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An essay on the fertilization

ABSTRACT. The paper presents the author's views to all whom they may concern. An inspiration of the considerations was provided by the splendid works shown in the bibliography.

KEY WORDS: rational fertilization, careful fertilization, poise fertilization

Agriculture can be defined as man's activity aiming to produce agricultural raw materials made by a controlled use of plants and animals. Fertilization in crop production is one of many simple farming practices, which from the scientific point of view are connected with plant nutrition, soil variability, weather, natural environment and economic considerations. That is what makes practical problems in the crop management. From the agricultural point of view, there was established a division of elements into macro- and microelements. In crop production five groups of elements may be distinguished, and the essential elements in the development of plants include only three main groups of elements. The first, basic elements are C, H, and O. The second are macroelements: N, P, K, Ca, Mg, and S, while the third includes microelements: Fe, Mn, Zn, Cu, Ni, B, Mo, and Cl. The fourth, beneficial elements are Na, Co, and Si. The fifth, xenoelements are not essential elements for plants but in the agrosystems the occurrence of a smaller or bigger amount of a substance may sometimes be harmful to plants. A common term trace elements, for a group of some elements is certainly proper but the term toxic elements is not correct, because there are not toxic elements, and just the man is the greatest pest in nature, which by anthropopression leads to a situation that some elements make a problem of toxicity, which rather refers to chemical compounds in the feed and food, and sometimes to environmental hazards, too.

Agrosystem, as an agricultural term, came from the agronomic system, and may be defined as a system of soil and atmosphere in the environment of cultivated field; in terms of size, i.e. three-dimensional space, a commonly cultivated field refers to an area as a plain, i.e. surface. As long as agroecosystem is an agosystem and natural environmental of the agrosystem, then, it is rather an extensive and more undefined area. In general, it can be accepted that in fertilization, the most basic factors which should be taken into practical consideration are soil properties and soil conditions. Soil properties are relatively constant soil's traits such as chemical, physical and biological properties of the soil. Soil conditions are variable traits of the soil including soil air-water relations and temperature. Soil properties and soil conditions are connected with the fertility of the soil as well as fecundity of agrosystem, and are finally expressed by productivity of crops. Soil fertility comprises interactions between soil properties. The available mineral components in the soil are expressed as elements or ion content in the soil. The content of elements in the soil is the ratio of element mass to unit mass. The accessible nutrient component of plants is determined in the soil usually as the content of elements in the soil, too. Then, the quantity of nutrient component in the soil is expressed as the ratio of determined element mass to the soil mass as the soil layer and the area of the field. A supply of soil classes comprises practical estimation of mineral component contents in the soil. The usually expressed supply as low, medium or high interpreted practically may be at low supply, an application of a given fertilizing component which may influence a yield increase, at medium supply, an application of a given component may increase the yield or not, and high supply may mean the lack of influence of the applied fertilizing component on crop's yield. Fecundity of agrosystem comprises interactions between soil properties and soil conditions, the traits that influence the nutrients accessibility in the soil. Productivity of crops means efficiency of crops, and it is expressed by the cultivated plant's yielding. All this should be mentioned because there is a notional confusion in agricultural scientific literature, where despite soil fertility, often soil productivity is incorrectly used. Meanwhile, the soil is not and cannot be productive, it is evident and certain.

It is highly improper in the applications of fertilizing component in agrosystem to use an approach based on a view of similarity of plant nutrition and animal nutrition. Meanwhile, there are the most significance differences between nutrition in the plant's vegetation and animal's existence. In essence, the plants use mineral-C^{4+}, and the animals take up organic-C^{4-}. Further differences include the role of water in plant nutrition and animal nutrition. In plant's metabolism, water is both the substrate in chemical reaction and it makes the environment of chemical changes, too. On the other hand, in animal's metabolism, water is the only environment of chemical changes. In the plants for the production of organic compounds, the water is used up in the quantity of 0.002 kg H_2O per 1 kg of plant dry matter, and on average the water is taken up at about 1 kg water per 1 kg of dry matter production. The quantity of CO_2 and H_2O, which plants use for biomass production in the agrosystem, and the amount of substance of C in relation to macro- and microelements in plants, indicates that fertilization as application of fertilizing components: N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Ni, B, Mo, and Cl, should be considered only as a supplement application of fertilizing nutrients: NH_4^+, NO_3^-, $H_2PO_4^-$, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Fe^{2+}, Mn^{2+}, Zn^{2+}, Cu^{2+}, Ni^{2+}, BO_3^{3-}, MoO_4^{2-}, and Cl^-. It means that of many main important factors reducing crop production, such as light, carbon dioxide, water, temperature, diseases and pests, and fertilizing nutrients, it is easy to see that water is obviously the most important fertilizer applied in agrosystem.

In general, different materials are applied in plant production. An application of organic matter in the soil is really an application of organic-C, in the case of application of farm yard manure in the quantity of mass 1-3 kg/m^2 it is applied 0.25-0.75 kg/m^2 of dry mass of organic matter, and the rate of N in the range of 0.005-0.015 kg/m^2. Fertilization, as the application of fertilizers in agrosystem in the quantity of fertilizers mass 0.005-0.05 kg/m^2, i.e. the rates of fertilizing components in the range of 0.0001-0.025 kg/m^2. And liming as application of base compounds in the quantity of mass 0.1-0.5 kg/m^2, i.e. the rate of CaO in the range of 0.025-0.25 kg/m^2. In fertilization, that is to say in the application of fertilizers, two quantifications are often misused, the first is the rate of fertilizing component, and the other is the quantity of fertilizer mass. The rate refers only to fertilizing component, and it is the ratio of fertilizing component mass to the area unit of the field, and usually it is expressed in kg/ha. On the other hand, quantity as a doze or portion refers to the mass of fertilizer, and may be expressed as fertilizer mass on the area unit of field, or on a given area of field, e.g. if urea is applied in the quantity of 350 kg on the field of 7 ha, then the rate of nitrogen is 23 kg/ha.

Generally, the content is the ratio of the determined mass of matter to the whole mass of matter, and may be expressed in units or in indices. Practically, content is usually expressed in a percent index. From definition, percent is a ratio of a part to the whole, then as a ratio of two values of the same system. Percent index is commonly used, because it may express any state or situation.

Also, it make a calculation easier, especially when the decimal fraction as factor is used. In the plant analysis the determination of dry mass is a very important analysis, because it gives the basis to express the content of elements in the plant by recalculation into waterless plant's mass. Practically, it is also important to express the nearest of elements content in the percent index, e.g. if the element content in plant is 0.0001%, i.e. in the fundamental unit mass is 10^{-3} g/kg, i.e. 1 ppm. If the elements content in a soil or a plant is 10^{-6} g/kg, it is 10^{-3} mg/kg, i.e. 1 ppb, then the nearest in the ppm should be 0.001. Now it is clear that giving the elements content in soils or plants is expressed in the nearest as 0.0001%, is not exaggeration, but necessity, because the data or results may be properly recalculated to the nearest of 1 ppm, as sufficient in the agrosystem. However, in fertilizers, if a fertilizing component is expressed practically in % to the nearest of 1.0 or 0.1, it is sufficient precision, of course. Nevertheless, elements are a specific form of substances; therefore, elements content should be expressed as the amount of substance, e.g. when nitrogen content is 0.0255%, i.e. 18.205 mmol N/kg. Expression of the content of elements in the amount of substance unit is useful to calculate the ratios of elements and to determine a sequence of elements content. For example, if the content of B is 5 ppm, and the content of Cu is 5 ppm, then mass elements ratio of B to Cu is 1, and real molar elements ratio of B/Cu is 5.8.

It is necessary to commonly use the units of the SI system in the science and practice, too. However, the notation of units is not connected with those used the IS unit system. Meanwhile, the notation of the units is sometimes quite strange and without any physical sense, e.g. $plant^{-1}$, cut^{-1}, pot^{-1}, ha^{-1}, day^{-1}, $week^{-1}$, $month^{-1}$, $year^{-1}$, $rabbit^{-1}$, rat^{-1}, etc. And the only virtue of such notation may be a laughing mood. The notation of units may be text or power style, but power notation is necessary only when in the notation there are more than two units together, e.g. g m^{-2} s^{-1}. Then, the notation of the units, e.g. g/kg is correct, as well as notation of the g kg^{-1}, and the right notation may be too, e.g. the 5 g/10 kg i.e. 5 g per 10 kg or the 5 g/15 plants, i.e. 5 g per 15 of plants. There is no superiority of text or power notation, nor is there any need to write $3 \cdot 4^{-1}$ instead of 3 : 4 or 3/4. And multiplication sign as ' · ' should be used only between the numbers in the floating point notation, but without the sign ' · ' between the units, e.g. $5 \cdot 10^{-3}$ g kg^{-1}. Sometimes it becomes evident that in some research so much mathematic approach appears as there is a power style notation of units.

Incorrect calculations and interpretations of pH index are often found in scientific literature, and pH index is often named as pH unit, which is a basic error, because pH is not any unit, of course. Values of pH index are commonly and falsely considered as a set of pH numbers data. Often too, even in serious scientific papers it is written that values of pH will change by a unit. In this case, it probably means that the value of pH index changes by value of 1, e.g. from pH 3 to pH 4. However, such an interpretation is incorrect, because the change of index value from pH 3 to pH 4 is not the same as the change from pH 7 to pH 8. Furthermore, many errors are made during statistical calculations using pH index. Thus, one must not calculate the mean value directly from the value of pH index. It is easy to show that the mean value for pH 4 and pH 8 is not pH 6, but the correct mean value is pH 4.3. The evidence will not be presented in the hope that the reader will feel like testing it himself. Also, in calculation of variance analysis experimental data expressed with pH index must not be used, because in this statistical method based on the mean values experimental data must be a normal distribution, which cannot be fulfilled in this case. Besides, the relationships between values of pH index and other experimental data must not be calculated, because pH index in fact is number value of the 10^{-pH}. Then, false statistical calculations based on the pH number data often lead to a nonsense of interpretations.

Fertilizer recommendations define the rates of fertilizing component and the quantity of fertilizers mass for application needs of the agrosystem and based on the nutrient requirements of crops and fertilization. Nutrient requirements of crops determine the total fertilizing component uptake by plants to produce the yield with the remaining mass of other parts of crops, and expressed in the quantity of fertilizing elements per 1 ton of yield, e.g. for cereals it is at about 24 kg N per 1 ton of grains. Fertilization needs of an agrosystem determine the fertilizing component that should be applied to obtain the assumed yield, then fertilization needs include nutrient requirements considering soil availability supply and natural conditions of agrosystem, and they are expressed in the rate of fertilizer component to the application in the field.

Research on optimization of the application of fertilizers are not a proper way of looking for the practical progress in fertilization. In agriculture production process cannot be normalized because materials used for the production during the metabolic processes of living organisms change properties of the substrate, then in the final products there are other compounds and substances with fully exchanged properties of products. In the plant development, which includes growth and organs differentiation, the substrates are completely changed to absolutely other and new product to plant's biomass. The natural conditions in the crop production are not repeatable and never happen again; therefore, agricultural production should not be considered as a manufacture. Then, instead of optimization of the fertilizing component rate for every field, which is difficult to perform in practice and not a realistic way to apply, one should be looking for a simple way in fertilizer recommendations through a search for the modern poise fertilization.

In elements composition in the soil and in the plants there is very important and useful information in the poise fertilization. For example, take into consideration the plant elemental composition if assumed that elements content in the flowering stage of cereals are mean, e.g. N 1.4231%, P 0.2535%, K 1.7407%, Mg 0.0729%, and S 0.1749%, then series of element content based on the mass unit is: K > N > P > S > Mg, and a real series based on unit of amount of substance is: N > K > P > S > Mg. The series of elements value ratios, in the scheme of elements sequence by the next element, based on the mass unit is: K/Mg > N/Mg > K/S > N/S > N/P > P/Mg > P/S > N/K > Mg/S > P/K, and real series of values element ratios based of amount of substance is: N/Mg > N/S > K/Mg > N/P > K/S > P/Mg > N/K > P/S > Mg/S > P/K. However, calcium is the essential nutrient for plants and was not excluded here accidentally.

Maybe, poise fertilization is not an adequate name referring to fertilization, but in some way it is wise; it can be hardly correctly said when the native language of the author is not English. Thus, poise fertilization may be defined as application of fertilizer components in an agrosystem basing on, in the first place, the ratios between elements in crops at the flowering stage, and considering the nutrients component occurring as minimum in the agrosystem. In fact, any proper fertilization may be named as poise fertilization. Therefore, the notion should be widened using additional terms and it may be also minimal, rational, balanced, careful, economic fertilization. An exception is ecological fertilization because now all things may be ecological. Therefore, ecological fertilization could improperly suggest crop production without fertilization, no fertilization or zero fertilization. The basis for poise fertilization should be recognition of agrosystem, and looking for the most limited factors of crop yield by a diagnosis of soil and plant analysis. The basic determination of element ratios in the fertilization could be plant elemental composition at the flowering stage of 5 fertilizing components: N, P, K, Mg, and S, and on the basis of the ratios to the element which limits the crop yield if it is, e.g. N, then in poise fertilization should include the ratios: P/N, K/N, Mg/N, and S/N.

Fertilization as top dressing should regard mainly nitrogen, and practically may be determined using a control plot. Foliar fertilization may be considered as preventive or supplementary application of fertilizing component, mainly microelements. However, most often, foliar fertilization is applied without reasonable needs as an act of kindness and just in case. The great practical problem in fertilization is commonly expressed a fertilizing component, e.g. P and K as oxide forms, i.e. P_2O_5 and K_2O. Such oxide forms do not exist, either in the soils or in the plants, nor in fertilizers. It should be changed because generally speaking, it is traditionalism, and of course anachronism, and what more, a legal nonsense. However, oxide form CaO is correct only if equivalent of bases is expressed in materials applied as liming.

And what do people know about fertilization? Everybody knows that fertilizers are harmful and an application of fertilizing compound to the soil is dangerous, i.e.: $(NH_4)_2SO_4$, $NaNO_3$, KNO_3, $Ca(NO_3)_2$ $4H_2O$, NH_4NO_3, $CO(NH_2)_2$, $Ca(H_2PO_4)_2$ H_2O, $Ca_3(PO_4)_2$, $NH_4H_2PO_4$, $(NH_4)_2HPO_4$, KCl, K_2SO_4, $MgSO_4$ H_2O, and others, e.g. $CaCO_3$, $MgCO_3$, $CaSO_4$ $2H_2O$, etc. And nobody knows that the same chemical compounds are added to food, too, i.e.: ammonium sulphate, sodium nitrate, potassium nitrate, calcium nitrate, ammonium nitrate, urea, monocalcium phosphate, tricalcium phosphate, monoammonium phosphate, diammonium phosphate, potassium chloride, potassium sulphate, magnesium sulphate, and others, e.g. calcium carbonate, magnesium carbonate, calcium sulphate, etc. And hardly anybody knows that the crop yields without fertilization may even attain 1 ton grain per hectare. Then, recommending crop productions without fertilization means simply lack of knowledge. The [illegible] and common misconception connected with fertilization is frightening people with fertilizers. Nevertheless, fertilizing compounds in the fertilizers are quite harmless. However, application of fertilizers in inappropriate amounts and proportion may influence the quality of crops yield as well as the quality of environmental nature. Then, in practice, fertilization should regard a careful application of fertilizing component for the sake of yield quality without environmental hazards. It is commonly known that the yield of crops depends mainly on the weather, and that the knowledge of general rules of fertilization is often more important than the authorized fertilizer recommendations. However, it easy to look around to see that fertilization is most often based on the farmers' intuition.

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