

The effect of bottom sediment on biomass production by Italian ryegrass and maize

Barbara Wiśniowska-Kielian

Agricultural University in Krakow, Department of Agricultural Chemistry, 31-120 Kraków, al. Mickiewicza 21,
e-mail: rkielia@cyf-kr.edu.pl

A two-year pot experiment (2005 and 2006) was conducted to estimate an effect of dredged bottom sediment from Rożnów Reservoir addition to the light, very acid soil on the plant biomass production. The sediment was applied in the amount from 1 to 20% of the substratum mass. Italian ryegrass (*Lolium multiflorum* L.) and maize (*Zea mays* L.) were cultivated as the successive test plants. The lowest amount of plant biomass was obtained on the soil (control) and each sediment addition to the substratum caused an increase of the biomass production, both tops as well as the roots of the plant. Larger sediment additions (7% and more) caused a significant increase of the yield, of both the individual plant species and the total biomass during the two years of the experiment. The bottom sediment added to the light, very acid soil distinctly improved the plant yielding and the way of biomass utilisation should be assessed on the basis of its chemical composition analysis.

Keywords: : bottom sediment, utilization, Italian ryegrass, maize, biomass production, estimate.

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INTRODUCTION

Silting of dam reservoirs is a result of an erosion of the watershed terrain^{1,2}, which leads to a decrease in their retention capacity³. The Rożnów Reservoir is the fastest silting dam reservoir in Poland. After 50 years of operation its length decreased by 40%. The condition necessary for prolonging the operation time of silted reservoir is its reclamation. It may be performed with various methods and one of the most radical and most efficient ways of the restoration of the primary functions of the reservoir is mechanical reclamation by means of dredging⁴. Dredging involves the removal of accumulated settlements up to the natural bottom⁵. Large masses of sediments requiring proper management are generated as a result of dredging. The bottom sediments are the main link in the matter cycle in the water ecosystem, they constitute the reserve of many elements, particularly in a sedimentary cycle, which underwent a periodical deactivation^{6,7,8}. As a result of self-purification of waters an increase in metallic element concentrations in settlements is observed, therefore even the bottom deposits from the relatively clean reservoirs may contain considerable amounts of harmful substances. The dredged bottom sediments, both from the natural and artificial reservoirs, reveal alkaline reaction and a sizeable fraction of silt and clay. The bottom sediments of dam reservoirs, particularly situated on the mountain rivers, usually contain less organic matter and total nitrogen than the reservoirs of the lowland rivers^{9,10}.

Light soils, the majority of which reveal considerable acidification, prevail in Poland and consequently the lower yields are generated on them than under optimal conditions¹¹. The greatest fault of light soils is their small sorption capacity in relations to nutrients and also small water capacity. Intensive fertilization of these soils does not give positive results because of fast nutrient leaching into the soil profile. Biogenic compounds lost in this way enrich the underground and surface waters causing their

eutrophication. The improvement of the physical, physicochemical and chemical properties of light soils may contribute to the enhancement of their productivity and diminishing the negative impact upon the environment. The dredged bottom sediments from water reservoirs are similar materials to mine waste rocks formed during coal extraction, which due to high contents of clay and silt particles in their textures may improve the physical and physicochemical properties of soils¹². Bottom sediments have been used from time immemorial and are also used nowadays. The deposits dredged in wintertime from irrigation canals in the Indus Basin or from the Nasser Reservoir are utilized as an important source of fertilizer components on the nearby arable fields^{13,14}.

The bottom sediments containing large amounts of alkaline substances may be considered as valuable material for improving the chemical and physicochemical properties of light acid soils, because they may affect them in a similar way as furnace wastes¹⁵. Therefore, they should be managed for environmental and/or agricultural purposes. Due to possible high concentrations of harmful substances, bottom sediments should be analyzed for their effect on soil and cultivated crops¹⁶. Although they are not the waste according to the Degree on wastes, their biological management is the method of their utilization most recommended for the environment, otherwise they are stored in natural depressions within the river inundation terrace. In case of sediment utilization it must meet the criteria for the permissible contents of trace metals stated in the Decree of the Minister of the Environment concerning the soil quality standards and land quality standards¹⁷.

The investigations aimed at an assessment of potential environmental application of bottom sediment basing on the effect of increasing the share of sediment in the substratum on crop yields on light, very acid soil.

MATERIAL AND METHODS

A two-year pot experiment was conducted in a vegetation hall to assess the effect of the supplement of the bottom sediment, dredged from the Rożnów Reservoir, to a light soil, on the crop of biomass production. The soil had the light sand texture, very acid reaction ($\text{pH}_{\text{KCl}} = 4.40$), contained relatively low organic carbon, $4.73 \text{ g C}_{\text{org}} \cdot \text{kg}^{-1}$, and showed very low abundance of available phosphorus and high in bioavailable potassium forms. The sediment had the heavy loam texture, revealed alkaline reaction ($\text{pH}_{\text{KCl}} = 7.20$), contained $3.65 \text{ g C}_{\text{org}} \cdot \text{kg}^{-1}$ and showed low abundance of available phosphorus and low in available potassium forms. The total content of all alkaline elements in the sediment 14 times exceeded their contents in the soil used for the experiment, of which calcium and magnesium contents were 17 and 7 times higher, respectively. The total contents of potentially toxic trace metals (Zn, Cu, Ni, Cr, Pb, Cd) in the soil and the bottom sediment met the criteria for their natural contents in the soil proposed by Institute of Soil Science and Plant Cultivation (IUNG)¹⁸. According to the Decree of the Minister of the Environment of soil quality standards and land quality standards¹⁷ both components contained permissible amounts of trace metals.

The experimental design comprised 13 combinations of substrata in three replications. The sediment was added in the amounts of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15 and 20% of the substratum mass, which was 4 kg (Fig. 1). The soil without sediment addition was the control object. Basic fertilization of 1 g N, 0.25 g P and 1.25 g K per pot was applied on all objects. Solutions of NH_4NO_3 , KH_2PO_4 and KCl salts, pure for analyses, were used as fertilizers and thoroughly mixed with the substratum components.

The test plants were Italian ryegrass (*Lolium multiflorum* Lam.), Gaza c.v., cultivated in 2005 and maize (*Zea mays* L.), Bora c.v., cultivated in 2006 as a consequent plant. Three cuts of Italian ryegrass were harvested. Maize was gathered at the beginning of flowering (panicle and cob forming). Roots were taken out each time after the aerial part harvesting. The gathered plant material was dried in a drier with the forced air flow at 65°C and the aboveground biomass yield and root mass were assessed. The amount of the biomass yields and the significance of differences were assessed by means of the ANOVA analy-

sis and least significant differences (LSD at $\alpha = 0.05$) were calculated.

RESULTS

The yields of the aboveground biomass of the subsequent cuts of Italian ryegrass were decreasing by over 40% and were on average 12.53, 7.26 and 4.03 g d.m. per pot, respectively for the I, II and III cut (Fig. 1). Plants growing on the soil without any supplement (control) produced the smallest aboveground biomass, respectively 11.99, 5.28 and 3.10 g d.m. per pot. The greatest of the I cut biomass was obtained when sediment addition amounted 9%, and of the II and III cuts when the sediment constituted 20% of the substratum mass, 15.15, 10.42 and 6.29 g d.m. per pot, respectively. During the vegetation period Italian ryegrass growing on the soil without any supplement generated 19.35 g d.m. of the aboveground biomass, while the largest yields of 29.64 and 29.65 g d.m. per pot were obtained with 15 and 20% share of the deposit in substratum (Fig. 2). Each supplement of the bottom sediment caused an increase in the biomass yield in all cuts, but statistically a significant increase in yield of the I and III cuts and the total yield of the aboveground biomass was registered when the sediment share in the substratum was 2–3% and 7% and more. Respective $\text{LSD}_{0.05}$ values were 1.30 g, 1.06 g and 2.84 g d.m. per pot. In the case of the II cut a 6% and higher sediment supplement caused a significant increase in the yield ($\text{LSD}_{0.05} = 1.28 \text{ g d.m. per pot}$). The mass of the produced roots ranged between 7.11 and 14.54 g, on average 9.90 g d.m. per pot. A substantial increase in the mass of the produced roots was caused by 7%, 10% or larger sediment admixture ($\text{LSD}_{0.05} = 2.99 \text{ g d.m. per pot}$). The smallest quantity of the aerial parts and root biomass, 26.60 g d.m. per pot, was produced by the grasses growing on the control object, while the greatest, 44.18 g d.m. per pot, when the sediment constituted 15% of the substratum mass. Larger sediment supplement, 7% or more, caused a significant increase in the total biomass in comparison with that obtained on the soil without admixtures ($\text{LSD}_{0.05} = 5.52 \text{ g d.m. per pot}$).

Maize cultivated as a consequent plant more apparently responded to deposit admixtures to very acid soil. On the control object the plants produced the smallest amount of

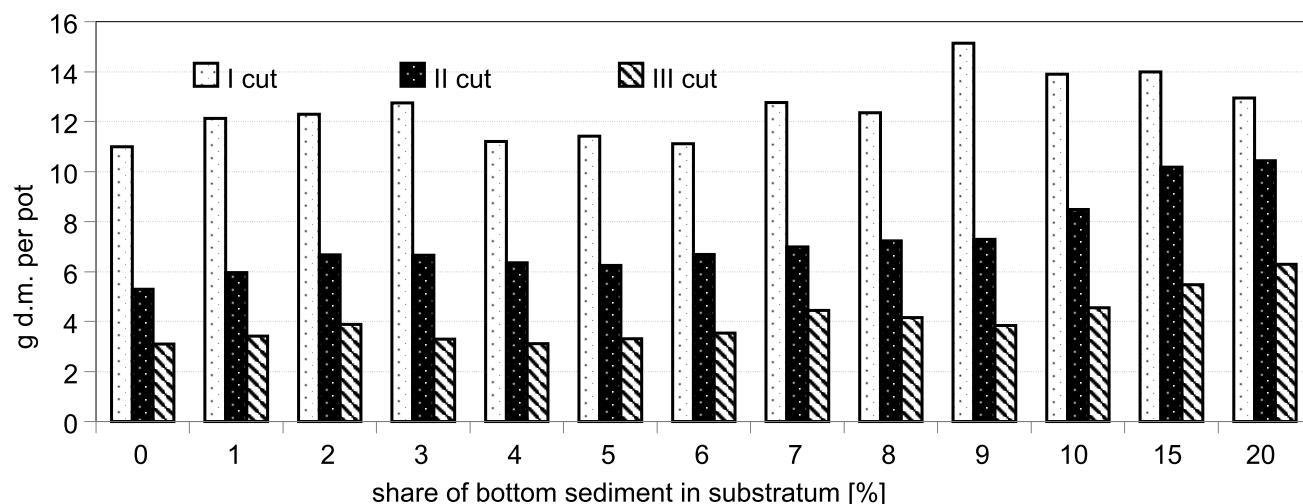


Figure 1. The amount of aerial biomass yield of successive cuts of Italian ryegrass dependent on the share of the bottom sediment in the substratum (g d.m. per pot)

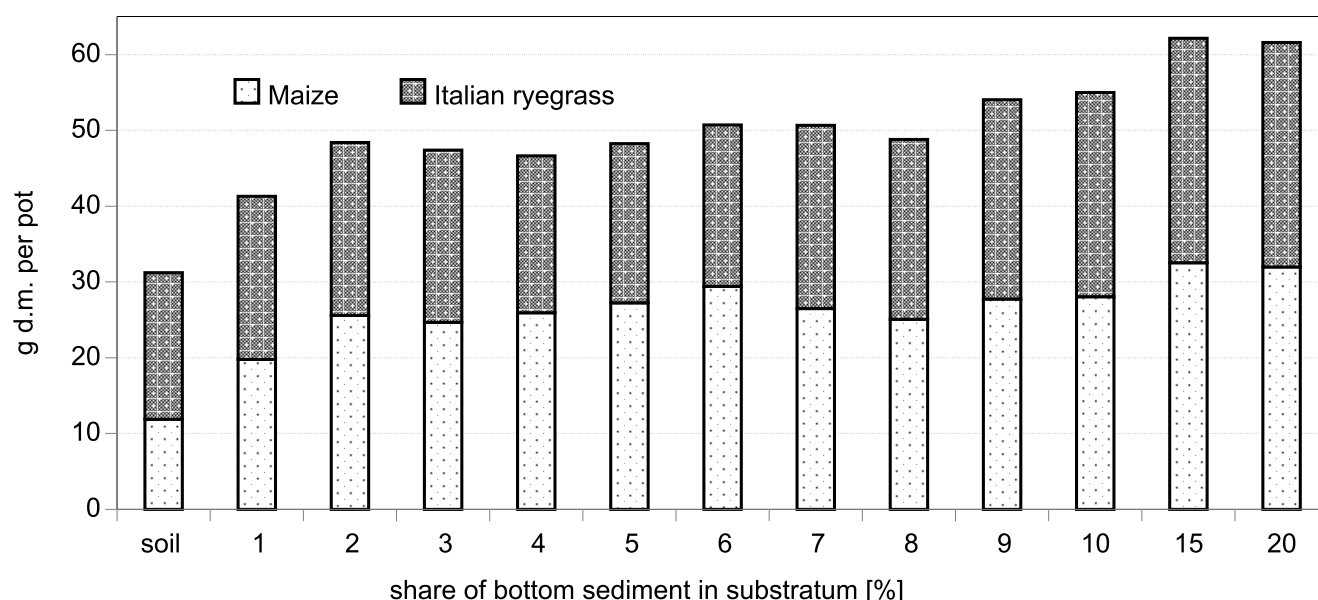


Figure 2. The amount of aerial biomass yield of maize and the total yield of aerial biomass of Italian ryegrass dependent on the share of the bottom sediment in the substratum (g d.m. per pot)

the aboveground biomass, 11.85 g d.m. per pot, and with the 15% share of the sediment the highest mass, 32.52 g d.m. per pot (Fig. 2). Similarly, the smallest root mass was registered for the plants grown on the soil without any supplement – 2.99 g d.m. per pot and the largest 7.37 g d.m. per pot when the sediment admixture was 15%. In the consecutive effect each sediment addition caused a significant increase in the yield of maize aboveground biomass and the root biomass in comparison with the one obtained on the same soil and respective $LSD_{0.005}$ were 5.63 g and 6.84 g d.m. per pot. In the case when the deposit share in the substratum reached 20%, a slight worsening of the maize crop yield was observed in relation to the object where 15% admixture was applied, but still the yield remained on the level about three times higher than on the control.

Similar relations were obtained in the case of the total amount of aerial biomass of both cultivated plants (Fig. 2).

DISCUSSION

The bottom sediment used for the described experiment revealed a relatively high content of calcium but had lower contents of organic carbon and total N than lake deposits^{9, 10} and contained small amounts of available phosphorus and potassium forms. The bottom sediment added to the soil in the amount constituted of 1% of the substratum mass caused an increase in the mass of the produced aboveground parts and roots of the test plants. For the first crop subsequent admixtures were increasing the mass to a small extent, but higher additions, of 7 or 8% and more, caused significant mass growths. Baran et al.¹² conducted experiments on the improvement of soil physico-chemical properties through an admixture of mine waste rocks to light soils, also obtained positive results which are demonstrated in the increased crop yields. Cantel et al.¹⁹ stated that the bottom deposits dredged from Albufer Lake and added to the sandy soil in the amounts of 180 to 720 Mg · ha⁻¹ led to an improvement in their water capacity and cation exchange capacity, which favourably influenced the crop yields of potatoes and lucerne. A

similar improvement of the properties and productivity of soil after the application of deposit from a water reservoir was found by Pelczar et al.²⁰. Besides the soil texture improvement, the reason of such reaction in plant yielding in the presented study might have been a positive effect of deposit admixture on the soil reaction, which tended towards alkaline with each subsequent increase in the deposit share in the substratum [data not included]. This beneficent effect became even more pronounced in the consequent plant yield. Both plants used in the experiment, especially maize, reveal relatively strong resistance to soil acidification but develop better when the soil reaction is close to neutral. Both plants also respond positively to large doses of fertilizer components, these however were the same on all experimental objects, therefore a significant increase in yields should be ascribed to an addition of the bottom sediment.

A supplement of sediment as a substance abundant in calcium and magnesium neutralizing soil acidity and amending magnesium deficiency in the light, very acid soil causes similar results as the application of calcium or calcium and magnesium fertilizers, whereas a high content of silt and clay fractions acts similarly to soil claying. Both these features of the sediment may cause a limiting bioavailability of potentially harmful elements, aluminium and heavy metals, whose phytoavailability depends not only on their total contents in the substratum but also on the soil properties, such as reaction and texture. Even under the conditions of considerable substratum enrichment in trace metals, at simultaneous regulation of soil reaction and improvement of its texture, a diminished accumulation of these elements in plants is observed, i.e. remedial action. As it was demonstrated by previous research conducted by the Author on larger supplements of the sediment, a significant limiting of trace metal uptake by the tested plants occurred despite a slight change of their total contents in the substratum²¹. The smallest admixtures of deposit supply to the substratum calcium quantities equal to a double value of hydrolytic acidity, which causes a rapid de-acidification of the substratum and may explain an apparent response of plant yield even at small sediment

supplements. When sediment additions were larger than 10%, it did not change the substratum reaction so apparently, therefore only slight decreases in the yield are registered in the case of the consequent plant. In this case also the changes of air-and-water conditions at considerable amount of silt and clay fractions supplied to the soil with sediment may modify the plant development. Air-and-water conditions of the substratum influence crop yields to a considerable degree; these may reveal high sensitivity to water excess in the soil, as e.g. wilting and a subsequent decline in the yield²².

CONCLUSIONS

The conducted research demonstrated that the application of the bottom sediment from the Rożnów Reservoir as an addition to the light, very acid soil causes an increase in the crop yield as a result of the improvement of the physicochemical properties of the substratum and a possible limiting of the uptake of potentially toxic trace elements. The bottom sediment may be recommended as a factor for the remediation of soils contaminated with trace elements. Although the bottom sediment and the soil used in the experiment, which were the components of the substratum, contained small quantities of organic matter, an improvement in the crop yield was observed, which should be ascribed to a positive effect of the bottom sediment on the substratum reaction, as it was found after the experiment completion. The dredged bottom sediment favourably influences crop yields but the way of biomass utilisation should be assessed on the basis of its chemical composition analysis.

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