EFFECTS OF DIFFERENT FORMS OF NITROGEN IN COMBINATION WITH DIFFERENT DOSES OF CALCIUM IN FORM OF GYPSUM ON YIELDS

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ABSTRACT

To valorise sediments left after iron mineral extraction in an area of about 2500ha of coverage in Liberia, a concept of appropriate fertilizer was developed. A comparative study was carried out on two types of soil : the first one was enriched in organic matter, and the second one was formed exclusively with sediments. The results showed that the choice of different types and forms of fertilizer on one hand, associated with the choice of different plant species on other hand, have an important impact on the movement and availability of soil nutrients, thereby on the augmentation of crop yields. With or without organic matter, no significant effect on yields was obtained with different doses of nitrogen fertilizers, compared to the application of different doses of combinations from calcium nitrogen fertiliser and calcium and potassium (in form of sulfate).

Keywords: Sediments, fertilizer, movement, oat, Chinese cabbage, perennial rye-grass, Liberia.

INTRODUCTION

The "Bong Mining Company" has been mining since 1960s an iron deposit in Bong County in Liberia. The importance of this mine lies on the number of employees who are working in. Europeans settled in this mining region. In fact, this mining society has attracted many labours from different regions of the country. Presently, a small town with 40,000 inhabitants is founded in the region. The dwellers relyon small mining related craft activities to survive. The supply of foods, such as vegetables, comes from far distance where farming system is mostly shifting cultivation. Rice in particular is imported from outside. For agricultural production, farmers of the region lack, not only knowledge, but also space for farming Barrett (2007) ; World Bank (2007); Baumann (2000) ; Coulter et al. (1999). It must be noticed in general that peoples settled in this region will lack, in the long term, food supply for their subsistence. In addition, the iron deposit is projected to finish in the short future ; and the anticipated close of the company could occur due to the rentability challenge related to the evolution of the new iron industry. The return of this population to their different tribes of origin will not be possible without difficulties. This problematic situation is well known of the managers of the mine. Consequently, efforts have been putting place to finance local activities development and food supply through agricultural intensification. Mountainous aspect of the region could be an obstacle to agricultural development due to erosion challenge. The same natural factors do not favour the valorization of the zone. The goal of this project is to come out with research methods for the valorization of this swampy sediment called 'Tailings Pond', which covers the surface area of approximatively 2500 ha. The point of view of Sommer (1975) and N'Doreyaho are against the general opinion because of the infertility of the zone Coulter et al.(2013); The reasons are the soil poverty in nutrients associated with the muddy and structureless status of the sediment at the one hand, and at the other hand its content in iron which is of 10%. The advantage of these surfaces is that they are piled up flattened ; its proximity to the region, its exploitation by the native farmers who have a high qualified trainings killed associated with a help from an agricultural project implemented in the region since a while. The condition to succeed this research work is the elaboration of a concept of an appropriate fertilizer to this type of soil which would contribute to its valorization. The aim of this trial is to study whether and how the anions of mineral fertilizers such as nitrate, chlorite and sulfate would influence the availability of the nutrients (sulfate in particular) in the high acid soils. It is why ammonium nitrate and calcium nitrate were chosen as nitrogen fertilizer in the program. The chloride and sulphate were applied in potassium form. The chloride and sulphate were chosen in the program because they have basic reaction in the normal conditions with the rest of the anions in soil (Villachica et *al*. 1974; Chien et *al*., 1988 ; Voigt and Henskel 1981).

MATERIALS AND METHODS

Methods of analysis of soil samples

Experimental design

The experimental design comprised sixteen treatments with four replications of two types of soil. The soil samples were put in pots in greenhouse according to the system of Kick-Brauchmann (1964). The treatments were arranged on the tracks that are provided each with a guage to record the water level at each stage of plant growth. The system then enables to move the experimental device out of the greenhouse according to the climatic hazards . These trials were carried out at the Agrochemistry Institute of the University of Bonn, in Germany.

Soils samples

All the nutrients in the soil samples were disolved in a solution mixed with 1N HCl and 1N H_2SO_4at the respective proportion of 1 : 3 called ‘‘Königswasser’’. The pH of the soils were determined after dilution of the samples in the solution described as follows : distilled water ; 0.01M ; $CaCl_2$; 0.05M K_2SO_4 according to Jensen’s method. The carbon content was determined using the method of Lichterfeld ; total nitrogen by the method of Forester (1980) ; the available phosphate by the method of Schachtschabel (1984) ; and calcium and potassium were determined by the flamephotometer. The results were presented in Table I.

EXPERIMENTAL MATERIALS

The soil samples

The soil samples were collected from Liberia. They were two types of soils and were as follows :

Arable land : a fertile soil of the Region.
Tailings Pond :Sediments extracted from the iron mine factory. These sediments contained 15% of iron of dark gray and powdery colour.

Organic and mineral manures

The nitrogen was applied in two forms at the rate of 1 g N per pot each. The treatments 1, 3, 5, 7, 8 and 16 received ammonium nitrate (NH_4NO_3) respectively, while the treatments 2, 4, 6, 9-15 were enriched with calcium nitrate ($Ca(NO_3)_2$). The phosphate was applied in very soluble form (KH_2PO_4) at 0.8 g P per pot and the magnesium in form of magnesium sulfate ($MgSO_4$) at 0.6 g de Mg per pot. The potassium was applied in form of potassium chloride (KCl) for the treatments 1 to 4, 11 and 12, whilst the treatments 5 to 10 and 13 to 15 were enriched with potassium sulfate (K_2SO_4) at the dose of 0.99 g K per pot respectively. All the treatments received each 1 g K per pot due to the dose of potassium (0.1 g/pot) contained in the phosphate fertilizer applied. To address magnesium deficiency often noticed in tropical soils, the magnesium was applied in form of $MgSO_4$ at the dose of 0.6g Mg per pot. The calcium was applied in form of calcium chloride ($CaCl_2$) to the treatments 1, 3 and 4 at the dose of 1.43 g Ca per pot ; and in form of calcium sulfate ($CaSO_4$) to the treatments 7, 9 and 14 at the dose of 1.43 g Ca per pot and to the treatments 8, 10, 15 and 16 at the dose of 4.29 g Ca per pot. Each treatment was enriched with micro-elements described as follows:

$CuSO_{4:}$ 16 mg Cu/pot
$MnSO_{4:}$ 14.6 mg Mn/pot
H_3BO_3 : 5.0 mg B/pot
$ZnSO_4$: 16.7 mg Zn/pot
$(NH_4)_2$ MoO_4 : 3.3 mg Mo/pot.

Finally, the treatments 11 to16 received 60.0 g per pot of sawdust each as source of organic matter.

test crops

Oat (Avenae sativa) was chosen as main crop ; chinese cabbage (Brassicae sp) and perennial Lolium were respectively selected as relay crops.

Table I : Some chemical characteristics of the soils.

Characteristics	Arable land	Sediments	Sawdust
C Total	1.77	0.14	4.11
N Total	0.12	0.06	0.09
C/N	14.75	2.34	41.67
P_2O_5 (méq/100 g)	2.50	2.24	-
Mg M. NaCl) mg/100	0.72	0.69	-
K_2O*	3.32	2.86	-
Water	5.5	7.6	-
pH 0.01 $CaCl_2$	4.2	6.8	-
0.05 M K_2SO_4	4.1	6.6	-

Lactate dual method
Similar results showed also NDoreyaho (1978) ; Mûckenhausen et al. (1972).

Analytic study of the samples of the test crops

To determine the yield components, the different test crop samples were dried at 105° C in stove for three days. To determine the mineral elements in the samples, the mean of the four replications of each treatment was finely grounded in a mill. The grains and straws were separately in cinerated at 450 ° C in an oven; then the following nutrients were determined:
Phosphate through ammonium-vanadate method (Gericke et Kurmies 1952),
Potassium and calcium by Gettkandt (1965) method,
Magnesium and the micro-elements with the atomic absorption spectrometry
Nitrogen by the Kjeldahl distillation mixed with selenium of Winninger cited in Naumann et al. (1976).

The evaluation of the experiment results was done through ANOVA with three factorials of Schuster and von Lochow, (1978).

OAT
Table 2: Yields of oat ; arable land, sediments.

Treatments	Fertilizers N-forms	Fertilizers Ca-dose	Yields (g/pot) grain	Yields (g/pot) straw	Yields (g/pot) grain+straw
Arable land					
7	NH_4NO_3	s.$CaSO_4$	84.4	94.4	168.8
9	$Ca(NO_3)_2$	s.$CaSO_4$	125.7	90.2	215.9
8	NH_4 NO_3	h.$CaSO_4$	87.3	89.2	176.5
10	$Ca(NO_3)_2$	h.$CaSO_4$	97.0	89.6	186.5
Sediments					
7	NH_4NO_3	s.$CaSO_4$	104.0	94.8	200.8
9	$Ca(NO_3)_2$	s.$CaSO_4$	133.2	115.9	249.0
8	NH_4NO_3	h.$CaSO_4$	89.1	89.4	178.5
10	$Ca(NO_3)_2$	h.$CaSO_4$	96.5	102.9	199.4
PPDS 5%			1.2	6.2	11.5

f= small dose h= high dose

Table 2 shows that the application of high dose of $CaSO_4$ (calcium sulfate) in form of gypsium in combination with different forms of nitrogen, such as ammonium nitrate (NH_4NO_3) or calcium ammonium nitrate decreased the yields Chien et al. (2004). The highest decrease in yields was observed with treatments 8 and 10, which wereen riched with calcium ammonium nitrate Bordolai et al. (2013) ; Li et al. (2013). However, there was no sensible difference in the combination of different treatments on the two types of soil. The highest yield was obtained with treatment 9 (small dose of calcium sulfate+ calcium nitrate at a dose of 1.43 g /pot) Nadou et al. (2001). The augmentation of $CaSO_4$ dose from 1.43 g to 4.29 g per pot led to the decrease in the yields on the two types of soil. The combination of calcium sulfate and ammonium nitrate

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equally decreased the yields. F-test revealed statistically significant differences between the two types of soil, forms of nitrogen and the different doses of calcium. There were interactions between the different yields in grain, straw, total, and forms of nitrogen, as well as the different doses of calcium.

Chinese cabbage

Tableau 3: Yield in dry matter of Chinese cabbage on arable land and sediments

Treatments	Forms of N	Forms of Ca	Yield (D.M.g/pot)
Arable land			
7	NH_4NO_3	s.$CaSO_4$	16.6
9	$Ca(NO_3)_2$	s.$CaSO_4$	21.0
8	NH_4NO_3	h.$CaSO_4$	17.9
10	$Ca(NO_3)_2$	h.$CaSO_4$	21.0
Sediments			
7	NH_4NO_3	s.$CaSO_4$	25.8
9	$Ca(NO_3)_2$	s.$CaSO_4$	22.5
8	NH_4NO_3	h.$CaSO_4$	26.4
10	$Ca(NO_3)_2$	h.$CaSO_4$	26.8
PPDS 5 %			1.7

s = small dose h = high dose D.M =Dry Matter

With chinese cabbage , the application of high dose of $CaSO_4$ did not give any sensible augmentation in the yields of dry matter for the correspondent treatments on the two types of soil (Table 3) Montalvo et al.(2010) ;Jankowski et al. (2015) . Also, no sensible decrease in dry matter yield was observed with this application von Willert and Stehouwer (2007) presented different results. The difference in dry matter yields were statistically significant for the two types of soil. There were equally interactions between soil types and forms of nitrogen.

Perennial rye-grass

The results of the rye-grass yields obtained with different treatments, as well as with the twosoil types, confirmed the previous results of oat and chinese cabbage ; therefore, the application of high dose of $CaSO_4$ did not increase the yields of the different crops tested (Table 4) Sienkiewicz et al. (2015).

Table 4 : Yields in dry matter of rye-grass, second relay crop on arable land and sediments.

Treatments	Forms of N	Forms of Ca	Yields (D.M g/pot)
Arable land			
7	NH_4NO_3	s.$CaSO_4$	8.7
9	$Ca(NO_3)_2$	s.$CaSO_4$	10.6
8	NH_4NO_3	h.$CaSO_4$	10.2
10	$Ca(NO_3)_2$	h.$CaSO_4$	10.8
Sediments			
7	NH_4NO_3	s.$CaSO_4$	9.8
9	$Ca(NO_3)_2$	s.$CaSO_4$	9.8
8	NH_4NO_3	h.$CaSO_4$	10.2
10	$Ca(NO_3)_2$	h.$CaSO_4$	5.2
PPDS 5%			5

D.M = Dry Matter s = small dose h =high dose

At this part of the work, only the results of the analysis of oat nutrients and their correspondent treatments will be presented.

Table 5 : Content and quantity of exported N for oat : arable land, sediments.

	Content in %N				mg N-exported/pot							
	Grain		straw		Grain		straw		total		N-balance(%)	
Treatments	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.
7	1.90	1.27	0.44	0.17	1857	1347	373	170	2230	1517	111	76
9	1.97	1.48	0.48	0.23	2486	1975	445	267	2931	2242	146	112
8	1.99	1.24	0.53	0.18	1831	1109	481	166	2312	1275	115	63
10	1.72	1.29	0.49	0.19	1676	1251	442	204	2118	1455	106	73

a.l = arable land ; sed = sediments

It was observed from Table 5that the N content of grains was clearly higher for all treatements on arable land, compared to the treatments on sediments. The similar results were obtained with N content of straw :Sawicka et al. (2013) ; Kavvadias et al. (2012). For all treatments, the N content was lower for straw than grain Rinz Diaz et al. (2008).

Table 6 : Content and quantity of exported phosphorous

	Content in % P				mgPexported/pot					
	Grain		Straw		Grain		Straw		total	
Treatments	a.l	sed.	a.l	sed	a.l	sed.	a.l	sed.	a.l	sed
7	0.88	0.90	0.10	0.08	767	599	77	41	844	660
9	0.97	0.86	0.18	0.06	423	549	121	43	54	592
8	1.00	0.94	0.16	0.11	993	139	104	1069	1069	1097
10	0.97	0.93	0.11	0.06	941	896	104	67	1045	963

t.a = terre arable séd.= sédiments

It could be observed from Table 6that the P content of oat grain was pratically the sameat all treatment levels on both sediments and arable land. However, the P content of the straw was generally lower than that of the grain. Though the P content was pratically the same at all treatment levels on the two types of soil, the total in P content exported per pot, which was mobilised and assimilated by oat was remarkably more higher for the treatment 9 on both sediments and arable land. This can be explained by the optimal combination of sulfate ions, which increased their availability at the ion absorption complex of the croproots Cooke and Gasser (2006).

Table 7 : Content and rate of potassium exported: Oat : Arable land, sediments

	Content in %K				mg of K exported/pot					
	Grain		Straw		Grain		Straw		total	
Treatments	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.
7	1.24	1.15	2.72	3.41	1155	1224	2296	3234	3451	4458
9	1.08	1.12	2.62	3.16	1365	1499	2363	3667	3728	5166
8	1.20	1.21	2.62	3.31	1133	1081	2340	2959	3473	4040
10	1.17	1.18	2.62	3.66	1104	1143	2346	3754	3450	4897

a.l = arable land sed. = sediments

Table 7 showed that the content and quantity of K exported were considerably higherat the straw level than grain level. This result was evident, since this nutrient plays the role of physical regulator for plant through their stomata.

Table 8 : Content and quantity of Mg exported : Oat : arable land, sediments

	Content in %Mg				mg of Mg exported/pot					
	Grain		Straw		Grain		Straw		total	
Treatments.	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.
7	0.28	0.88	0.14	0.04	263	939	122	41	385	980
9	0.27	0.92	0.14	0.02	344	1236	126	25	470	1261
8	0.29	0.90	0.14	0.03	277	806	125	30	402	836
10	0.27	0.72	0.14	0.06	267	696	114	67	382	764

a.l = arable land sed. = sediments

Table 8 revealed that the Mg content was uniformly higher for the treatments of sediments than those of arable land. This content in Mg was considerably lower at straw level than grain level for all the treatments of sediments.

Table 9 : Content and rate of calcium exported: Oat : arable land, sediments

	Content in % Ca				mg of Ca exported/pot					
	Grain		Straw		Grain		Straw		Total	
Treatments.	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.
7	0.65	0.45	3.73	1.17	60	48	315	111	376	160
9	0.55	0.45	3.64	1.00	69	60	328	116	398	176
8	0.60	0.60	3.14	1.25	57	53	280	111	337	165
10	0.65	0.45	3.98	1.89	63	44	354	194	420	238

a.l = arable land sed. = sediments

The grain content in calcium was highly lower than that of the straw, especially for the treatments of sediments (Table 9). The lower value of calcium content in the sediments proved that they did not have any capacity of exchangeable base, despite of their high p^H value.

Table 10 : Content in micro-elements, manganese, zinc and iron (mg/kg) : Oat : arable land, sediments.

	mgof Mn/kg				mg of Zn/kg				mg of Fe/kg			
	Grain		Straw		Grain		Straw		Grain		Straw	
Traitements	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed.	a.l	sed
7	65	60	65	39	57	26	34	10	173	159	275	53
9	52	63	52	50	45	27	27	8	136	156	229	66
8	57	65	57	62	54	37	35	10	149	166	222	60
10	56	53	55	72	45	24	30	14	146	143	153	70

a.l = arable land sed. = sediments

It was shown from Table 10 that micro-elements, manganese, zinc and iron were present at arate lower than the toxicity tresh old for the crop. Besides, manganese rates were almost the same for the two types of soil Sperotto et al. (2013). Similarly, iron rates of the grain were practically the same for the two types of soil. Contrari wise, zinc content of the grain was obviously higher for the treatments of arable land than those of sediments.

CONCLUSION

It emerged from the study results that sediments are also usable as arable land in the region. As far as the application of mineral fertilizers is concerned, one must take into account the nutrients deficit, except iron and manganese. It could be assumed, for the fertilization plan, that there was no nutrient in stock in those sediments. As for example, the exploitation of those sediments in the region will require huge investments for fertilizer purchases especially in the first years. The application of small dose of mineral fertilizer would leave no hope for any profitable yield. Thorough attention should be paid to the balance of anions in the choice of fertilizers. This is very important for potash fertilizer that only has to contain 25% of sulfate chlorite to avoid the decrease of crop yields. Particular attention should be given to the application of calcium to these sediments. The relatively high pH of the sediments does not guarantee the availability of calcium necessary for plant. Indeed, it is preferable to fix the calcium deficit by applying little amount of calcium sulfate combined with little amount of soluble calcium nitrate. In case of the application of mineral fertilizer, nutrient mobility should be taken into account, since the sediments do not possess any capacity of absorption. For this reason, during rainy seasons, except phosphate, all mineral fertilizers should be incorporated or applied in small doses to ensure their effectiveness and avoid leaching. The intensity of absorption of trace elements such as manganese and iron which are also heavy metals, not only depends on the plant species, but also on the nature and form of the mineral fertilizers which are used.

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