ASSESSMENT OF OPTIMUM SOIL FEATURES AND PLANT FOOD COMPOUND DEFICIENCY USING THE METHODS BASED ON FEEDBACK PRINCIPLES

DOI:10.24411/2588-0209-2018-10014

UDK 631.41 631.4

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Summary

The expediency of assessment of plant biophile element supply using the feedback principles is shown in this paper. The experimental data on assessment of plant needs for food compounds by chloroplastid activity, the content of positively and negatively charged cation complex compounds, by the photosynthesis parameters of plants developing in soil suspension after bringing the ions under study into the suspension are presented.

The methods are based on principle addition into the soil or plants and on the plant feedback analysis and the extremum assessment. The expediency of their use for the assessment of plant needs for food compounds (plant species and cultivars depending on their stage of development) has been shown by their absorption out of the analysed soil suspension, and then out of the culture solution. The assessment of sorption properties of plant root systems is provided.

Keywords: soil fertility, need for food compounds, photosynthesis, complex compounds, sorption properties of roots

The assessment of soil food compound supply and soil contamination level is of great relevance for agroecology and economy. Soil and plant analyses, field and greenhouse trials are used to determine these problems. However, under the sufficiency of biophile elements in soil, they may not supply to plants because of extremely high or low wetness and temperature indexes, where there are soil ions which block either ion delivery from soil to roots, or their transfer from roots to leaves.

The plant diagnostic method makes it possible to determine the elements failure in leaves, but the ion under investigation may not pass to the leaves for several reasons. That sidelines the using of just soil analytics or just plant analytics for the assessment of plant needs for food compounds.

Field and greenhouse trials give an objective account of soil and plant food compounds supply and their contamination level. However, they require high inputs and take long time. Given that the regularities arranged for certain soil and conditions, for certain species and varieties of plants, are not suitable for other conditions and plants [1, 4, 6, 10, 17],.

In our opinion the optimal experimental method of the assessment of plant needs for food compounds is the method which is based on feedback principles: bringing an element into the soil or the plant – identification of the plant feedback response – optimal stimulation seeking.

Soddy podzolic [2, 9] and black [11, 12] soils, and some other soil kinds which stand in marked contrast by their properties and the level of heavy metals pollution, are chosen as a subject of research. Apple trees [9], roses, rice, herbs of taiga-forest zone, wheat, fir-trees, lime trees have been used as biological tests.

The research methodology was made up of the assessment of positively and negatively charged complex compounds content in plants [13], of the assessment of plant photosynthesis activity [12], of the sorption properties characterization in root systems [11], of the soil and plant evaporation tests [15], of the chloroplastid activity tests [19], of the color spectrum evaluation in leaves [18, 13]. The analyses of the element concentration in soil and plants were carried out by standard methods [2, 3, 5, 14].

Experimental procedure

Assessment of plant needs for food compounds by bringing them into the plants and by the plant feedback response analysis

The plant food compound deficiency can be specified by the leaf chemical composition [3, 5, 18]. Reportedly, the plant food compound supply can be long-range estimated by the leaf color spectrum using computerized diagnostics methods, by electrophoretic element bringing into leaves and analyses of photosynthesis parameters, by electrophoretic element bringing into leaves and footstalks and definition of positively and negatively charged complex compounds content in them, by chloroplastid activity. That is illustrated by the experimental material available from our studies.

Definition of the plant food compound deficiency by the leaf color spectrum

Reportedly, plant food compound deficiency is reflected in the leaf color spectrum (leaf ribs, leaf centers, leaf edges). That is illustrated by the following tabulated data.

Table 1

Color spectrum of the soil with biophile element deficiency

Variant	Color intensity									
	C	M	Y	K	L	A	b	G/M	C/Y	M/Y
Check	61,2	37,2	58,8	45,5	34,5	9,0	7,2	8,5	1,0	0,60
N deficiency	15,2	23,7	80,2	5,0	76,0	1,7	58,0	0,6	0,2	0,30
P deficiency	50,0	19,7	77,2	19,2	57,0	20,0	32,7	2,5	0,6	0,25
K deficiency	52,0	21,0	74,2	21,7	54,5	19,5	28,2	2,5	0,7	0,28

As reflected by the submitted data, deficiency of some plant biophile elements may cause the variation of leaf color spectrum intensity in tristimulus values CMYK, Lab, and the color relation variation.

The deficiency = f $\Sigma k1\lambda1$; $ki\lambda1/\lambda2$; $kn\lambda2/\lambda3$ and etc. (for different plants and different leaf parts these indexes have to be determined for different wavelength).

Quite simple express estimation method of the assessment of soil and plant food compound supply and their contamination level is electrophoretic element bringing into plants and identification of the object feedback by the content and the proportion of positively and negatively charged ion compounds content, which is defined by the chemical autography method based on electrolysis.

Podzolic illuvial-ferruginous sandy-loam soils and soddy-alluvial sandy-loam soils of Prioksko-Terrasny Biosphere Reserve, along with pine and lime trees of the soils under study are chosen as the subject of research.

When using the feedback system for the assessment of plant food compound supply, the ions from the ion-permeable membrane saturated with them were being transferred electrophoretically into leaves under 9V voltage for 5 minutes. And after 30-minutes break the branches were excised off the tree, and in 3 hours the mobile ion content was determined in the plant matter using the chemical autography method based on electrolysis at the previously indicated parameters. The elements, which came on a sheet of the chromatographic paper proximate to catelectrode and anelectrode, were eluted out of the sorbing agent 0,1n HC1, and then were defined with the atomic absorbing spectrophotometer.

The test principle is based on the fact that if there is no element excess in the plant then its bringing into the plant causes the element complex formation with the plant metabolism products. The ionic form concentration (Mn+ when adding a cation or An- - when adding an anion) does not increase dramatically. The same sort of situation occurs for the soil. If the soil or plant are polluted by the element brought into them, then selective sorption spaces are occupied, and the amount of ion compound forms not united in complexes (-Mn+ - for cations and An- - for anions) increases under the element electrophoretic bringing into the object. Severable breach of this regularity may be linked to the formation of positively charged cation complexes and negatively charged anion complexes, to the disrupting of the complexes with metabolism products under high rate of ion application into the object, due to change of pH, Eh, ionic strength. Herewith, this method can be used for the ions which are prone to complex formation.

Reportedly, the bigger quantity of ML^{n-}/ML^{n+} ratio was specific to Mn, Fe (2,1-2,4), and the smaller one - to Mg (0,8). The similar relation was specific to pine straw. Electrophoretic addition of copper into lime leaves increased the content of mobile compounds Cu in leaves, and Zn addition increased the content of mobile compounds Zn in leaves. Herein, their positively charged compounds quantity rose too.

Under electrophoretic transfer of H_2PO_4 into plants the quantity of negatively charged Zn, Mn, Fe, Cd, Cu compounds decreased, but the quantity of negatively charged Mg compounds (obviously Mg phosphates) rose. The electrophoretic addition of NO_3 into plants mostly increased the mobility of all leaf cations, upon that the quality of their negatively charged compounds increased too. The electrophoretic addition of Pb, Ca, NH_4 into leaves caused the reduction of the quantity of negatively charged compounds of all cations under study.

Reportedly, under electrophoretic transfer of Cu into acerouse leaves the content of negatively charged copper compounds in it changed from 0,6 to 1,8, and the positively charged copper compounds content changed from c 0,5 to 1,4 mg/l. The content of Zn negatively charged compounds was varied from 0,8 to 4,2 mg/l by Zn bringing into acerouse leaves, and the content of positively charged ones was changed from c 0,8 to 4,1 mg/l. The content of mobile Fe and Cu was sharply increased by the electrophoretic addition of К+ into acerouse leaves, evidently resulting from some structural damages. Thereby, the content of positively charged ion compounds rose notably.

The content of mobile iron compounds in acerouse leaves was increased by electrophoretic addition of both Cu, Ca, Pb, Zn and NH4+, NO3- into leaves. The same sort of situation occurs for Cu and Zn. However, electrophoretic ion addition into acerouse leaves had far less effect upon Cd, Mg, Mn mobility.

Definition of the plant food compound deficiency by photosynthesis parameters under electrophoretic principlet addition into leaves

Reportedly, the feedback advanced technique is electrophoretic element addition into leaves – the plant feedback identification by photosynthesis parameters.

Table 2

Variation of rose leaf photosynthesis intensity under bringing Mg, Ca, Zn into them

Variant	Photosynthesis, mole/m2per sec
check	11,7±0.2
+ Mg	14,2±0,4
check	13,6±0,1
+ Ca	14,8±0,1

check + Zn	12,9±0,9 15,6±0,2

As reflected by the submitted data, the electrophoretic addition of Mg, Ca, Zn into rose leaves have increased the leaf photosynthesis, that is illustrative of these elements deficiency for the plants.

Definition of the plant food compound deficiency by chloroplastid suspension activity

The assessment of plant needs for food compounds by chloroplastid activity was worked out by A. Pleshkhov and B. Yagodin [19]. The method made a good showing under production conditions at plant cultivation in growing houses. In compliance with the methodology, the elements under study are added into the chloroplastid suspension, and then the deficiency or excess of the tested elements is evaluated by the change in chloroplastid activity in the required time lag.

It has been established that plant needs for food compounds depends on the stage of plant development. So, reportedly, at cucumber cultivation between 6th and 11th weeks of development the plant needs for nitrogen were 109% against the optimum content, the needs for phosphorus were 101%, for kalium - 95%, for calcium - 90%, for magnesium - 81%. In 13-14 weeks of the plant development the needs for N in percentage correlation against the optimum was 111, for P – 96, for K – 110, for Ca – 104, for Mg – 109%.

Culture solution composition was notable for different plant cultivars. So, the increase of chloroplastid activity for ground nut varieties GH-119, 47-10 and 28-206 under addition of P2O5 into their suspension was 8,1±1,6; 18,2±2.3 and 16,7±1,1 appropriately. The less need of GH-119 for phosphorus was in evidence.

Assessment of soil food compounds supply by bringing them into soil and soil feedback analysis

Express methodology for the assessment of soil ion compounds in the transformation field under their electrophoretic addition into the object and their further analysis of positively and negatively charged compounds content in the soil was suggested by us. The soil examination approved that negatively charged Fe, Mn, Cu compounds predominated in A_1 horizon generally, and positively charged ones were in B_{OX} horizon. In the majority of horizons Mg was featured by positively charged compounds.

The electrophoretic ion addition into wet soil was carried out under 9V voltage during 5 minutes. Then in 60 minutes the ion ejecting out of the soil was made by the chemical autography method based on electrolysis under the same electrochemical parameters.

Under electrophoretic addition of ions into soil their active form content increases, the correlation of positively and negatively charged compounds changes. Meanwhile, the ions transferred electrophoretically into the soil interact with already-existing compounds based on the effect of competitive complex formation and displace other absorbed ions out of the soil solid body.

Under electrophoretic addition of phosphates into soil the phosphate complexes of multivalent cations may be formed, and formation of precipitation may be possible under high concentration of phosphates and cations. It is much more likely that negatively charged complexes of multivalent cations are formed, that must cause the increase of the quantity of their negatively charged compounds in the soil.

Under electrophoretic addition of ions into soil other cations are excluded from the solid body of the soil absorbing complex. Thereby, it's much more likely that they will appear in ionic form, and only partially they will be in the form of hydroxy-complexes, so the increase of the quantity of positively charged ion compounds is most probable.

The negatively and positively charged cation compounds ratio in a check was 1,5±0,4 for all horizons and soils under study; it was 1,2±0,2 under electrophoretic addition of Pb, Ca, Cu into soil; it was 0,75±0,1 under electrophoretic addition of H2PO4 into soil. The evidence was indicative of predomination of negatively charged cation compounds in A1 horizon, of the disruption of organo-mineral complex compounds both under Pb, Ca, Cu adding into soil and H2PO4-adding notedly.

Assessment of plant needs for food compounds by bringing them into soil and by the feedback analysis of the plants germinating in this soil

Reportedly, the investigation of the state of both soil and plants and employing the methods based on the feedback are more meaningful for the assessment of needs of the plants germinating in the soil for food compounds.

Assessment of plant needs for food compounds by soil evaporation and plant transpiration product profile

Under food compound deficiency in soil the plants eliminate them marginally during transpiration, and under their excess they eliminate considerably. The following table data pictorialize that.

Assessment of plant food compound deficiency by plant transpiration product profile

Table 3

Copper elimination during plant transpiration

Plant	Variant	Cu in transpiration products, mg/l
dandelion	check	0,13
	+ Cu	0,27
plantain	check	0,03
	+ Cu	0,35

Plant food compound absorption out of soil suspension and culture solution as a soil fertility criterion

The perspectivity of the assessment of plant food compounds supply by plant absorption of these compounds out of the test soil suspension and then out of the culture solution was shown in the conducted studies. Under some principle deficiency in soil they are taken up by the plants out of the culture solution more efficiently then. Such an example is presented in the following table.

Table 4

К and Ca absorption by root systems of wheat germs out of soil suspension and then out of culture solution, mg/100 g

Variant	Content	
	К	Ca
soil suspension	50,1	27,0
+ plant	43,3	18,5
culture solution	32,8	4,0
+ plant	24,4	15.1

It is seen from the data presented, the plants placed into the culture solution after their being in the soil suspension have absorbed kalium but have eliminated calcium. That indicates K deficiency and Ca excess.

Definition of plant biophile element deficiency by plant photosynthesis parameter variation under principle bringing into the soil suspension where the plants are cultivated

Plant photosynthesis parameters change substantially under the change of soil suspension composition where these plants develop. When adding a toxicant into the suspension the photosynthetic rate subsides but CO_2 content in intercellular ducts increases, when adding missing food compounds, the photosynthetic rate increase is in evidence. This is evidenced by the data of the following tables.

Table 5

Change of photosynthesis parameters of the plants developing in soil suspension under $Pb(NO_3)_2$ addition into it

Variant	CO_2 content in intercellular ducts*	Stomatal resistance**	Photosynthetic rate***	Transpiration ****
check + Pb	377±65 1134±290	20,3±2,7 127,4±16,2	6,6±0,7 2,2±0,3	0,6±0,1 0,2±0,1

*) рpм; **) sec/Ohm; ***) mole/m2per sec; ****) mole/m2per sec

Table 6

$Ca(OH)_2$ influence on photosynthesis of the plants growing in sour soddy podzolic soil

Variant	CO_2 content	Stomatal resistance	Photosynthetic rate	Transpiration
check + $Ca(OH)_2$	382,4±22,8 308,8±44,3	54,9±9,9 40,1±5,7	0,9±0,1 1,6±0,2	0,2±0,03 0,3±0,03

Consequently, the method of the assessment of soil ion transformation under their electrophoretic adding into the soil and under the further analysis of positively and negatively charged ion compounds in the soil is offered on the ground of the studies conducted. As compared to other methods the advantage of the recommended one is due to the fact that only cation or anion is added into the soil, not both at once.

The electrophoretic principle addition into the leaves and the further definition of positively and negatively charged compounds in the leaves are proposed for the assessment of the plant food compound deficiency. Under the particle excess in the leaf its supplementary electrophoretic addition causes the decrease of complex compounds of this particle in the leaf (for Cu, Zn, Mn, Fe – the decrease of negatively charged compounds).

The method based on the feedback principles – principle addition into the soil suspension – the feedback identification of the plants which grow in this suspension by plant photosynthesis parameters is introduced for the assessment of the optimum soil features for certain cultures and cultivars.

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