Assessment of Fish Processing Wastes for the Improvement of Soil Properties

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Abstract

Two soils differing in pH value and in the texture have been taken for the experiment settlement – medium heavy loam and sandy loam. In order to examine the possibilities of fish and rape processing wastes to improve soil properties, the methodology was elaborated and the experiment started. Thus, after the preparation of fish bones, their powder was obtained and when mixed 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 results obtained show that fish bones application has significantly influenced the increase of available phosphorus, mineral, nitrate and ammonium nitrogen content in the both experimentally tested soils. In general, the noticeable higher positive impact of fish bones application was observed in the sandy loam (forest) soil. The fish bones application have had positive effect on the content of available potassium, calcium and available sulfur in the medium heavy loam soil as well as on the content of available potassium, calcium, magnesium, total nitrogen and available sulfur in the sandy loam soil. In the case of magnesium and total nitrogen content, the increase was significant. Also, the fish bones application has decreased the acidity of sandy loam (forest) soil by 0.1–0.3 unit. Neither the amount nor the time of fish bones application didn't show any noticeable impact on soil pH value, magnesium and total nitrogen content in medium heavy loam soil. The organic carbon content remained unchanged both in medium heavy loam and sandy loam soils. Fish bones application has significantly influenced the increase of microbiota abundance in medium heavy loam (agricultural) as well as in sandy loam (forest) soils. However, the significantly by 2-9 times higher abundance was estimated in amended agricultural soils. Microbial biomass carbon and nitrogen in tested soils have been increasing along with fish bones application but not so drastically as microbial abundance. In amended agricultural soils the microbial biomass nitrogen was more than 2 times and carbon more then 3 times higher than in forest soils.

Key words: soil, fish bones, nutrient availability, microbial abundance.

Introduction

Nowadays a food production without waste is very important, therefore, it is necessary to find appropriate utilization ways of waste products. In general, many organic wastes contain nutrients and organic matter that may benefit plant growth and soil productivity. Recycling these materials onto land captures nutrients that would otherwise be lost, and helps sustain our resource base.

Fish waste management has been one of the problems having the greatest impact on the environment in recent years. Due to its high organic content, fish waste is often classified as a certified (prescribed) waste which is even more costly to dispose (Jesperson et al., 2000). Nevertheless, treated fish waste has found many practical applications among which the most important are animal feed, biodiesel/biogas, dietic products (chitosan), natural pigments (after extraction), food-packaging applications (chitosan), cosmetics (collagen), enzyme isolation, Cr immobilisation, soil fertiliser and moisture maintenance (hydrolysates) in foods (Arvanitoyannis and Kassaveti, 2008).

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 (El-Tarabily et al., 2003; Walworth et al., 2003; Abbasi et al., 2004; Knucky et al., 2004; Abbasi et al., 2006; Quilty J. and Cattle S., 2010). 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 is to identify any changes to soil characteristics (pH level, nutrient availability) and soil microbiota (abundance, microbial biomass carbon and nitrogen) as resulting from the fish bones application rates and time.

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 steel 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. The experiment has been implemented in 4 variants and 6 replications.

Scheme of the fertilization with fish bones experiment
1. Control (without fish bones application)
2. 2.5 t ha^{-1} (18 g of fish bones powder into the vegetative pot)
3. 4.5 t ha^{-1} (32 g of fish bones powder into the vegetative pot)
4. 6.5 t ha^{-1} (46 g of fish bones powder into the vegetative pot)

The vegetative pots with the soil and fish bones mixture have been stored at the different temperature regime: (1) first 30 days will be kept at 10°C degree, and (2) remaining 60 days - at 18°C degree. Simultaneously, some vegetative pots with the soil and fish bones mixture were kept at the 1-5°C temperature regime in order to estimate possible changes of nutrients in cold conditions corresponding winter season. The moisture of substrate (mixture) is 70% from the water holding capacity. It is planned to measure the changes of mineral nutrients in substrate three times: (1) 30 (one months), (2) 120 (four months) and (3) 360 days (twelve months) after the fish bones application. Chemical soil analyses were carried out by the appropriate conventional methods at the Agrochemical Research Laboratory of the Lithuanian Research Centre for Agriculture and Forestry.

Results and discussion

Before the experiment pH value of medium heavy loam soil was 6.7 (close to neutral) and after the one month of fish bones application it practically didn't change (Table 1). However, after the four months of fish bones application some changes in soil pH value have been apparent but they were not significant. It was found that the value of soil pH has changed by 0.05 unit after the application 2.5 and 4.5 t ha^{-1} of fish bones and by 0.15 unit – after the application 6.5 t ha^{-1} of fish bones. Before the experiment a sandy loam soil was strongly acid (pH_{KCl} 4.2). After one month of the experiment it was found that soil acidity decreased by 0.1 unit when 2.5 and 4.5 t ha^{-1} of fish bones applied and by 0.3 unit after the application 6.5 t ha^{-1} of fish bones (Table 5). After four months of the experiment pH value of the sandy loam soil was found at the same level as it was one month after the fish bones application. However, pH value of sandy loam soil increased by 0.2 in the case when 4.5 t ha^{-1} of fish bones applied and thus has showed the same effect as it was obtained with the 6.5 t ha^{-1} of fish bones application.

Table 1. **The impact of fish bones application on the pH value change in different textured soils**

Rate of fish bones applied into the soil	Soil pH_{KCl}			
	In medium heavy loam		In sandy loam	
	After 1 month	After 4 months	After 1 month	After 4 months
Control	6.70	6.70	4.2	4.2
2,5 t ha^{-1}	6.70	6.75	4.3	4.3
4,5 t ha^{-1}	6.70	6.75	4.3	4.5
6,5 t ha^{-1}	6.65	6.85	4.5	4.5
LSD_{05}	0.113	0.161	0.113	0.291

Before the experiment a medium heavy loam soil contained 88-100 mg kg^{-1} of available phosphorus (P_2O_5) and 50 mg kg^{-1} of available potassium (K_2O). After one month of fish bones application the content of available phosphorus significantly increased and that directly depends on the fish bones rate that was applied (Table 2). The content of available phosphorus increased in 6.72 times after the application 2.5 t ha^{-1} of fish bones and it has reached even 1376 mg kg^{-1} when the rate of fish bones have been increased up till 6.5 t ha^{-1}. Although a tendency of some further increase in available phosphorus content was estimated four months after of fish bones application, it was insignificant in comparison with the effect estimated one month after fish bones application. Having analyzed fish bones application impact on available potassium in the medium heavy loam soil it was found a considerable increase of this element both one and four months after fish bones application. Respectively, one month after fish bones application the content of available potassium increased by 8.2-30.6 % and four months after application by 13.2-15.1 % in comparison with control variant. The maximum potassium increase (18.9 %) four months after fish bones application was found in the case when the maximum rate of 6.5 t ha^{-1} have been applied. 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.

Table 2**. The impact of fish bones application on the available phosphorus (P_2O_5) and available potassium (K_2O) content changes in medium heavy loam soil**

Rate of fish bones applied into the soil	Content of available phosphorus (P_2O_5) in the soil mg kg^{-1}		Content of available potassium (K_2O) in the soil mg kg^{-1}	
	After 1 month	After 4 months	After 1 month	After 4 months
Control	94,0	100,0	49,0	53,0
2,5 t ha^{-1}	726,0	763,0	53,0	61,0
4,5 t ha^{-1}	951,0	949,0	57,0	60,0
6,5 t ha^{-1}	1376,0	1597,0	64,0	63,0
LSD_{05}	287,29	419,21	1,837	3,869

Before the experiment a sandy loam soil contained only 45-51 mg kg^{-1} of available phosphorus (P_2O_5) and 51-52 mg kg^{-1} of available potassium (K_2O). In both cases it is considered as very poor conditions according to the Lithuanian classification of soil richness in available phosphorus and potassium. However, it was found that content of available phosphorus significantly increased in all cases after fish bones application and that directly depends on the rate of fish bones that was applied (Table 3). Respectively, one month after fish bones application the content of available phosphorus increased by 334.5-787 mg kg^{-1} and four months after application – 364-568.5 mg kg^{-1}. Thus, after the fish bones application sandy loam soil richness in available phosphorus corresponds to group V (very high amount).

Table 3. **The impact of fish bones application on the available phosphorus (P_2O_5) and available potassium (K_2O) content changes in sandy loam soil**

Rate of fish bones applied into the soil	Content of available phosphorus (P_2O_5) in the soil mg kg^{-1}		Content of available potassium (K_2O) in the soil mg kg^{-1}	
	After 1 month	After 4 months	After 1 month	After 4 months
Control	47.0	54.0	51.5	60.5
2,5 t ha^{-1}	381.5	364.0	61.5	80.0
4,5 t ha^{-1}	487.0	519.5	63.0	81.5
6,5 t ha^{-1}	834.0	568.5	84.5	90.0
LSD_{05}	321.56	151.37	9.787	25.756

Having analyzed fish bones application impact on available potassium in the sandy loam soil it was found a considerable increase of this element both one and four months after fish bones application. Respectively, one month after fish bones application content of available potassium increased by 10-33 mg kg^{-1} and four months after application by 32.2-34.7 % in comparison with control variant. The maximum and significant potassium increase (48.8 %) four months after application was found in the case when the rate of 6.5 t ha^{-1} fish bones applied. 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 both in medium heavy loam and sandy loam soils (Table 4). For instance, one month after fish bones application the content of organic carbon even slightly decreased (0.7-1.1 %) in heavy medium loam but it was not significant difference. On the contrary, in sandy loam soil, one month after fish bones application the content of organic carbon has slightly increased (3.5-4.5 %) but also it was not significant difference. Similarly, such the nonessential tendencies have been observed four months after the fish bones application both in heavy medium loam and sandy loam soils.

Table 4. **The impact of fish bones application on the organic carbon content in medium heavy loam and sandy loam soils**

Rate of fish bones applied into the soil	Content of organic carbon in the soil % in medium heavy loam		Content of organic carbon in the soil % in sandy loam	
	After 1 month	After 4 months	After 1 month	After 4 months
Control	8.81	7.90	1.72	2.235
2,5 t ha^{-1}	7.71	8.50	1.78	1.87
4,5 t ha^{-1}	8.11	9.72	1.8	1.865
6,5 t ha^{-1}	7.89	8.06	1.8	1.865
LSD_{05}	0.712	1.890	0.231	0.319

Before the experiment a medium heavy loam soil contained 7748–7892 mg kg^{-1} of calcium and 652 mg kg^{-1} of magnesium. One month after fish bones application the content of calcium has slightly increased up to 8386–9202 mg kg^{-1} as dependent on the rate of fish bones has been applied. Similarly, four months after fish bones application the content of calcium increased up to 8376–9322 mg kg^{-1}. However, there was no effect of fish bones application on magnesium content in medium heavy loam soil both one and four months after fish powder application (Table 5).

Table 5. **The impact of fish bones application on calcium (Ca) and magnesium (Mg) content in medium heavy loam soil**

Rate of fish bones applied into the soil	calcium (Ca) content in the soil mg kg^{-1}		Magnesium (Mg) content in the soil mg kg^{-1}	
	After 1 month	After 4 months	After 1 month	After 4 months
Control	7820	8044	652	700
2,5 t ha^{-1}	8386	8376	660	714
4,5 t ha^{-1}	8455	8780	657	690
6,5 t ha^{-1}	9202	9322	676	706
LSD_{05}	320.262	984.725	30.608	54.824

Before the experiment a sandy loam soil contained only 490 mg kg^{-1} of calcium (Ca) and 88 mg kg^{-1} of magnesium (Mg). It was found that content of calcium steady and significantly increased in all cases after fish bones application and that directly depends on the rate of fish bones that was applied (Table 6). Respectively, one month after fish bones application the content of calcium increased up to 1387–1583 mg kg^{-1} and four months after application – up to 873–1519 mg kg^{-1}. Nevertheless, four months after fish bones application it was estimated some calcium content decrease in comparison with the content of calcium one month after fish bones application. Probably, such a tendency is connected to the high acidity level (pH 4.2-4.5) of sandy loam soil. Having analyzed the impact of fish bones application on magnesium content in the sandy loam soil it was found a considerable increase of this element both one and four months after fish bones application (Table 6). Respectively, one month after fish powder application content of available potassium increased by 30 % – 57 % and four months after application – by 14 % – 25 % in comparison with control variant.

Table 6. **The impact of fish bones application on calcium (Ca) and magnesium (Mg) content in sandy loam soil**

Rate of fish bones applied into the soil	calcium (Ca) content in the soil mg kg^{-1}		Magnesium (Mg) content in the soil mg kg^{-1}	
	After 1 month	After 4 months	After 1 month	After 4 months
Control	493	547	90	118
2,5 t ha^{-1}	1387	873	117	134
4,5 t ha^{-1}	1652	1204	123	142
6,5 t ha^{-1}	1583	1519	141	147
LSD_{05}	886.459	164.941	25.126	5.626

Before the experiment it was found 0.591–0.648 % of total nitrogen and 45.98–47.71 mg kg^{-1} of mineral nitrogen in a medium heavy loam soil. The experimental date have shown (Table 7) that in some cases the content of total nitrogen slightly decreased (by 0.03–0.04 %). Even so, the mathematical-statistical analysis of nitrogen content doesn't show any determinant impact of fish bones utilization in a medium heavy loam soil one and four months after the application. Having analyzed the impact of fish bones application on mineral nitrogen in medium heavy loam soil it was found positive effect both one and four months after fish bones application. Respectively, one month after fish bones application the content of mineral nitrogen has significantly increased from 90.13 up till 223.15 mg kg^{-1} and four months after fish bones application – from 130.39 up till 321 mg kg^{-1} in comparison with the control variant. In all cases such a tendency was strongly connected to the applied fish bones rate.

Table 7. **The impact of fish bones application on total and mineral nitrogen content in medium heavy loam soil**

Rate of fish bones applied into the soil	Total nitrogen content in the soil %		Mineral nitrogen content in the soil mg kg^{-1}	
	After 1 month	After 4 months	After 1 month	After 4 months
Control	0.620	0.659	46.85	93.30
2,5 t ha^{-1}	0.620	0.668	136.98	223.69
4,5 t ha^{-1}	0.616	0.673	207.61	266.98
6,5 t ha^{-1}	0.617	0.655	270.00	414.30
LSD05	0.046	0.052	9.192	18.989

Before the experiment it was found 0.137 – 0.128 % of total nitrogen and 33.66 mg kg^{-1} of mineral nitrogen in a sandy loam soil. One month after fish bones application, the content of total nitrogen slightly increased (by 0.03–0.05 %) in comparison with the control variant (Table 8). Although four months after fish bones application the content of total nitrogen increased only by 0.03–0.04 % when the rate of 2.5 and 4.5 t ha^{-1} of fish bones utilized, it was found to be a significant increase. Having analyzed the impact of fish bones application on mineral nitrogen content in sandy loam soil it was estimated positive effect both one and four months after the fish bones utilization. Thus, one month after fish bones application the content of mineral nitrogen has significantly increased from 75.92 up till 212.03 mg kg^{-1}. Similarly, a significant increase of mineral nitrogen was found four months after fish bones application when 4.5 and 6.5 t ha^{-1} utilized. In all cases this increase is strongly dependent on the applied fish bones rate.

Table 8. **The impact of fish bones application on total and mineral nitrogen content in sandy loam soil**

Rate of fish bones applied into the soil	Total nitrogen content in the soil %		Mineral nitrogen content in the soil mg kg^{-1}	
	After 1 month	After 4 months	After 1 month	After 4 months
Control	0.133	0.142	36.06	141.47
2,5 t ha^{-1}	0.162	0.156	111.98	205.46
4,5 t ha^{-1}	0.184	0.178	142.27	314.76
6,5 t ha^{-1}	0.165	0.167	248.09	470.58
LSD05	0.057	0.016	28.042	99.631

Before the experiment it was found 41.15–42.85 mg kg^{-1} of nitrate nitrogen and 4.83–4.86 mg kg^{-1} of ammonium nitrogen in a medium heavy loam soil. It was found that content of nitrate nitrogen consistently increased in all cases after fish bones application and that directly depends on the rate of fish bones that was applied (Table 9). Respectively, one month after fish bones application the content of nitrate nitrogen increased from 212 % up till 522 % and four months after application – from 143 % up till 351 %. Having analyzed the impact of fish bones application on ammonium nitrogen content it was estimated a significant increase of this compound by 1.18–3.84 mg kg^{-1} one month after the fish bones utilization in medium heavy loam soil. A strong correlation has been found between ammonium nitrogen content in the soil and fish bones rate. The slightly increase of ammonium nitrogen was estimated also four months after the fish bones application in comparison with the control variant. On the other hand, four months after the fish bones application a significant decrease of ammonium nitrogen content was observed in comparison with the amount of ammonium nitrogen that was estimated one month after the fish bones utilization.

Table 9. **The impact of fish bones application on nitrate (NO_3) ant ammonium nitrogen (NH_4) content in medium heavy loam soil**

Rate of fish bones applied into the soil	Nitrate (NO_3) nitrogen content in the soil mg kg^{-1}		Ammonium (NH_4) nitrogen content in the soil mg kg^{-1}	
	After 1 month	After 4 months	After 1 month	After 4 months
Control	42.0	91.02	4.85	2.28
2,5 t ha^{-1}	130.95	220.9	6.03	2.79
4,5 t ha^{-1}	200.06	263.75	7.56	3.23
6,5 t ha^{-1}	261.31	410.7	8.69	3.6
LSD05	8.508	0.088	0.742	1.133

Before the experiment it was found 30.13–34.7 mg kg^{-1} of nitrate nitrogen and 3.53–3.75 mg kg^{-1} of ammonium nitrogen in sandy loam soil. It was found that content of nitrate nitrogen consistently increased both one and four months after the fish bones application (Table 10). Thus, one month after the fish bones application the content of nitrate nitrogen has increased from 75.62 up till 191.47 mg kg^{-1}. Four months after the fish bones application the content of nitrate nitrogen significantly increased when 4.5 and 6.5 t ha^{-1} fish bones have been applied. Having analyzed the impact of fish bones application on ammonium nitrogen content it was estimated a significant increase of this compound one month after the fish bones utilization in sandy loam soil. A significant increase by 3.41–20.56 mg kg^{-1} was estimated when the rate 4.5 and 6.5 t ha^{-1} of fish bones have been applied. Four months after the fish bones application the analogous tendency observed.

Table 10. **The impact of fish bones application on nitrate (NO_3) ant ammonium nitrogen (NH_4) content in sandy loam soil**

Rate of fish bones applied into the soil	Nitrate (NO_3) nitrogen content in the soil mg kg^{-1}		Ammonium (NH_4) nitrogen content in the soil mg kg^{-1}	
	After 1 month	After 4 months	After 1 month	After 4 months
Control	32.42	136.60	3.64	4.88
2,5 t ha^{-1}	108.04	196.25	3.95	9.19
4,5 t ha^{-1}	135.23	306.10	7.05	8.08
6,5 t ha^{-1}	223.89	449.30	24.20	21.28
LSD05	27.303	102.492	0.936	5.648

Before the experiment it was found 3.6 mg kg^{-1} (poor level) of available sulfur in medium heavy loam soil. One month after the fish bones application some slightly increase in the content of sulfur (by 0.1–0.5 mg kg^{-1}) observed. The much more significant increase of sulfur content estimated four months after the fish bones application (from 3.55 up till 15.9 mg kg^{-1}) but the only statistically significant increase was found when 6.5 t ha^{-1} of fish bones has been utilized. Before the experiment it was found only 0.8 mg kg^{-1} (very poor level) of available sulfur in sandy loam soil. One month after the fish bones application some changes observed but they were very much irregular. Four months after the fish bones applied, the content of available sulfur significantly increased from 18.33 up till 26.38 mg kg^{-1} in comparison with the control variant. 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.

The fish bones application has significantly influenced the increase in microbiota abundance in tested soils (Table 11). However, the higher mean total abundance of microbiota was in agricultural soils. It was estimated, that the abundance of microbiota have been increasing along with fish bones application and in agricultural soils it comprised from 997.6 to 11259.5 thousand CFU g^{-1}. Though, the mean total abundance of microbiota in amended forest soils was significantly ($p<0.05$) by 2–9 times lower than in amended agricultural soils. Even though, the abundance of microbiota have been also increasing along with fish bones application the mean microbiota abundance here comprised from 498.8 to 1316.7 thousand CFU g^{-1}.

Table 11**. The impact of fish bones application on microbiota mean total abundance in tested soils**

Rate of fish bones applied into the soil	Abundance of microbiota thousand CFU g^{-1} (DM)	
	In medium heavy loam after 4 months	In sandy loam after 4 months
Control	997.6 ± 47.1	498.8 ± 23.6
2.5 t ha^{-1}	2526.1 ± 272.4	725.4 ± 25.8
4.5 t ha^{-1}	5932.6 ± 472.3	899.8 ± 10.2
6.5 t ha^{-1}	11259.5 ± 127.3	1316.7 ± 106.7

Note: in the tables 11 and 12, the average data of standard nutrient mediums is presented. Standard errors of means (n = 6) are given in the table.

The mean values for microbial biomass C were 59.2 and 102.0 µg C g^{-1} in forest, thus, 136.1 and 321.2 µg C g^{-1} in agricultural soils (Table 12). The results of the soil microbial biomass analysis indicate that the amended agricultural soils contained significantly 2-3 times highest microbial biomass C than in amended forest soils. The same tendencies could be determined estimating the microbial biomass nitrogen in tested soils. However, the differences were not considerably high. The mean values for microbial biomass N ranged from 8.2 to 14.2 μg N g^{-1} in forest, and from 12.4 to 29.2 μg N g^{-1} in agricultural soils.

Table 12. **The impact of fish bones application on microbiota biomass carbon and nitrogen mean concentrations in tested soils**

Rate of fish bones applied into the soil	Microbiota biomass carbon μg C g^{-1} after 4 months		Microbiota biomass nitrogen μg N g^{-1} after 4 months	
	In medium heavy loam	In sandy loam	In medium heavy loam	In sandy loam
Control	136.1 ± 4.8	59.2 ± 2.1	12.4 ± 0.4	8.2 ± 0.3
2.5 t ha^{-1}	239.2 ± 8.0	77.2 ± 2.6	21.7 ± 0.7	10.7 ± 0.4
4.5 t ha^{-1}	264.4 ± 9.2	91.2 ± 3.2	24.0 ± 0.8	12.7 ± 0.4
6.5 t ha^{-1}	321.2 ± 9.3	102.0 ± 3.6	29.2 ± 0.8	14.2 ± 0.5

Conclusions

The fish bones application has significantly influenced the increase of available phosphorus, mineral, nitrate and ammonium nitrogen content in the both experimentally tested soils. In general, the noticeable higher positive impact of fish bones application was observed in the sandy loam (forest) soil.

The fish bones application have had positive effect on the content of available potassium, calcium and available sulfur in the medium heavy loam soil as well as on the content of available potassium, calcium, magnesium, total nitrogen available and sulfur in the sandy loam soil. In the case of magnesium and total nitrogen content, the increase was significant. Also, the fish bones application has decreased the acidity of sandy loam (forest) soil by 0.1–0.3 unit.

Neither the amount nor the time of fish bones application didn't show any noticeable impact on soil pH value, magnesium and total nitrogen content in medium heavy loam soil. The organic carbon content remained unchanged both in medium heavy loam and sandy loam soils.

Fish bones application has significantly influenced the increase in microbiota abundance in medium heavy loam (agricultural) as well as in sandy loam (forest) soils. However, the significantly by 2–9 times higher abundance was estimated in amended agricultural soils.

Microbial biomass carbon and nitrogen in tested soils have been increasing along with fish bones application but not so drastically as microbial abundance. In amended agricultural soils the microbial biomass nitrogen was more than 2 times and carbon more than 3 times higher than in forest soils.

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