysis of soil pH for 911 samples leads us to the fact that a number of 136 samples have moderately acidic reaction, representing 14.92%. The values of soil pH in H_2O are increasing from a minimum of 5.10 to a maximum of 5.89 pH units. The values of pH in KCl ranged from 4.30 to 5.09 pH units. The value of the mean difference between the two eluents is 1.00 pH units (*Fig. 2*).

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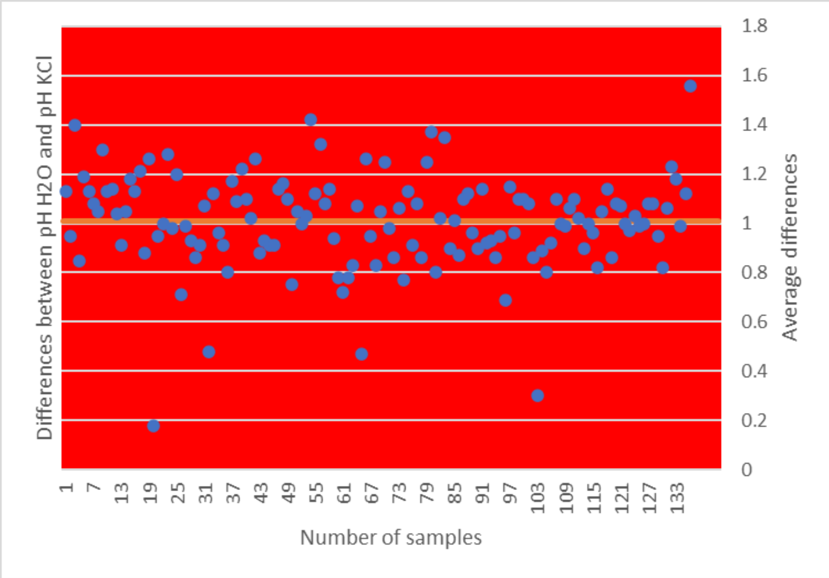

Figure 2. *Soil pH in moderately acidic reaction class*

The class of slightly acidic reaction is represented by 289 soil samples, meaning 31.72% from the total number of analyzed samples. It was registered a minimum value of 5.90 pH units and a maximum one of 6.79 pH units, in the case of H_2O eluent. The values determinate in KCl eluent ranged between 5.10 pH units to 6.09 pH units. The mean difference between the two eluents is 1.03 pH units (*Fig. 3*).

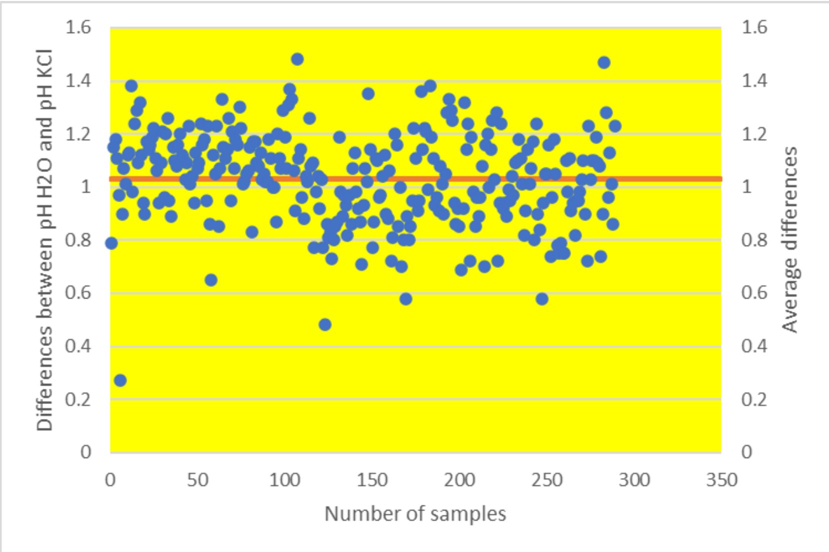

Figure 3. *Soil pH in slightly acid reaction class*

In the neutral soil reaction class 74 soil samples were placed, representing 8.12% from all the analyzed samples. In the case of pH in H_2O the determinated values ranged between 6.81 pH units to 7.20 pH units. In the case of soil pH in KCl the minimum registered value is 6.10 and the maximum one is 6.59 pH units. The average difference of the values between those two methods was 0.96 pH units (*Fig. 4*).

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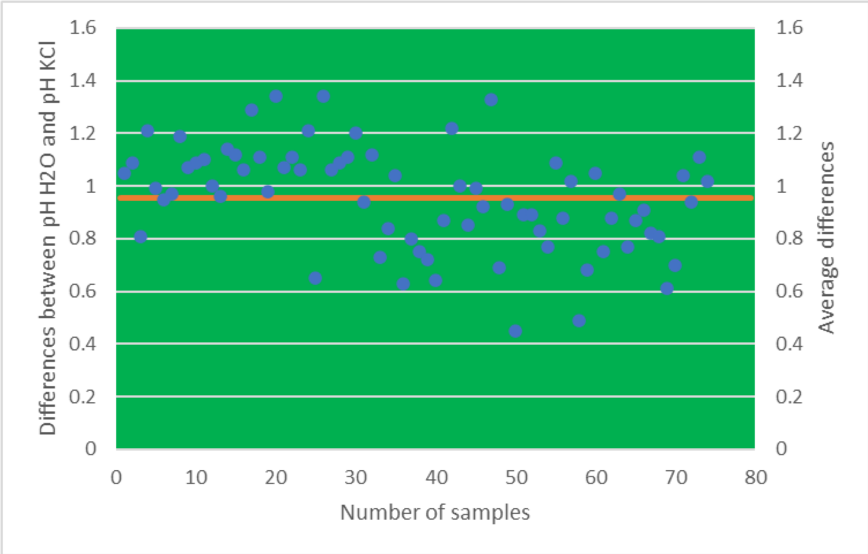

Figure 4. *Soil pH in neutral reaction class*

A number of 405 soil samples were registered in slightly alkaline reaction class, which represents 44.45% of the total analyzed samples. Soil pH values in H_2O are ranged between a minimum of 7.21 pH units to a maximum of 8.49 pH units. In the case of pH in KCl eluent the registered values ranged from 6.60 pH units to 8.07 pH units. The mean difference between the two eluents is 0.75 pH units (*Fig. 5*).

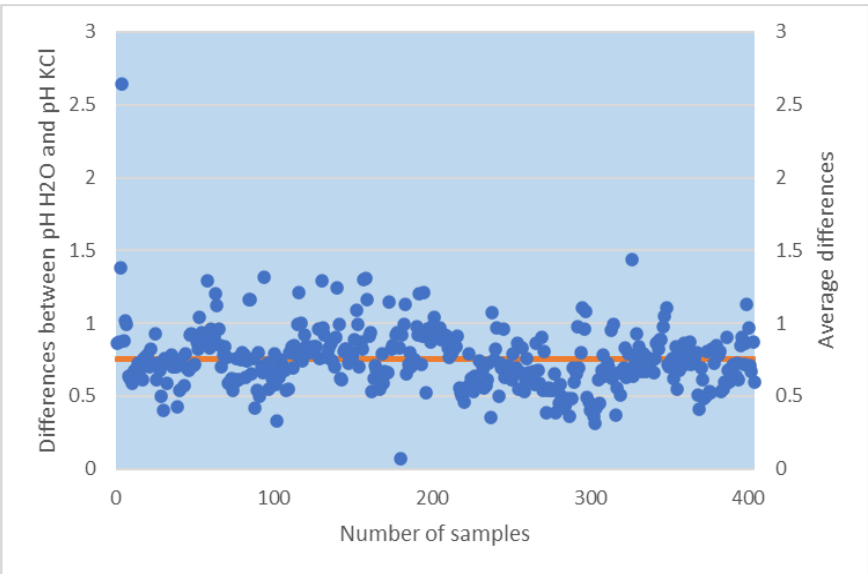

Figure 5. *Soil pH in slightly alkaline reaction class*

The 911 soil samples for which the pH was determined, separated by two methods into eluent H_2O (pH_{H2O}) and eluent KCl (pH_{KCl}), respectively, are characterized by the indicators presented in the statistical summary in *Table 2*.

The difference between the averages of the two groups is 0.90 pH units. The mean value for the sample group in H_2O was 6.98.

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Table 2. *Statistical summary describing pH values in H_2O and KCl*

Indicator	Indicator value (pH_{H2O})	Indicator value (pH_{KCl})
Mean	6.9808	6.0856
95% CIM Lower Bound	6.9181	6.0138
95% Upper Bound	7.0436	6.1574
Median	6.94	5.95
Std. Deviation	0.96477	1.10421
Minimum	4.12	3.60
Maximum	8.49	8.07
Range	4.37	4.47

Confidence Interval for Mean 95% (95% CIM) in which it is estimated to be placed the real value of the average, is given by the limits 6.91 to 7.04. For the group of values tested in the KCl eluent, the average value is 6.08 and the given limits of 95% CIM are 6.01 and 6.15 respectively.

Statistical testing of the differences between the two groups was performed using Paired Samples t Test in SPSS. The null hypothesis, regarding the fact that the data do not show differences between them was rejected, using the value $t = 115.1$ with $df = 910$ and $sig. < 0.001$. The differences between the two groups are therefore of statistical significance. The value of the correlation coefficient $r = 0.983$ with $sig. < 0.001$ indicates a strong correlation between the two sets of values.

In addition, nonparametric testing with Sign Test indicates that the differences between the pH values measured in the KCl eluent and those measured in the H_2O eluent are negative ($pH_{KCl} < pH_{H2O}$). The value of the test is Z = -30.1 with sig. < 0.001.

The choice of the model was made on the one hand by observing the linear trajectory of the correspondence pH_{H2O} - pH_{KCl} but also using the SPSS Regression/Curve estimation procedure.

The linear function, together with the polynomial with second and third degree, has a high coefficient of determination, $R^2 = 0.96$ with sig. < 0.001. The data consisting of the 911 pair values lead to the graphical representation in *Figure 6*.

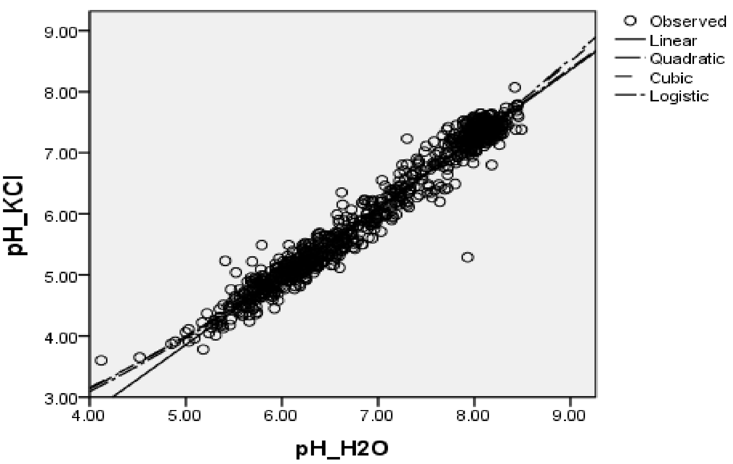

Figure 6. *Graphical representation of the pH values determined in the eluent KCl as a function of the pH values determined in the eluent H_2O, respectively the regression line (n = 911 paired values). Source: graphical representation using IBM SPSS 23*

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Moreover, in *Figure 6* were also graphically represented the trajectories generated by the proposed functional models. The high values of the coefficient of determination, respectively the value of sig. from *Table 3*, thus led to the choice of the functional models below.

Table 3. *Evaluation of the functional model that describes the relationship between pH values measured in H_2O eluent according to those measured in KCl eluent*

Model summary and parameter estimates							
Equation*,**	**Model summary**			**Parameter estimates**			
	R Square	**F**	**Sig.**	**Constant (b0)**	**b1**	**b2**	**b3**
Linear	0.967	26492.948	0.000	-1.771	1.125	-	
Quadratic	0.968	13765.799	0.000	0.733	0.388	0.053	
Cubic	0.968	13812.743	0.000	1.512	0.000	0.116	-0.003
Logistic	0.968	27197.178	0.000	0.952	0.717	-	-

*Dependent Variable (Y): pH_KCl. The independent variable (t): pH_H_2O
**Linear Y = b0 + b1*t, Quadratic Y = b0 + b1*t + b2*t^2, Cubic Y = b0 + b1*t + b2*t^2 + b3*t^3, Logistic Y = 1/((1/u) + b0*b1^t) [Documentation IBM]
Source: the results were obtained using IBM SPSS 23

Specifically, the expression of the linear model is:

$$pH_{KCl} = 1.125 \cdot pH_{H_2O} - 1.771 \quad \text{(Eq.1)}$$

Solving the above linear equation, the inverse expression is also immediately determined:

$$pH_{H_2O} = 0.889 \cdot pH_{KCl} + 1.574$$

The quadratic model has the following form:

$$pH_{KCl} = 0.733 + 0.388 \cdot pH_{H_2O} + 0.053 \cdot pH_{H_2O}{}^2 \quad \text{(Eq.2)}$$

The expression of the cubic model is:

$$pH_{KCl} = 1.512 + 0.116 \cdot pH_{H_2O}{}^2 - 0.003 \cdot pH_{H_2O}{}^3 \quad \text{(Eq.3)}$$

The logistics model is expressed as:

$$pH_{KCl} = \frac{1}{\frac{1}{14} + 0.952 * 0.717^{pH_{H_2O}}} \quad \text{(Eq.4)}$$

Through the results obtained in this study, we want to underline the fact that soil pH is a key parameter with the help of which we can observe the health of the soil as a

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whole, the availability of nutrients, the occurrence of pollution phenomena as well as the probability that some polluting elements end up in the human food chain, which is undesirable, as Grant (2009) and Zhang et al. (2019) also pointed out.

Discussion

The soil pH measurements in water are highly affected by soil electrolyte concentration compared to those measured in KCl, similar observations being made by Gavriloaiei (2012), Kabala et al. (2016) and Kome et al. (2018).

From Kabala et al., 2016 point of view, the difference between soil pH_{KCl} and pH in water, is that the addition of KCl helps to suppress the salt effect, named also the suspension effect or junction potential effect, which is due to the exchange of excess calcium and potassium ions with hydrogen and aluminum ions on the surface of soil colloids, when pH is lower than 5.5.

In farmlands that we use in this study, the soil acidification is due, in most of the cases, to an improper fertilizer application, which influence the nutrient availability for plants, but also, other chemical elements may manifest toxicity for the crops. This tendency of soil acidification, caused in particular by the abusive use of fertilizers and the non-use of calcium amendments, was observed also by Watros et al. (2019).

A topic of interest of the study is to determine a functional model to evaluate the pH values in one of the studied eluents knowing the corresponding value measured in the other eluent.

Similar studies have revealed the linear function as a suitable model for this purpose, but also second-degree polynomial or logarithmic functions were used (Gavriloaiei, 2012; Kabala et al., 2016; Kome et al., 2018; Jessy Mol et al., 2020; Minasmy et al., 2011).

This study focuses on possible mathematical relation between soil pH measured in distilled water in comparison with the one measured in potassium chloride, it is a case study on agricultural soils from Romania. In our country, we encounter a great variability of soil types, with often very different physical and chemical properties, mainly caused by the shape of the relief, the parent rock on which they were formed, the local climatic conditions, as well as the way of sustainable cultivation or not.

As it is well known and described by other researchers (Fageria et al., 2005, 2014; Tian et al., 2015), the main cause of soil acidification is leaching of bases as Ca, Mg, K, Na from soil profile, and affects large surfaces in Romania, mostly due to the improper utilization of fertilizers, especially with nitrogen ones for a long time by the farmers. In order to improve this inconvenience, besides applying amendments, a solution is also the cultivation of plants that tolerate acidity.

Also, as other researchers mentioned before (Sintorini et al., 2021; Robson, 1989; Jensen, 2010; Soumare et al., 2016), by understanding soil reaction in a certain area, we can better understand the management of soil nutrients, which is an important aspect in maintaining the soil productivity and default the quality of the agricultural products. Monitoring soil pH values is an important control tool, because by comparing the obtained data it can be observed if a process of acidification or alkalinisation is present in the studied area. By having knowledge about this phenomenon it can be prevent this trend to continuing through correct management measures. Similar results were obtained in Great Britain by Malik et al. (2018), showing that even there, arable soils also show a great variability of reaction classes, from moderately acidic to moderately

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alkaline. Analysis of the results from the soil survey in Romania shows that 91.85% of the soil resources are vulnerable to anthropic acidification and alkalinisation. A special attention must be paid to cultivated soils, formed naturally acidic or alkaline, in order to control, avoid and prevent anthropogenic soil degradation.

At the beginning of this study, it was impossible to predict what soil pH values we would deal with. However, the results of the analysis showed that, agricultural soils are overwhelmingly affected by the phenomena of acidification and alkalization. These two phenomena are dangerous, because they determine a limitation of soil fertility and, implicitly, a reduced productivity of crop plants. Given the results of this study, we want to draw the attention on the need to rethink the current fertilization methods, as well as the type of fertilizers used on a large scale in contemporary agriculture. It is certain that these phenomena of degradation of soil properties are found not only in the studied territory, but also in the other countries in East and Central Europe. At the same time, these phenomena should be further investigated, with the purpose of preserving and improving soil health. The statements presented above and based on the results of our analysis can contribute to the improvement of current knowledge about the importance of soil pH.

Conclusions

The analysis of 911 soil samples coming from the agricultural lands of the Romanian farmers, representing different types of soils and having different chemical properties leads to the general conclusion that over 90% of them are affected by the phenomenon of acidification and alkalization.

Completing this study, we were able to conclude that most of the soil samples fell into the slightly acidic reaction class, as well as the slightly alkaline one.

Soil reaction data determination in different eluents (H_2O and KCl) can be converted and integrated in international soil databases, using the mentioned equations, and also these equations can be utilized for intern laboratory quality control.

The variability of soil reaction classes, that can be observed during this study can be explained as usually soils which are formed in an arid climate are alkaline, despite ones formed in a wet and cold climate, which are acidic, and these climatic conditions are characteristic in Romania. Also, at regional scale, such as South-Eastern Europe, soil pH variations are influenced by local climate factors, especially in the last decades due to the actual context of climate changes.

The fact that the pH values obtained are so varied, from the strongly acidic to the slightly alkaline reaction class, regardless of the eluent used, is also due to the fertilization practices of the farmers but also to the parent material on which they were formed, as well as various environmental factors.

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APPENDIX

Appendix 1. *Soil pH raw data*

Sample	Strongly acid reaction class		Moderately acid reaction class		Slightly acid reaction class		Neutral reaction class		Moderately alkaline reaction class	
	pH (H_2O)	pH (KCl)	pH (H_2O)	pH (KCl)	pH (H_2O)	pH (KCl)	pH (H_2O)	pH (KCl)	pH (H_2O)	pH (KCl)
1.	4.89	3.91	5.10	4.30	6.01	5.22	6.97	6.19	7.82	6.96
2.	5.03	3.91	5.17	4.30	6.45	5.30	7.08	6.19	8.03	7.16
3.	5.00	4.06	5.18	4.30	6.73	5.55	7.19	6.38	8.18	6.80
4.	4.52	3.65	5.22	4.37	6.37	5.26	7.15	6.34	7.93	6.69
5.	4.85	3.87	5.24	4.37	6.10	5.13	7.20	6.21	8.02	7.14
6.	5.03	4.11	5.27	4.38	6.62	6.05	7.00	6.10	7.88	6.86
7.	4.42	3.65	5.28	4.38	5.94	5.04	7.24	6.27	8.20	7.21
8.			5.30	4.30	6.24	5.17	7.15	6.19	7.96	7.32
9.			5.31	4.31	6.24	5.23	7.20	6.15	7.98	7.36
10.			5.32	4.31	6.61	5.49	6.94	6.15	8.00	7.41
11.			5.33	4.32	6.10	5.10	6.92	6.12	7.95	7.29
12.			5.34	4.32	6.54	5.16	6.93	6.13	7.94	7.26
13.			5.35	4.44	6.43	5.45	6.88	6.12	7.94	7.32
14.			5.36	4.31	6.38	5.14	6.89	6.15	7.93	7.20
15.			5.36	4.31	6.33	5.04	6.98	6.16	8.03	7.35
16.			5.37	4.32	6.27	5.18	6.84	6.18	8.01	7.32
17.			5.38	4.32	6.25	5.10	6.90	6.16	7.97	7.36
18.			5.39	4.51	6.65	5.53	7.10	6.19	8.03	7.27
19.			5.39	4.51	6.35	5.41	6.91	6.13	7.62	6.86
20.			5.41	5.09	6.75	5.85	6.94	6.16	8.04	7.26
21.			5.44	4.49	6.48	5.31	7.00	6.19	8.06	7.36
22.			5.45	4.45	6.22	5.08	7.07	6.16	8.00	7.18
23.			5.46	4.45	6.17	5.01	6.98	6.12	8.10	7.37
24.			5.46	4.48	6.24	5.05	6.96	6.15	7.91	7.19
25.			5.47	4.47	6.20	5.10	6.83	6.18	7.34	6.61
26.			5.47	4.76	6.41	5.30	6.84	6.15	7.99	7.38
27.			5.48	4.49	6.72	5.66	6.93	6.17	7.99	7.26
28.			5.48	4.55	6.47	5.53	6.96	6.18	8.06	7.38
29.			5.51	4.65	6.60	5.51	6.92	6.18	8.08	7.58
30.			5.51	4.60	6.01	5.18	7.19	6.19	8.00	7.60
31.			5.52	4.45	6.09	5.13	6.82	6.18	8.02	7.26
32.			5.52	5.04	6.35	5.15	6.96	6.14	8.03	7.44
33.			5.53	4.41	5.90	5.14	7.12	6.39	8.00	7.27
34.			5.56	4.60	6.59	5.64	7.03	6.19	8.07	7.32

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35.			5.56	4.65	6.56	5.67	6.90	6.16	8.12	7.34
36.			5.56	4.76	6.67	5.52	6.86	6.23	7.97	7.27
37.			5.56	4.39	6.09	5.19	6.93	6.13	7.97	7.27
38.			5.58	4.49	6.42	5.34	6.94	6.19	7.97	7.27
39.			5.58	4.36	6.56	5.40	6.94	6.22	8.07	7.64
40.			5.59	4.49	6.37	5.17	6.86	6.22	8.16	7.62
41.			5.59	4.57	6.42	5.30	7.15	6.28	7.92	7.17
42.			5.59	4.33	6.41	5.30	6.79	6.15	7.95	7.19
43.			5.60	4.72	6.30	5.27	7.18	6.18	7.85	7.28
44.			5.60	4.67	6.12	5.13	7.20	6.37	7.61	6.82
45.			5.60	4.69	6.25	5.12	7.19	6.20	7.96	7.27
46.			5.61	4.70	6.06	5.15	6.81	6.18	8.05	7.37
47.			5.62	4.48	6.11	5.17	6.83	6.15	7.98	7.06
48.			5.62	4.46	5.97	5.13	6.85	6.16	7.32	6.69
49.			5.63	4.53	6.20	5.17	7.05	6.12	7.94	7.23
50.			5.64	4.89	6.62	5.55	7.20	6.18	8.06	7.34
51.			5.64	4.59	6.51	5.42	6.88	6.19	8.04	7.17
52.			5.64	4.64	6.57	5.33	7.20	6.34	8.02	7.20
53.			5.65	4.62	6.14	5.18	7.03	6.20	7.52	6.68
54.			5.66	4.34	6.64	5.46	7.18	6.41	8.21	7.27
55.			5.66	4.54	6.57	5.62	7.13	6.04	8.19	7.31
56.			5.66	4.34	6.53	5.30	7.01	6.13	8.20	7.30
57.			5.67	4.59	6.49	5.63	7.05	6.03	8.26	7.38
58.			5.67	4.53	6.72	6.07	7.04	6.55	7.56	6.67
59.			5.67	4.73	6.33	5.21	7.20	6.54	7.91	7.08
60.			5.68	4.90	6.43	5.38	7.06	6.01	8.24	7.28
61.			5.68	4.96	6.62	5.39	7.14	6.39	8.17	7.27
62.			5.68	4.90	6.38	5.53	6.97	6.09	8.21	7.31
63.			5.69	4.86	6.04	5.17	6.89	6.19	7.59	6.69
64.			5.69	4.62	6.76	5.43	7.20	6.44	7.43	6.61
65.			5.69	5.02	6.05	5.19	6.89	6.12	8.13	7.17
66.			5.70	4.44	6.26	5.15	6.96	6.15	8.17	7.32
67.			5.70	4.75	6.12	5.18	7.12	6.30	8.01	7.31
68.			5.70	4.87	5.96	5.10	7.17	6.36	8.13	7.35
69.			5.70	4.65	6.69	5.74	7.07	6.46	7.35	6.61
70.			5.70	4.45	6.40	5.19	6.90	6.20	8.14	7.37
71.			5.71	4.73	6.66	5.59	7.20	6.22	8.06	7.47
72.			5.72	4.86	6.07	5.19	7.20	6.28	8.10	7.50
73.			5.72	4.66	6.49	5.33	7.20	6.17	8.05	7.43
74.			5.72	4.95	6.54	5.24	7.20	6.20	8.06	7.52
75.			5.72	4.59	6.65	5.43			7.92	7.33
76.			5.72	4.81	6.37	5.36			7.23	6.67
77.			5.72	4.64	6.20	5.18			7.42	6.81
78.			5.72	4.86	6.25	5.20			7.84	7.23
79.			5.73	4.48	6.16	5.10			8.05	7.30
80.			5.73	4.36	6.23	5.18			7.60	6.80
81.			5.73	4.93	6.05	5.22			8.14	7.36
82.			5.73	4.71	6.37	5.20			7.89	7.26
83.			5.74	4.39	6.30	5.13			7.57	6.83
84.			5.75	4.85	6.02	5.13			7.99	6.83
85.			5.75	4.74	6.09	5.11			7.51	6.65
86.			5.76	4.89	5.90	5.17			7.96	7.31
87.			5.76	4.66	5.98	5.15			8.13	7.37
88.			5.76	4.64	6.38	5.33			7.94	7.52
89.			5.76	4.80	6.15	5.13			8.04	7.50

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90.			5.77	4.87	6.29	5.27			7.82	7.02
91.			5.78	4.64	6.48	5.30			8.07	7.57
92.			5.78	4.86	6.25	5.14			8.21	7.51
93.			5.78	4.85	6.78	5.78			7.98	7.32
94.			5.78	4.92	6.36	5.36			7.03	6.71
95.			5.78	4.83	6.06	5.19			7.35	6.65
96.			5.78	5.09	6.61	5.41			8.11	7.38
97.			5.78	4.63	6.32	5.21			7.42	6.87
98.			5.78	4.82	5.92	5.15			7.96	7.27
99.			5.79	4.69	6.74	5.45			8.03	7.41
100.			5.79	4.69	6.62	5.43			8.17	7.38
101.			5.79	4.71	6.23	5.16			7.42	6.84
102.			5.79	4.93	5.90	5.15			7.71	7.38
103.			5.79	5.49	6.19	5.18			8.14	7.51
104.			5.79	4.90	6.25	5.19			8.06	7.31
105.			5.79	4.99	6.72	5.66			7.72	7.01
106.			5.79	4.87	6.14	5.23			8.24	7.54
107.			5.79	4.69	6.60	5.12			8.45	7.77
108.			5.81	4.81	6.21	5.11			8.02	7.48
109.			5.81	4.82	6.17	5.13			7.78	7.23
110.			5.81	4.75	6.19	5.23			8.23	7.43
111.			5.81	4.71	6.17	5.29			8.30	7.46
112.			5.81	4.79	6.20	5.16			8.21	7.52
113.			5.81	4.91	6.11	5.19			8.26	7.41
114.			5.81	4.81	6.03	5.17			8.24	7.46
115.			5.81	4.85	6.58	5.50			8.30	7.31
116.			5.81	4.99	6.59	5.50			7.65	6.64
117.			5.81	4.76	6.38	5.61			8.02	7.02
118.			5.82	4.68	6.25	5.27			8.21	7.47
119.			5.82	4.96	5.94	5.19			8.23	7.31
120.			5.82	4.74	6.14	5.22			8.30	7.46
121.			5.83	4.76	6.58	5.55			8.22	7.42
122.			5.83	4.83	6.37	5.60			8.21	7.37
123.			5.84	4.87	6.63	6.05			8.29	7.48
124.			5.84	4.81	6.24	5.38			8.29	7.49
125.			5.85	4.86	6.09	5.28			8.29	7.45
126.			5.85	4.85	5.96	5.13			8.28	7.44
127.			5.86	4.78	6.21	5.48			8.32	7.48
128.			5.86	4.78	6.17	5.37			8.28	7.32
129.			5.88	4.93	6.07	5.22			8.24	7.48
130.			5.88	5.06	6.52	5.65			7.69	6.64
131.			5.88	4.82	6.10	5.19			8.17	7.20
132.			5.89	4.66	6.79	5.81			8.26	7.34
133.			5.89	4.71	6.58	5.69			8.24	7.47
134.			5.89	4.90	6.21	5.24			8.33	7.54
135.			5.89	4.77	6.27	5.34			8.45	7.62
136.			5.82	4.26	5.94	5.12			8.23	7.37
137.					5.96	5.19			8.21	7.47
138.					5.96	5.10			8.17	7.47
139.					6.16	5.19			7.83	6.93
140.					6.32	5.19			7.14	6.60
141.					6.32	5.34			8.02	7.03
142.					6.14	5.22			8.01	7.39
143.					6.37	5.50			8.00	7.39
144.					6.38	5.67			7.98	7.17

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145.					6.30	5.37			7.95	7.13
146.					6.64	5.57			7.67	6.85
147.					6.12	5.10			8.18	7.45
148.					6.51	5.16			8.11	7.36
149.					6.06	5.19			8.08	7.32
150.					6.28	5.51			8.12	7.32
151.					6.09	5.22			7.87	6.98
152.					6.12	5.10			7.07	6.60
153.					6.12	5.12			7.14	6.65
154.					6.31	5.35			8.19	7.49
155.					6.34	5.37			8.46	7.59
156.					5.90	5.16			8.16	7.34
157.					6.08	5.16			7.72	6.62
158.					6.50	5.60			7.80	6.69
159.					6.51	5.63			7.30	6.64
160.					5.91	5.15			8.28	7.37
161.					6.11	5.39			7.38	6.64
162.					6.44	5.63			8.12	7.59
163.					6.36	5.16			8.10	7.48
164.					5.90	5.17			8.07	7.36
165.					6.04	5.19			8.07	7.39
166.					6.14	5.14			8.20	7.54
167.					5.97	5.27			7.93	7.38
168.					6.45	5.65			8.02	7.23
169.					6.07	5.49			8.33	7.74
170.					6.03	5.14			8.41	7.74
171.					6.21	5.41			8.45	7.79
172.					6.74	5.89			8.44	7.78
173.					6.74	5.79			7.63	6.68
174.					6.44	5.22			8.15	7.33
175.					5.93	5.18			8.13	7.28
176.					6.52	5.61			7.90	7.07
177.					6.06	5.11			7.96	7.04
178.					6.13	5.17			7.90	6.96
179.					6.37	5.23			8.06	7.23
180.					6.42	5.20			7.30	7.23
181.					6.42	5.21			7.80	6.88
182.					6.67	5.68			7.72	6.73
183.					5.96	5.15			7.40	6.67
184.					6.52	5.33			8.12	7.47
185.					6.31	5.20			8.15	7.43
186.					6.14	5.21			8.15	7.35
187.					6.41	5.45			8.30	7.60
188.					5.93	5.10			8.34	7.61
189.					6.24	5.16			8.44	7.69
190.					6.23	5.22			8.27	7.29
191.					6.07	5.17			8.15	7.23
192.					6.09	5.14			7.55	6.65
193.					6.60	5.32			8.25	7.53
194.					6.18	5.15			7.68	6.77
195.					6.24	5.15			7.32	6.61
196.					6.78	5.53			7.75	7.23
197.					5.92	5.18			8.01	7.05
198.					6.56	5.70			7.97	7.07
199.					6.23	5.31			7.98	7.11

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2101_373392

200.					6.62	5.77			7.96	6.98
201.					6.59	5.90			7.98	6.94
202.					5.95	5.10			7.95	7.01
203.					6.14	5.12			7.94	7.03
204.					6.74	5.60			7.97	7.02
205.					6.75	5.51			8.00	7.03
206.					6.36	5.64			8.04	7.15
207.					6.25	5.16			8.14	7.23
208.					6.69	5.71			8.11	7.19
209.					6.25	5.40			8.08	7.17
210.					6.11	5.15			8.02	7.19
211.					6.35	5.46			7.98	7.21
212.					6.26	5.30			7.96	7.17
213.					6.51	5.43			7.99	7.18
214.					6.39	5.69			8.01	7.16
215.					6.18	5.12			8.02	7.18
216.					5.94	5.14			8.06	7.15
217.					6.21	5.21			7.78	7.22
218.					6.26	5.12			8.11	7.59
219.					6.35	5.10			8.09	7.59
220.					6.15	5.12			8.00	7.54
221.					6.24	5.16			8.11	7.55
222.					6.24	5.52			8.18	7.64
223.					5.98	5.14			8.08	7.29
224.					6.37	5.13			7.97	7.39
225.					5.99	5.17			8.12	7.50
226.					6.25	5.31			8.02	7.49
227.					6.24	5.35			8.15	7.51
228.					6.24	5.25			8.06	7.47
229.					6.26	5.31			8.08	7.50
230.					6.00	5.16			8.12	7.38
231.					6.15	5.18			8.11	7.38
232.					6.01	5.12			8.20	7.52
233.					6.07	5.17			8.00	7.44
234.					6.21	5.13			8.09	7.52
235.					6.20	5.19			7.62	7.01
236.					6.72	5.71			7.45	6.72
237.					6.30	5.48			8.42	8.07
238.					5.92	5.10			7.52	6.65
239.					5.95	5.18			8.06	7.31
240.					6.47	5.46			7.90	7.08
241.					6.03	5.16			7.08	6.61
242.					5.98	5.18			7.40	6.90
243.					6.73	5.93			7.39	6.66
244.					5.92	5.18			8.03	7.34
245.					6.19	5.29			7.33	6.67
246.					6.29	5.45			8.11	7.48
247.					6.57	5.99			8.19	7.53
248.					6.36	5.42			7.28	6.67
249.					6.29	5.24			7.88	7.21
250.					6.04	5.19			7.76	7.15
251.					6.11	5.15			7.03	6.64
252.					6.24	5.50			8.00	7.35
253.					5.99	5.13			8.17	7.48
254.					5.90	5.12			8.08	7.22

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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255.					6.73	5.68			8.02	7.47
256.					6.22	5.44			7.95	7.29
257.					6.64	5.89			7.17	6.64
258.					6.22	5.43			7.97	7.44
259.					5.93	5.18			7.99	7.38
260.					6.06	5.31			8.22	7.46
261.					6.50	5.40			8.18	7.52
262.					6.06	5.18			7.90	7.28
263.					6.28	5.17			8.08	7.47
264.					6.10	5.19			8.09	7.42
265.					6.14	5.20			7.98	7.40
266.					5.93	5.11			7.74	6.88
267.					6.12	5.17			8.03	7.35
268.					6.00	5.15			7.99	7.40
269.					6.04	5.16			7.83	6.93
270.					6.51	5.48			7.77	7.23
271.					6.63	5.53			7.65	6.84
272.					6.00	5.10			7.67	7.28
273.					6.67	5.95			8.03	7.49
274.					6.36	5.13			7.27	6.71
275.					6.00	5.17			7.69	7.15
276.					6.55	5.45			8.16	7.62
277.					6.31	5.21			8.08	7.43
278.					6.15	5.16			7.50	7.11
279.					5.91	5.18			7.22	6.66
280.					5.91	5.13			7.92	7.47
281.					6.59	5.85			7.89	7.31
282.					6.51	5.61			8.03	7.53
283.					5.92	5.15			8.06	7.64
284.					6.56	5.28			8.00	7.57
285.					6.64	5.68			8.01	7.56
286.					6.51	5.38			8.04	7.56
287.					6.62	5.61			7.81	7.45
288.					6.09	5.23			8.04	7.56
289.					6.15	5.19			7.87	7.18
290.									7.89	7.29
291.									8.31	7.66
292.									7.31	6.63
293.									7.92	7.23
294.									7.76	6.96
295.									7.31	6.62
296.									8.16	7.20
297.									7.72	6.64
298.									7.30	6.81
299.									7.48	7.02
300.									7.58	7.18
301.									7.88	7.46
302.									7.89	7.53
303.									7.73	7.42
304.									7.91	7.49
305.									7.98	7.37
306.									7.92	7.47
307.									8.05	7.37
308.									7.59	6.81
309.									8.00	7.36

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2101_373392

310.									7.94	7.25
311.									8.10	7.37
312.									8.05	7.36
313.									7.73	6.78
314.									8.06	7.44
315.									8.10	7.11
316.									7.88	7.51
317.									8.00	7.44
318.									7.81	7.15
319.									7.85	7.34
320.									8.07	7.40
321.									7.39	6.70
322.									7.46	6.63
323.									7.60	6.97
324.									7.88	7.09
325.									8.11	7.45
326.									7.64	6.62
327.									8.10	7.46
328.									8.29	7.58
329.									8.15	7.22
330.									8.20	7.42
331.									8.17	7.33
332.									8.27	7.60
333.									7.99	7.29
334.									8.03	7.24
335.									8.04	7.37
336.									7.90	7.13
337.									7.96	7.22
338.									7.98	7.24
339.									7.92	7.18
340.									7.99	7.33
341.									7.86	7.10
342.									8.03	7.17
343.									8.13	7.31
344.									8.17	7.28
345.									8.13	7.24
346.									7.81	6.83
347.									8.43	7.38
348.									8.49	7.38
349.									8.16	7.44
350.									8.18	7.48
351.									7.95	7.21
352.									7.96	7.20
353.									7.64	7.02
354.									7.30	6.66
355.									7.74	7.19
356.									7.89	7.21
357.									7.93	7.23
358.									8.07	7.29
359.									8.33	7.47
360.									7.35	6.63
361.									8.05	7.24
362.									8.02	7.25
363.									8.12	7.25
364.									7.81	7.09

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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365.									8.01	7.28
366.									8.07	7.32
367.									8.08	7.28
368.									8.01	7.50
369.									7.98	7.57
370.									7.85	7.16
371.									7.97	7.36
372.									7.79	7.31
373.									7.96	7.46
374.									7.09	6.68
375.									8.00	7.47
376.									8.09	7.57
377.									7.65	6.83
378.									7.50	6.77
379.									7.84	7.03
380.									7.28	6.63
381.									7.57	6.79
382.									7.54	6.73
383.									8.15	7.62
384.									8.18	7.63
385.									7.95	7.35
386.									7.46	6.66
387.									8.05	7.37
388.									7.73	7.13
389.									8.11	7.50
390.									7.97	7.26
391.									8.01	7.29
392.									8.09	7.45
393.									7.70	6.97
394.									8.11	7.50
395.									8.19	7.34
396.									8.35	7.45
397.									7.99	7.27
398.									8.22	7.36
399.									8.26	7.13
400.									8.12	7.15
401.									8.05	7.34
402.									7.95	7.28
403.									8.18	7.31
404.									7.78	7.18
405.									8.09	7.45

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