Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 2, 2020
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

THE INFLUENCE OF RESIDUAL RED MUD ON WINTER WHEAT PLANTS

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Abstract

Recent researches recommend red mud (red sludge) by using in a possible correction of soils with acid reaction and poor content in nutrients. In addition, it was observed that plants of Poaceae family (called generic herbs) show a certain tolerance to this residue. Wheat plants grown in the second year after applying different doses of red mud have shown significantly positive plants trends. Thus, wheat plants grown at a dose of 60 t/ha compared to those of 10 t/ha red mud, formed ears 1 cm longer, had two (2) additional spikes, and the weight of the ear was larger by 0.4 grams. The number of grains in an ear was greater by seven (7), the weight of the grains in the average ear was 0.3 grams more, while the grains were relatively similar in size. The use of red mud in agricultural field conditions was used for the first time on the white luvic soil at the Pitești- Albora resort.

Key words: *ears, grains, red mud, variability.*

INTRODUCTION

One of the residual products of alumina extraction is red mud/red sludge. The highly alkaline reaction and its content in different chemical elements (macro and microelements), led in time to a possible preservation through herbs (Xendis et al., 2005). Red sludge is one of the residues obtained in the process of alumina (Al_2O_3) extraction from bauxite. Extraction from the bauxite ore is done with **sodium hydroxide** at high temperature and pressure (Bayer process). This sludge contains **iron oxides**, aluminium oxides, titanium oxides, clay minerals, which together form sodium alumino-silicates. The product as such cannot be used in agricultural fields mainly due to its caustic nature and the content of very fine sand particles that impede the development of the root system of plants. In addition the residue has a high pH (> 10), high electrical conductivity (EC > 30 $dS.m^{-1}$) and a high percentage of exchangeable sodium (> 70%). Therefore, the crude residue is recommended to be separated on one side by sand and the other part by red mud/red sludge (Figure 1).
A treatment with positive effect, namely seawater, has also been suggested. In this case, there is an increase in the concentration available to plants for calcium (Ca) and magnesium (Mg) together with the reduction of pH values.

Figure 1. The PG 102 wheat variety

In contrast, recent research has shown that red sludge resulting from different technological processes can be improved by mixing with different materials used in plant cultivation (Jala & Goyal, 2006). Thus, combinations of different doses of red sludge have been used with manure, compost, domestic sludge and even crop soil (Eastham & Morald, 2006a; Eastham et al., 2006b). From here it was suggested the idea of using improved red mud in agriculture (Gupta et al., 2002; Snars et al., 2004). The high pH values of the red mud could cause a relative improvement of the acidity of the crop soils, while the modest microelement contents could have a beneficial effect on the died of the plants. The first tests from us were carried out in vegetation vessels with soil in which cetain doses of red slurry were introduced. For the vegetation different plants were used, of which also some herbs (plants of the *Poaceae* family). Highlighting the effect of red sludge on culture soil requires longer- term research, usually over 3-4 years. For field conditions an experiment was chosen on the white luvicsoil within the Pitești resort. In addition to the various chemical analyzes of soil and plants, series of morphological determinations on plants have also been carried out. The present material presents results obtained from the winter wheat cultivated in the second year of research.

MATERIALS AND METHODS

In 2018, a stationary experiment was established, consisting of different doses of red mud (factor A with 10, 20, 40 and 60 t/ha) on a constant basis of mineral and organic fertilization (factor B). The duration of the research lasts 3 years (until 2020), in the rotation of the maize- winter wheat- sunflower. Doses of red mud were applied to the maize crop under the plow. The data in this paper refer to the winter wheat of the second year, as a carry over effect of the red mud (Figure 2). The variants had an area of 40 m^2 (5 x 8 m), in three replicates, placed according to the block design method. The winter wheat variety used was *PG 102*. The culture technology was the one recommended by the resort. The chemical analyzes performed complied with the standard methods known in such situations.

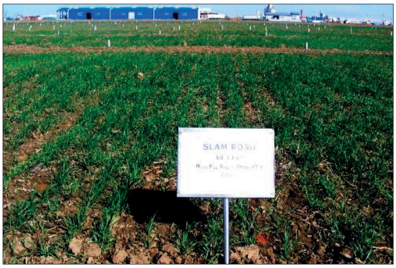

Figure 2. 60 t/ha red mud in wheat crop

In order to observe the influence of exclusive doses of red mud on wheat plants, a number of morphological aspects were analyzed. Among the variants used, we compared wheat plants grown exclusively at the dose of 10 t/ha red mud compared to those obtained exclusively at the dose of 60 t/ha red mud (without fertilizers of any kind). Thus, 100 plants each from three repetitions were chosen, cut and brought to the laboratory. The determinations included: the length of the ear, the weight of the ear, the number of spikelets in the ear, the number of grains in an ear, the weight of grains in the ear, the length and thickness of the grain.

The morphological characters obtained were analyzed by the histograms (or frequency polygons) method. In their expression were used the class intervals established according to the specific string of values obtained. The study carried out highlighted several aspects namely: i) the modal values (with the highest frequencies), ii) the limits of the intervals of variability of the studied characters and iii) the specificity of each character of the wheat variety in the analyzed area. Between the analyzed characters the respective correlations were established, with the help of which they could also observe their tendencies within the studied variety. The Excel program was used to express the values. The significance of the correlation coefficients was obtained by comparing with the r_{max} values (Erna Weber, 1961) for the 5%, 1% and 0.1% levels of the transgression probabilities.

In the statistical calculation of all the obtained values, the analysis of variance (Anova test) was used, namely on the ranges of variation. Statistical parameters were calculated used the formulas: $\bar{a} = \Sigma x/n$, where $\bar{a}$ = media of determinations, and x = values, S^2 (variance) = $1/n\text{-}1.[\Sigma x^2\text{-}(\Sigma x)^2/n]$, S (standard error) = $\sqrt{S^2}$ and S % (variation coefficient,%) = $S/\bar{a}.100$.

RESULTS AND DISCUSSIONS

Characteristics of the contents in chemical elements of soil and red mud. For the purpose of establishing the experiment, chemical analyzes of crop soil and red mud were performed. Thus, the soil was characterized by a moderately acidic reaction, with humus over 2% and with a low supply in macro-elements

(Table 1). The red mud had high pH, very low total nitrogen content (tN), relatively high phosphorus, and potassium- like crop soil. The mobile sulfur was more present in the mud and in lower concentration in the crop soil. The micro-element content of the soil shows relatively low values, both as total forms and as mobile forms (Table 2).

The exception is manganese, which has relatively high values, characteristic of this soil. The red mud contained total forms in micro-elements at higher values, while the mobile forms were very low. Of the chemical elements with a pollutant character, the red mud excelled in nickel and chrome.

Table 1. Contents in macro-elements

Elements	Luvicsoil	Red mud
pH	5.30	10.46
Nt, %	0.142	0.005
P_{AL} mg.kg^{-1}	39	352
K_{AL} mg.kg^{-1}	83	89
S-SO_4 mg.kg^{-1}	23	83
Humus, %	2,41	-

Table 2. Contents in micro-elements

Elements	Luvicsoil		Red mud	
	TF*	MF**	TF	MF
Zn mg.kg^{-1}	51	1.47	33	0.30
Cu mg.kg^{-1}	14	2.80	64	0.85
Mn mg.kg^{-1}	820	50.4	136	0.66
Ni mg.kg^{-1}	25		352	
Pb mg.kg^{-1}	16		5	
Cr mg.kg^{-1}	24		616	
Co mg.kg^{-1}	10		9	

*TF - total forms; **MF - mobile forms

Variability of some morphological characters of wheat plants. By increasing the doses of red mud in the soil of crops, gains of some morphological characters of wheat plants were observed. The data obtained are presented graphically by simultaneous evolutions within each character. Thus, the length of the spike was generally between 2.9 and 8.3 cm. The modal values were in the range 5.1-6 cm (35%) for wheat in the variant with 10 t/ha red mud and between 6.1-7 cm (34) at that of the dose of 60 t/ha red mud (Figure 3). Close limits were at 4.1-5 cm (29%) at wheat from the lower dose of mud and 5.1-6 cm (32%) at the higher dose of red mud. In both cases, the extremes constituted 1-2%. The number of spikelets in a spike ranged from 4 to 17. The modal values ranged from 10-11 spikelets/ spike at 10 t/ha red mud (34%) and 12-13 spikelets/ ear at 60 t/ha red mud (33%) (Figure 4). Close limits were at 8-9 spikelets (25%) at the low dose of mud and at 10-11 spikelets (28%) at the higher dose of red mud. Extreme values were at only 1-4% frequency. The weight of the wheat ear generally ranged between 0.40 g and 3.27 g. In the 10 t/ha mud, the ear had weight values between 0.40 g and 2.9 g, while the ears formed in the 60 t/ha red mud has values between 0.40 g and 3.27 g (Figure 5). The modal values were at 1.0-1.4 g (44%) at the lower dose of mud and the same interval 1.0-1.4 g (33%) at the higher dose of red mud. Close to these maximums were the frequencies of 28% in the range 0.5-0.9 g at the low dose of mud and 31% in the range 1.5-1.9 g at the high dose. And in these case the extreme frequencies constituted 1% of the total. The number of grains in a spike generally ranged from 7 to 51. In the lower dose of red mud the number of grains was between 7 and 40 grains, while in the higher dose they ranged from 8 to 51 grains. Modal values were in range of 11-20 grains (59%) in the low dose and 21-30 grains (36%) in the high dose of red mud (Figure 6). Close values were in the ranges fo 21-30 grains (25%) in the lower dose with 31-40 grains (30%) in the higher dose of red mud. the extreme values of the frequencies of this character constituted 1-2%. The weight of the grains from a spike ranged from 0.23 g to 2.78 g.

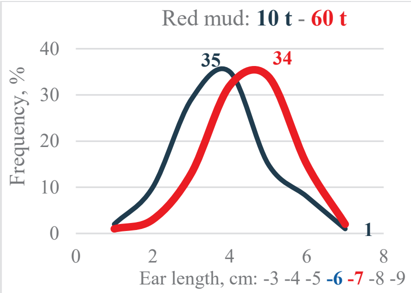

Figure 3. Frequency of ear length

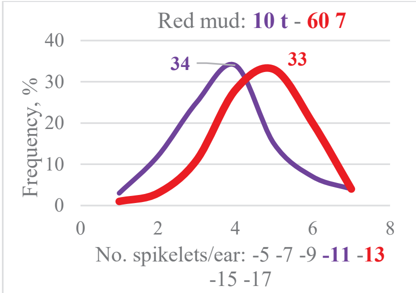

Figure 4. Frequency of no. spikelets/ear

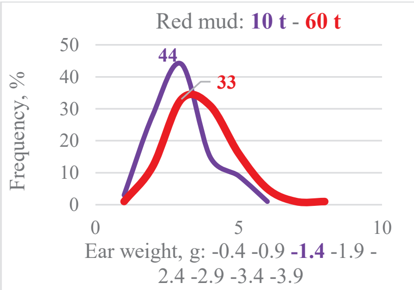

Figure 5. Frequency of ear weight

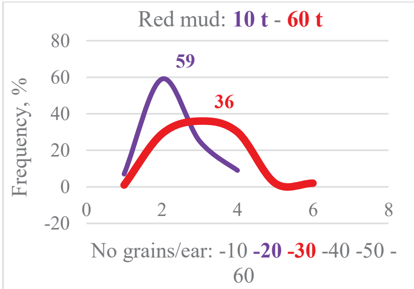

Figure 6. Frequency of no. grains/ear

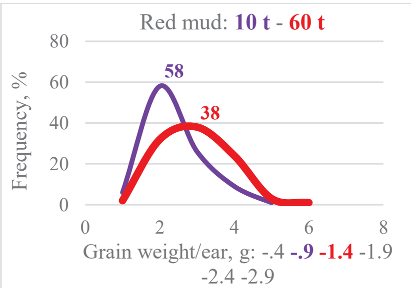

Figure 7. Frequency of grains weight/ear

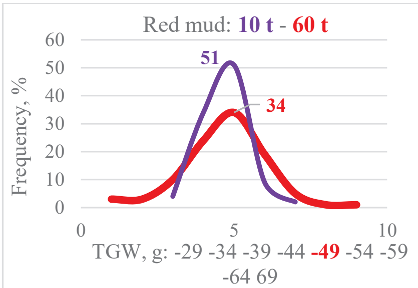

Figure 8. Frequency of a thousand grains weight (TGW)

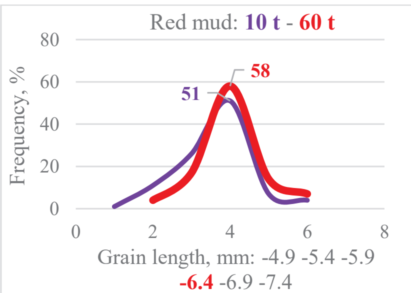

Figure 9. Frequency of grain length

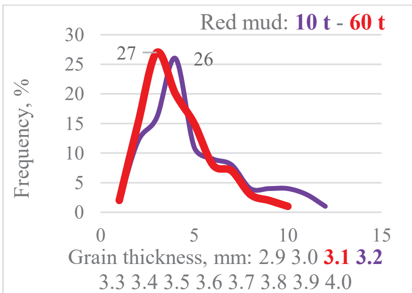

Figure 10. Frequency of grain thickness

The weight of the grains from an ear raised at the lower dose of red mud was between 0.23 and 2.04 g, and under the conditions of the higher mud dose they formed between 0.30 and 2.78 g (Figure 7). The modal values were in the range 0.5-0.9 g (58%) at the lower dose of mud and in the range 1.0-1.4 g (38%). Near values were in the range 0.5-0.9 g (32%) on the low dose of mud and on the 1.0-1.4 g (26%) on the higher dose of red mud. The mass of one thousand grains (MTG/TGW) had absolute values between 26.5 g and 65.5 g (figure 8). The small mud dose was formed with grains between 25 and 69 g, and on the larger mud dose the values were between 35 and 59 g. The modal values were at 45-49 g (34%) at the low dose of mud and in the same range 45-49 g (51%) at the high dose of residue.

The wheat grains formed under the conditions of the two doses of red mud have demonstrated approximately similar dimensions. Thus, the grain length had extreme values between 4.9 and 7.1 mm. The dominant frequencies were in the range 6.0-6.4 mm (51%) on the lower dose of mud and in the same range 6.0-6.4 mm (58%) on the higher dose of red mud (Figure 9). The thickness of wheat grains had extreme values between 2.6 and 4.0 mm, with a slightly greater dispersion in the conditions of wheat grown on the lower dose of red mud. The modal values were at the values of 3.2 mm on the low dose and 3.1 mm on the higher dose of mud (Figure 10).

Statistical analysis of the variability of morphological characters in wheat. The results obtained in the morphological analysis of some wheat characters showed specific aspects. Thus, the length of the spike/ear measured 5.3 cm a the small dose of mud (10 t/ha) and 6.0 cm on the larger dose of red mud (60 t/ha). The variability demonstrated medium to large values (Table 3). The weight of the wheat ear ranged from 1.21 g at the low dose of mud, to 1.57 g at the higher dose of red mud. The variability of this character was particularly high. The number of spikelets in one spike was 10.1 in the low dose and 11.9 in the spikelets raised on the higher dose of red mud. The variability of this character was great to very high. The number of grains in one spike ranged from 19.5 on the low dose of mud and 26.4 on the high ones on the high dose of red mud. The variability was very high in both situations. The grain/ spikelet weight ranged from 0.90 g for the lower dose of mud and 1.21 g for the larger dose of red mud. And for this parameter, the variability was very high in both situations.

Table 3. Statistical indices of winter wheat ears and grains

Indices	Ear length, cm	Ear weight, g	No. spikelets/ ear	No. grains/ ear	Grain weight/ ear, g	TGW, g	Grain length, mm	Grain thickness, mm
10 t/ha red mud								
Media, ā	**5.31**	**1.21**	**10.1**	**19.5**	**0.90**	**45.7**	**6.0**	**3.3**
Variance, s^2	0.381	0.205	6.745	45.06	0.135	47.35	0.194	0.072
Std. error, s	0.617	0.453	2.579	6.713	0.367	6.881	0.440	0.269
Var. coef.,%	**11.6**	**37.5**	**25.7**	**34.4**	**41.0**	**15.**1	**7.4**	**8.2**
60 t/ha red mud								
Media, ā	**6.02**	**1.57**	**11.9**	**26.4**	**1.21**	**45.4**	**6.2**	**3.2**
Variance, s^2	1.131	0.330	5.326	84.82	0.195	30.05	0.160	0.075
Std. error, s	1.064	0.574	2.308	9.210	0.442	5.482	0.400	0.187
Var. coef.,%	**17.7**	**36.5**	**19.4**	**35.0**	**36.6**	**12.1**	**6.5**	**5.8**

The mass of one thousand grains had average of 45.7 g at the wheat raised on the dose of 10 t/ha mud and 45.4 g at the wheat in the high dose of sludge. The grain size, length and thickness, had close relative average values. Thus, the grain length had values of 6.0 mm on small mud dose and 6.2 mm on the larger mud dose. The variability of wheat grain length was reduced in both situations. The thickness of the grain had average values of 3.3 mm for the wheat from the low dose of mud and 3.2 mm for the grains from the higher dose of the red mud. And in this case, the character variables were in the small category.

CONCLUSIONS

The sludge/red mud residue can be used as a product that can improve the chemical regime of the soil. It has been suggested that its agricultural role would be in the form of an amendment. Considering the alkaline reaction and a sensitive content in nutrients, the red mud was tested under the conditions of white luvic soil, an acidic soil with low reserves of plant food. In fact, there was a correction of the acid reaction of the soil together with the contribution of various chemical elements, necessary for the growth and development of the plants. Analyzes of both soil and red mud demonstrated these characteristics.

From the determinations it emerged that the winter wheat plants grew and developed normally, and to prove the effective contribution of the red sludge in the vegetation were made series of determinations on mature wheat plants grown on two doses of mud: 10 t/ha and 60 t/ha, without chemical fertilizers. The obtained data show the gain of the productivity elements from this environment improved with the red mud i.e.: an average ear/spike 0.7 cm longer, a heavier spike 0.36 g, a higher number of spikelets/spike 1.8, and the number of grains from ear was 6.9 higher. The weight of the grains in an ear increased by 0.31 g, and the absolute weight of the grains was similar to 45 g.

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