Bauxite Residue Safety Disposal and Possibilities to further Utilisation. II. Maize Plants Growth on the Acidic Soils (Pilot and Demonstration Stage)

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Abstract

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A new approach of bauxite residue use in agriculture concerns remediation of the acidic soil by deep reshaping of the land surface layer, in order to change its agro-chemical properties and to achieve a reasonable degree of fertility. This target was reached by using three soil properties control adjuvant: the bauxite residue for better pH and soil properties control, the organic fertilizer as a source of organic carbon and the Nitrogen (N), Phosphorus (P) and Potassium (K) or NPK mineral fertilizers as a source of the main macro and micronutrients. In an experiment carried out at glass house scale on maize plants, it was proved the above adjuvant promoted intensive vegetative growth in maize plants (waist, green mass and dried mass), as well as the high productions in cobs and grains. Also, samples of the harvested green mass, cobs and grains contain macronutrients, micronutrients and heavy metals in normally limits of concentration, usually found in maize. These results backed up all the reasons to resume the experiments at a pilot scale in natural conditions, on a well-known soil as a natural acidic soil. The research program has included the best choice of experimental factors, a meaningful analytical and measurement program, and the maize crop parameters measurements covering all the maize plants morphometric data at both flowering and maturity stages. Also, the macronutrients, micronutrients, heavy metals and lanthanides content were carefully investigated in soil, plants and grains. All the soil and crop parameters measurements, carried out in the larger experimental field set up, are in good agreement with the glass house experimental data. Accordingly, these new collected data confirmed, as a main contribution, the soil pH control in both high vegetative growth and raises in crop yield, as well as in the crop quality. This first stage of experiment on maize (2018) will continue with a second stage on wheat (2019) and third stage on lucerne (2020).

Keywords: bauxite residue, agro-chemistry, acid soil, remediation, maize crop.

1. Introduction

In our previous works [1, 2] it was demonstrated that bauxite residue, obtained as a by-product in alumina manufacturing technology, has some remarkable ecological properties: no radioactivity, low concentration level of the heavy metals and lanthanides, acceptable alkalinity, after natural drying and carbonation, and compatible particle size distribution with most of the agricultural soils. Also, several types of artificial soils with bauxite residue and other available residuals content, enriched with organic and mineral fertilizers, have been formulated for achieving a reasonable degree of fertility. These soils were tested with encouraging results on the growth of several common natural floras species and on crop plants [3-6]. This new approach of bauxite residue use in agriculture concerns the acid soils remediation by deep reshaping the land surface layer, in order to change the agro-chemical properties of this kind of soils and achieving a reasonable degree of fertility. This target was reached by using three soil properties control adjuvant: the bauxite residue for better pH and soil properties control, the organic fertilizers as source of organic carbon and NPK mineral fertilizers as source of the main macro and micronutrients. In a glass house scale experiment on maize plants, set up for the optimal dosages of the above adjuvant, it was proved the new reshaped soils really gained some higher fertility than the initial acid soil. Actually, the adjuvant promoted an intensive vegetative growth in maize plants (waist, green mass and dried mass), as well as the high productions in cobs and grains. Also, the samples of harvested green mass, cobs and grains contain the macronutrients, micronutrients and heavy metals in normally limits of concentration, found usually in maize. Under these conditions, Alum SA Tulcea decided to resume experiments at the pilot scale in natural conditions on a well-known soil recognized for its grade as acidic soil.

Our previous study on maize growth on amended acidic soils in glass house showed there is no crops growth, if the soil is not neutralized previously with an adjuvant like bauxite residue. Accordingly, the experimental program was intended to collect reliable data about the soil neutralization effects on soil itself, as well as on the crop growth of maize in terms of quantity and quality, under a meaningful organic and mineral fertilization.

The selected location for carrying out the experiments was the Agricultural Research and Development Station of Albota - Pitesti, Arges County, recognized for its works on the acid soils remediation. The entire research program was supervised by National Research and Development Institute for Soil Science, Agrochemistry and Environment ICPA Bucharest.

2. Experimental Part

For characterization of the experimental materials, the samples from soil and adjuvant were collected as follows: a) soil from the 0-20 cm horizons of all control variants; b) bauxite residue dried and partially carbonated material delivered by Alum SA Tulcea; and c) Organic Bio Enne Co-Actyl complex fertilizer and mineral NPK fertilizer. Physical and chemical properties of these experimental materials were measured by specific standardized methods, described in our previous works [1-5] and in the recent literature. [7].

2.1. Albota's Albic Luvosoil

The analytical data from Table 1 shows that reaction of the Albota's albic luvosoil in the 0 - 20 cm horizon is moderately acidic (pH_{H2O} = 5.30). This soil has a low humus content (2.45 %), a small-medium content of N_{TOTAL} (0.143 %), a high supply of mobile P_{AL} (39 mg/kg), a low mobile K_{AL} supply (83 mg/kg) and a good supply of mobile sulfur S-SO4 (23 mg/kg).

Table 1. Soil pH and and macronitrients content in the Albota albic luvosoil.

Soil Samples	Horizon	Depth, cm	pH, units	Humus, %	N_{T0tal}, %	P_{AL}, mg/kg	K_{AL}, mg/kg	S-SO4, mg/kg
Albota 1	Ao	0-20	5,14	2,44	0,158	38	89	23
Albota 2	Ao	0-20	5,21	2,50	0,138	41	80	24
Albota 3	Ao	0-20	5,29	2,41	0,132	39	80	23

*N_{TOTAL}-Nitrogen; P_{AL}-Phosphorus mobility; K_{AL}-Potassium mobility, $S\text{-}SO_4$-Sulphur mobility

Depending on the alkaline cations sum (SB), the Albota's albic soil (0 - 20 cm) falls into the low content class of alkaline cations (14.54 meq/100 g soil). The hydrolytic acidity (A_H) placed this soil into class of the strong hydrolytic soils (8.1 meq/100g sol). Hence, the analyzed soil has a high total cationic exchange capacity ($T_{8.3}$) (22.5 meq/100g soil) and its saturation in bases is oligomeric (64 %) (Table 2). The distribution of the exchangeable cations (given both in meq/100g soil and in percent, %, from total T exchange capacity in the Table 3 and Table 4) shows the presence of Ca 46.3 %, Mg 11.2 %, Na 0.2 %, K 1.1 %, and H 41.2 %. These values are micronutrients content in first leaf under the main maize ear, Macro- and mezzo- and content in maize grains, proteins and micronutrients content in the maize grains.

Vegetative growth: The increases of 43-64 % in green mass are real and repeatable in the flowering stages. It is reasonable to consider the dose of about 40 t/ha as optimal at least for maize plants growth in height and weight.

Maize grains production: The maize grain production was obviously increasing from variant 2 till variant 13. Roughly, the maize production growth rises from 11.4 to 16.8 t/ha, with an average yield of 14.4 t/ha, independently of fertilization formulas. In the terms of percentage, the yield growth due to application of research programs is ranging in 11.4 – 41.0 %, and all the data have statistical significance.

Macronutrients, mezzo nutrients and micronutrients in leaves under the main maize ear: It could be concluded that the application of bauxite residue to the Albota's albic luvosoil in association with mineral fertilization or with mineral and organic fertilization has contributed to a balanced nutrition of maize with all the classes of nutrients. Macronutrients and mezzo nutrients in grains status: There are unusual accumulation of potassium and magnesium in maize grains due to their ion high mobility in the treated and untreated experimental soil. Micronutrients in in grains status: There are differences of micronutrient concentrations in variants containing different doses of bauxite residue, but few of them have statistical relevance. Concentration variations are lower than usual known value

Proteins in grains status: Experimental data showed that crude protein content in maize grains lays between 5.38 % and 7.50 %, averaging 6.22 %. The average value was 38 % lower than the normal protein conten in maize.

5. References

1. Gheorghe Dobra et al., Bauxite residue safety disposal and possibilities to further utilization. Part 1. Acid soils remediation, *Journal of Siberian Federal University. Chemistry 2017* 10(1) 6-21.
2. Gheorghe Dobra et al., Bauxite residue safety disposal and friendly environmental processing permanent care at Vimetco Alum SA Tulcea,*Bauxite Residue Valorization and Best Practices Conference, Leuven,* 2015.
3. Gheorghe Dobra et al., Full analysis of Sierra Leone bauxite and possibilities of bauxite residue filtration, *Journal of Siberian Federal University. Eng. technol., 2016*, 9(5), 643-656.
4. Radu Lacatusu et al., Plant growth suitable nutritive red mud composite materials from the Romanian dry landfilled red mud. I. Red mud chemical and agrochemical characterization, *Rev. Chim (Bucharest)*, 2014, 65 (9), 1008-1014.
5. Gheorghe Dobra et al., Plant growth suitable nutritive red mud composite materials from the Romanian dry landfilled red mud. II. Formulation nutritive composite materials and plant growth tests at laboratory and glasshouse scale,. *Rev. Chim (Bucharest),* 2014, 65 (11), 1294-1305.
6. Radu Lacatusu et al., *Chimia globala a solului.Tera Noastra*, Iasi, 2017.
7. Radu Lacatusu et al., Growth of some pasture plants on a composite nutritive layer with red mud,*Research Journal of Agricultural Science*, 2015, 47(3), 69-78.
8. Radu Lacatusu et al., The effect of acid rock from Călimani mountains on making up a nutritive support for plants, based on red mud, *Soil Forming Factors and Processes from the Temperate Zone* 2013, 12 (2), 1-7.
9. Radu Lacatusu et al., Growth of some pasture plants on a composite nutritive layer with red mud,*Research Journal of Agricultural Science*, 2015, 47(3), 69-78.