Soil amendment with fish processing wastes at the low positive temperature regime

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In order to examine the possibilities of fish processing wastes to improve soil properties, the methodology was elaborated in 2012 and the experiment carried out in 2013. Having mixed the powder of fish bones with the soil, it was placed into the special vegetative pots of 5 l in volume up to the thickness of 25 cm. The experiment has designed in 4 variants and 6 replications. The vegetative pots with the soil and fish bones mixture were kept at the 1-5^{o}C temperature regime in order to estimate possible changes of nutrients at the low positive temperature regime.

The results obtained show that fish bones application has significantly positive effect on the content of available phosphorus, potassium, calcium, magnesium as well mineral, nitrate and ammonium nitrogen in the experimentally tested soils. Neither the amount nor the time of fish bones application didn't show any noticeable impact on soil pH value in medium heavy loam soil. However, the fish bones application has decreased the acidity of sandy loam (forest) soil by 0.2 unit after the application of 6.5 t ha^{-1}.

Soil, fish bones, nutrient availability

Introduction

From a practical point of view, it is important to evaluate short and long term effects of organic wastes amendments on soil quality because many of such materials contain nutrients that can benefit both the plant growth and soil productivity. Even more, recycling these materials onto land captures nutrients that would otherwise be lost, and helps sustain our resource base.

Among the by-products from fish processing plants are fish frames which include bone, heads and tails. Bones constitute a significant part of the fish; approximately 10-15% of total fish biomass is bones from the head and vertebrae and contain considerable amount of proteins and minerals (Amiza et al., 2013).

The fisheries waste is high in nitrogen and phosphorus, and also contains important trace elements making it an excellent broad-based organic fertilizer. A numerous researches over the years have showed the efficiency of fish by-products application for crop production and soil improvement, either singly or in combination with other amendments (Walworth et al., 2003; Abbasi et al., 2006; Arvanitoyannis and Kassaveti, 2008; Quilty J. and Cattle S., 2010, Pranckietienė et al., 2013). Some of these products may potentially help to improve or sustain soil health at relatively low application rates, through stimulating biological activity, enhancing nutrient and carbon cycling in the soil and potentially increasing the amount of organic carbon in the soil (Mondini et al., 2008; Rathore et al., 2009).

The aim of this work was to identify changes in soil chemical parameters while applying the fish processing wastes in different rates.

Material and methods

Two soils differing in pH value and in the texture have been taken for the experiment settlement – medium loam and sandy loam. This solution was based on the presumption that the transformation of non-available mineral nutrients into available for the plants mineral nutrients differ depending on soil pH value. Foreseen soil amount necessary for the experiment was collected with metallic auger from the upper 0-25 cm layer (humic horizon) in the arable and afforested land. Having received fish bones (T 681-5 VASKET Bein R1) they were dried at 105 ^{o}C temperature and milled up to 1.5 mm size particles in order to get suitable for the application fertilizer form. After the preparation procedure, the fish bones powder was mixed with the soil and placed into special vegetative pots of 5 l in volume up to the thickness of 25 cm (Fig. 1).

Fig. 1. Soil and fish bones powder mixture in the vegetative pots

The experiment has been implemented in 4 variants and 6 replications. Soil amendment with fish bones experiment scheme:

1. **Control** (without fish bones application)
2. **2.5 t ha^{-1}** (18 g in a vegetative pot)
3. **4.5 t ha^{-1}** (32 g in a vegetative pot)
4. **6.5 t ha^{-1}** (46 g in a vegetative pot)

The vegetative pots with the soil and fish bones mixture have been stored for the four months at the 1-5^{o}C temperature regime in order to estimate possible changes of nutrients that simulating conditions of the winter-spring season turn. The moisture of substrate (mixture) during the experiment period was steady kept at 70% from the water holding capacity.

Results and discussion

Before installing the experiment pH value of medium heavy loam soil was 6.7 (close to neutral). Although some changes in soil pH value have been apparent four months after the fish bones application, they were not significant (Table 1). Naturally, pH value of sandy loam soil was strongly acid (pH_{KCl} 4.3) before the experiment. It was found that pH value of sandy loam soil has increased by 0.2 in the case when 6.5 t ha^{-1} of fish bones applied and thus it was significant in comparison with the control variant (without fish bones application).

Table 1. Soil pH value changes four months after the fish bones application

Application rate	Soil pH_{KCl}	
	In medium heavy loam	In sandy loam
Control	6,7	4,3
2.5 t ha^{-1}	6,8	4,3
4.5 t ha^{-1}	6,6	4,4
6.5 t ha^{-1}	6,7	4,5
LSD_{05}	0,113	0,113

Before the experiment a medium heavy loam soil contained 92–100 mg kg^{-1} of available phosphorus (P_2O_5) and 50–63 mg kg^{-1} of available potassium (K_2O). Respectively, a sandy loam soil contained only 52 mg kg^{-1} of available phosphorus (P_2O_5) and 68–76 mg kg^{-1} of available potassium (K_2O). After four month of fish bones application the content of available phosphorus was found significantly increased both in medium heavy loam (556-2197 mg kg^{-1}) and sandy loam soils (262-490 mg kg^{-1}). Thus, after the fish bones application soil richness in available phosphorus corresponds to group V (very high amount). It is obvious that such a rise of available phosphorus (P_2O_5) concentration in the soil directly depends on the fish bones rate that was applied (Table 2).

Having analyzed fish bones application impact on available potassium concentration in the soil it was found a considerable increase of this element both in medium heavy loam soil and sandy loam soil.

Table 2. The concentrations of available phosphorus (P_2O_5) and available potassium (K_2O) in the soil four months after the fish bones application

Application rate	Available phosphorus (P_2O_5) in the soil mg kg^{-1}		Available potassium (K_2O) in the soil mg kg^{-1}	
	medium heavy loam	sandy loam	medium heavy loam	sandy loam
Control	96	52	57	72
2.5 t ha^{-1}	652	314	67	70
4.5 t ha^{-1}	1029	469	68	83
6.5 t ha^{-1}	2293	542	71	100
LSD_{05}	146.698	34.35	4.99	3.966

Respectively, four month after fish bones application the concentration of available potassium increased by 17.5–24.6 % in medium heavy loam soil and 15.3–38.9 % in sandy loam soil (Table 2). Nevertheless, even taking into account this considerable increase, it corresponds only to group II (small amount) according to the Lithuanian classification of soil richness in available potassium.

The experimental data doesn't show any determinant impact of fish bones application on soil organic carbon change in sandy loam soil (Table 3). On the contrary, in the medium heavy loam soil the concentration of organic carbon has significantly increased in the case when the rates of 2.5 and 4.5 t ha^{-1} fish bones applied and the slightly decrease observed when the maximum rate of 6.5 t ha^{-1} utilized.

Table 3. The concentrations of organic carbon and sulfur in the soil four months after the fish bones application

Application rate	Organic carbon in the soil %		Available sulfur (S) in the soil mg kg^{-1}	
	medium heavy loam	sandy loam	medium heavy loam	sandy loam
Control	7.56	2.27	5.8	11.6
2.5 t ha^{-1}	8.31	2.04	5.75	14.2
4.5 t ha^{-1}	10.26	2.30	14.5	19.8
6.5 t ha^{-1}	6.72	1.92	17.95	23.65
LSD_{05}	0.503	0.117	1.11	2.024

Before the experiment the medium heavy loam soil contained low concentrations of available sulfur (5.8 mg kg^{-1}). The data shows that soil amendment with fish bones application significantly increased available sulfur concentration both in medium heavy loam (14.5-17.95 mg kg^{-1}) and sandy loam soils (19.8–23.65 mg kg^{-1}) when the rates of 4.5 and 6.5 t ha^{-1} fish bones applied (Table 3). It is worthy to note that all soils containing > 12.0 mg kg^{-1} of available sulfur are considered to be rich in sulfur according to the Lithuanian natural conditions.

Before the experiment a medium heavy loam soil contained 6252–8344 mg kg^{-1} of calcium and sandy loam soil – 630–638 mg kg^{-1}. Four months after fish bones application the concentration of calcium significantly increased up to 8386–9202 mg kg^{-1} in the medium heavy loam soil and respectively in the sandy loam soil – up to 8386–9202 mg kg^{-1} (Table 4). Similarly, a significant increase of magnesium observed in the medium heavy loam soil after the fish bones application. However, it was not a case in sandy loam soil – although the tendency of magnesium concentration increase observed when 4.5 and 6.5 t ha^{-1} of fish bones applied, the amendment with the 2.5 t ha^{-1} showed even some slight decrease of magnesium concentration in the soil.

Table 4. The concentrations of calcium (Ca) and magnesium (Mg) in the soil four months after the fish bones application

Application rate	Calcium (Ca) in the soil mg kg^{-1}		Magnesium (Mg) in the soil mg kg^{-1}	
	medium heavy loam	sandy loam	medium heavy loam	sandy loam
Control	7298	634	634	120
2.5 t ha^{-1}	8495	814	759	111
4.5 t ha^{-1}	8788	1126	702	132
6.5 t ha^{-1}	9134	1353	705	138
LSD_{05}	642.059	84.139	47.984	16.331

Before the experiment it was found 0.543 – 0.659 % of total nitrogen in medium heavy loam soil and respectively – 0.14 – 0.15 % of total nitrogen in sandy loam soil. The amendment with fish bones has increased very slightly the total nitrogen concentration in the in medium heavy loam soil when the rates 4.5 and 6.5 t ha^{-1} of fish bones applied (Table 5). However, in spite of the rate utilized, a significant increase of total nitrogen concentration was estimated in the sandy loam soil four months after fish bones application in comparison with the control variant.

Table 5. The concentrations of total and mineral nitrogen in the soil four months after the fish bones application

Application rate	Total nitrogen in the soil %		Mineral nitrogen in the soil mg kg^{-1}	
	medium heavy loam	sandy loam	medium heavy loam	sandy loam
Control	0.601	0.146	78.25	46.42
2.5 t ha^{-1}	0.584	0.177	191.43	175.96
4.5 t ha^{-1}	0.629	0.180	246.92	239.41
6.5 t ha^{-1}	0.686	0.167	369.62	331.38
LSD05	0.108	0.018	32.796	9.707

Having analyzed the impact of fish bones application on mineral nitrogen concentration it was estimated positive effect both in the medium heavy loam and sandy loam soil (table 5). Thus, four months after fish bones application the concentration of mineral nitrogen has significantly increased by 113.18– 291.37 mg kg^{-1} in the medium heavy loam soil and accordingly in the sandy loam soil – by 129.54– 284.96 mg kg^{-1}. In all cases this increase is strongly dependent on the applied fish bones rate.

Before the experiment it was found 61.02–91.02 mg kg^{-1} of nitrate nitrogen in the medium heavy loam soil and respectively – 41.06–43.77 mg kg^{-1} in sandy loam soil. It was found that concentration of nitrate nitrogen in the soil consistently increased in all cases after fish bones application and that directly depends on the rate of fish bones that was applied (Table 6).

Table 6. The concentrations of nitrate (NO_3) ant ammonium nitrogen (NH_4) in the soil four months after the fish bones application

Application rate	Nitrate (NO_3) nitrogen in the soil mg kg^{-1}		Ammonium (NH_4) nitrogen in the soil mg kg^{-1}	
	medium heavy loam	sandy loam	medium heavy loam	sandy loam
Control	76.02	43.77	2.23	4.0
2.5 t ha^{-1}	187.8	169.8	3.63	6.16
4.5 t ha^{-1}	242.25	222.7	4.67	16.71
6.5 t ha^{-1}	364.55	298.1	5.07	33.28
LSD05	33.212	19.68	0.294	2.544

Thus, in the medium heavy loam soil the concentration of nitrate nitrogen increased by 2.5 – 4.8 times and accordingly in the sandy loam soil – by 3.9 – 6.8 times in comparison with the control variant. Having analyzed the impact of fish bones application on ammonium nitrogen concentration it was estimated a significant increase of this compound both in the medium heavy loam (by 14–2.84 mg kg^{-1}) and sandy loam (by 2,16 – 29,28 mg kg^{-1}) soils.

Conclusions

1. The fish bones application has significantly increased concentrations of available phosphorus and available potassium, calcium, magnesium, sulfur and nitrogen (mineral, nitrate and ammonium) in the tested differently-textured soils. In general, a relatively higher positive impact of fish bones application was observed in the light-textured (sandy loam) soil.
2. The concentration of organic carbon has significantly increased in the heaver-textured (medium heavy loam) soil in the case when the rates of 2.5 and 4.5 t ha^{-1} of fish bones applied and the slightly decrease observed when the maximum rate of 6.5 t ha^{-1} utilized.
3. The application of fish bones didn't show any noticeable impact on soil pH value in heaver-textured (medium heavy loam) soil. However, the amendment with fish bones has decreased the acidity of light-textured (sandy loam) soil by 0.2 unit after the application of 6.5 t ha^{-1}.

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Dirvožemio gerinimas žuvies pramonės atliekomis žemos teigiamos temperatūros sąlygomis

Santrauka

Tyrimai atlikti 2013 metais, siekiant ištirti ir įvertinti žuvų produktų atliekų panaudojimo galimybes dirvožemiui gerinti. Pagal parengtą metodiką žuvų kaulų miltai buvo skirtingomis proporcijomis sumaišyti su dirvožemiu, o gautas substratas 25 cm storio sluoksniu supiltas į 5 l talpos vegetacinius indus. Eksperimentas vykdytas 4 variantais ir 6 pakartojimais. Dirvožemis su žuvų miltais buvo 4 mėn. laikomas prie 1-5 ^{o}C temperatūros, siekiant išsiaiškinti augalams reikalingų mitybos elementų pokyčius žemos teigiamos temperatūros sąlygomis.

Tyrimų rezultatai rodo, kad žuvų kaulų miltai esmingai didino judriojo fosforo ir judriojo kalio, kalcio, magnio, sieros ir mineralinio (tiek nitratinio, tiek ir amoniakinio) azoto kiekius tirtuose skirtingos granuliometrinės sudėties dirvožemiuose. Žuvų kaulų miltų panaudojimas neturėjo jokios įtakos vidutinio sunkumo priemolio dirvožemio pH, tačiau naudojant maksimalią 6,5 t ha^{-1} normą lengvo priesmėlio dirvožemio rūgštumas esminiai sumažėjo (per 0,2 pH vnt.).

Dirvožemis, žuvų kaulai, mitybos elementų prieinamumas

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