African Journal of Biotechnology Vol. 10(73), pp. 16508-16515, 21 November, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.110
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Effect of sewage sludge and synthetic fertilizer on pH, available N and P in pasture soils in semi-arid area, Turkey

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Accepted 24 October, 2011

Activated sewage sludge from the aerobically-digested treatment and synthetic fertilizer were used to determine total N, available P and pH in different soil depth of pasture in semi arid ecological condition, in Van, Turkey. The study was carried out in a completely randomized block. Four treatment of sewage sludge, one treatment of synthetic fertilizer and no treatment as a control were used in two consecutive years. Soil samples were collected from surface soil (0 to 20 cm) and subsoil (20 to 40 cm) 11 months after SS (sewage sludge) and TSP (triple super phosphate) application and 7 months after AN application for both years. By using sewage sludge and synthetic fertilizers treatments, surface and subsoil pH decreased. The decreases of pH in SF and control plots in both soil depths in 2008 were attributed to root biomass. Although, sewage sludge contains less amount of nitrogen than synthetic fertilizer does, it enabled nitrogen detection in both soil depths for a longer time and in a higher amount. While an increase in the amount of nitrogen in surface soil and subsoil was determined in 2007, a decrease in these was determined in 2008 in both depths. Amount of subsoil available phosphorus increased more by sewage sludge applications. However, amount of surface soil available phosphorus increased more by sewage sludge applications in 2007, while it increased more by synthetic fertilizer application in 2008. The lowest pH value, highest amounts of total N and available P was obtained by higher doses of sewage sludge. However, when long time applications and mineralization process were considered, sewage sludge's dose of 2.5 ton/ha^{-1} ya^{-1} can be said to provide more beneficial results than the synthetic fertilization's highest dose which is suggested for pastures and meadows.

Key words: Sewage sludge, synthetic fertilizer, pH, N, P, available duration.

INTRODUCTION

Pastures and meadows are important for protection and sustainment of soil and water resources. Regaining the nutrient elements, which are removed from soil through grazing and cutting, is necessary for these areas to fulfill their protection and production functions. Therefore, like other agricultural areas, pastures and meadows need fertilization. Nitrogen and phosphorus are the main plant nutrient elements consumed in agriculture facilities. In Turkey, 65% of the fertilizers used up between the years 1981 and 2008 were nitrogenous fertilizers, while 32% of them were phosphorus fertilizers. While the rate of consumed N/P ratio was 1.5 at the beginning, this ratio has reached the 3.4 levels, nowadays (Eraslan et al., 2010). The concentration of P and N in overland flow usually exceeded state water quality targets (<0.04 mg P/L and <0.90 mg N/L), suggesting that, background losses of nutrients from these pasture systems could eutrophication (Robertson and Nash, 2008). Especially, to prevent leaching of nitrogen in synthetic fertilizer from soil in short time and to extend its usefulness duration, coating it with wax or plastic are suggested. However, there is a risk of extending environmental pollution by

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deposition of these coating materials in the soil (Karaçal and Tüfenkçi, 2010). Same researchers stated that the fertilizers called "super granule" which are as large as hazelnut and walnut should be mixed with soil and applied. But this application style is not practical for pastures and meadows. As can be seen, synthetic fertilizers have an important role in environmental pollution based on agriculture.

In recent years, in addition to conventional animal and herbal waste, sewage sludge remains in domestic wastewater treatment plants has begun to be used as a fertilizer. In European Union countries up to 80% of sewage sludge is used in agricultural and forestry as a fertilizer (Pogrzeba et al., 2001). Application of biosolids (sewage sludge) to agricultural land improve the physical properties (structure, porosity, etc.); increase macro-nutrient content have a positive effect on soils biology and biochemistry (Pascual et al.,1997). The disposal of sewage sludge is one of the major environmental concerns throughout the world (Singh and Agrawal, 2008).

Land application and land filling of sewage sludge are suggested to be the most economical and useful options of disposal sewage sludge (Sing and Agrawal, 2010). By use of sewage sludge as a waste in agriculture, the disposal of heavy metals in lower concentrations can be provided in addition to high N and P content. Since disposal by dumping at sea was banned in 1998 by regulations implementing the EU urban waste water treatment directive (91/271/EEC) and reduction of landfilling gradually (eurostat), the use of sewage sludge in agriculture is a necessity. The use of sewage sludge in agriculture has been increasing in countries where systematic flow of data is present like the United Kingdom, England and Wales, Spain and Poland except France and Germany (eurostat). It is an important deficiency that two major members of European Union (Germany and France) do not provide healthy statistical data about "total sludge production" which is a significant source of pollution (eurostat). Recycling biosolids (sewage sludge) to pasture-based animal production is quite productive as nutrient sources (Sigua, 2009). Organic N and inorganic P constitute the majority of total N and P, respectively of sludge (Singh and Agrawal, 2008). Warman and Termeer (2005) proved that aero-bically-digested sewage sludge could be effective sources of N, P and K for crop production, although, the nutrient availability of N and P from organic amendments was considerably lower than the 50% availability assumed. They indicated that continuous applications will likely lead to crop yield and nutrient uptake equivalent to conventional fertilizer because mineralization of organic fraction increase as the previous year's is added to the current year's application of organic amendments. This provides green forage along grazing season compared to synthetic fertilization.Application of sewage sludge increased total soil nitrogen in both of the soil depths (0 to 20 and 20 to 40 cm), but available phosphorus was increased only in 0 to 20 cm compared with the synthetic fertilizers at the end of the first and second year (Arvas, 2006). Also, McFarland et al. (2007) reported that, biosolid application increased the plant available phosphorus concentration in the surface soil layer (0.75 foot depth) than the bottom. This limited mobility led to roots growing in to the thick sewage compost layer near the soil surface (Warman and Termeer, 2005). Thus, soil erosion can be minimized as a consequent of prevention of overland flow.

The release of phosphorus and nitrogen is closely related with pH; maximum phosphorus release was observed at pH <3 and pH >10 and ammonium nitrogen was leached at near neutral pH conditions, while nitrate nitrogen increased as the leachant pH was increased from 2 to 12 (Batziaka, 2008). However, Arvas (2005) and Keramati et al. (2010) reported that sewage sludge application decreased alkaline soil pH because of the high buffering capacity of calcareous soil. Keremati et al. (2010) showed that there has been less knowledge in usage of sewage sludge in the calcareous in the arid and semiarid regions compared to the neutral and acidic soil. The minimum amount of metal ions removed from the solution by the adsorbents was at pH range of 6 to 8 pH and the maximum was at pH 2 and 12 (Igwe et al., 2005). Also, due to low mineralization rate of sewage sludge, as well as the risk of nitrate pollution and eutrophication decreases when compared to synthetic N and P, usefulness duration of these elements is extended. By this way, plants' green herbage period will extend and so duration of utilization from pastures and meadow will increase.

The aim of this study was to determine the most suitable sewage sludge dose for natural pasture and meadow in semiarid area ecology compared with synthetic fertilizer in respect to usefulness duration and being in different depths of nitrogen and phosphorus.

MATERIALS AND METHODS

The experiment was conducted at the poor quality pastureland. The study area was located approximately 5 km north west of Yucuncu Yil University, Van, Turkey (38°36′ 49 N and 43° 14′ 03 E coordinates, altitude of 1654 m). The experiment was started in the autumn of 2006. The study area was conserved after yearly cutting. Climate of the area was semiarid and the average long time precipitation was 387, 4 mm, the temperature was 8.9°C and the relative humidity was 58.8%. Annual rainfall was respectively 424.1, 356.8 and 318.7 mm for three consecutive years of the experiment. Average annual temperature was 10.1, 9.6 and 9.8°C, and annual relative humidity was 58.8, 60.7 and 52.5%, respectively (Table 1). The experiment soil was alkaline and loamy.

Activated and aerobically-digested sewage sludge and synthetic fertilizer were used as sources of N and P for two consecutive years in the same pastureland plots. The activated sludge that was used was stored for two years in dewatered unit before application. The treatment received wastewater from domestics; they were not discharged from heavy metal based industries. Sewage sludge contains 3 to 6% N by weight, typically (Sigua, 2009). But that used in the experiment contained 1.3% (Table 2). With the exception of

Table 1. Climate data of Van province* of 2006, 2007 and 2008 and to long term (LTM)**.

Month	Fall (mm)				Temperature (℃)				Relative humidity (%)			
	2006	2007	2008	LTM	2006	2007	2008	LTM	2006	2007	2008	LTM
January	90.4	18.1	12.5	35.4	-3.1	-4.6	-5.6	-3.6	68.1	70.0	62.6	68.0
February	47.7	10.6	31.0	32.5	-1.3	-0.9	-3.6	-3.2	71.7	70.0	73.6	69.0
March	45.7	35.0	31.5	45.7	3.0	3.0	5.8	0.9	68.6	69.0	55.5	68.0
April	39.6	86.8	24.8	56.6	9.8	5.9	10.5	7.4	69.5	63.0	52.2	62.0
May	35.4	27.3	39.9	46.3	14.6	15.7	12.3	12.9	57.6	67.0	51.1	67.0
June	0.1	9.1	2.1	18.4	21.5	19.9	19.5	17.8	49.5	50.0	41.9	50.0
July	22.4	28.6	11.1	5.1	22.3	22.7	22.7	22.0	46.4	44.0	32.8	44.0
August	2.4	7.2	6.8	3.9	24.1	21.8	23.9	21.5	39.5	42.0	37.3	42.0
September	0	0	44.7	13.0	18.0	17.8	18.3	17.0	48.7	43.0	39.6	43.0
October	46.9	7.6	56.6	45.3	11.6	12.2	11.0	10.6	63.4	59.0	60.5	58.0
November	49.3	75.2	21.0	47.9	3.0	4.2	4.9	4.4	66.0	67.0	60.5	66.0
December	44.2	51.3	36.7	37.3	-3.4	-2.0	-1.8	-0.8	68.1	69.0	62.6	69.0
***Mean.					10.1	9.6	9.8	8.9	58.8	60.7	52.5	58.8
Total	424.1	356.8	318.7	387.4								

*Van Province meteorology regional directorate records; **LTM, long-term mean; ***Mean, year mean.

Table 2. Physicochemical properties of the sewage sludge and study area soils.

Parameter	0-20 cm	20-40 cm	Sewage sludge
Texture	Loamy	Loamy	
Sand	36%	32%	
Silt	46%	48%	
Clay	18%	20%	
Organic Matter (%)	5.16	4.25	25
pH (1:2 Su)	8.42	9.3	6.20
Nitrogen (%)	0.067	0.068	1.30
*Phosphor (mg/kg)	11.2	16.7	2320.4
*Potassium (mg/kg)	212.4	151.8	2679.6
*Calcium (mg/kg)	1612.2	1023.6	10429.3
*Magnesium (mg/kg)	443.9	597.2	5680.9
*Iron (mg/kg)	0.040	0.40	12.712
*Manganese (mg/kg)	1.108	1.55	74.20
*Zinc (mg/kg)	Not detected	Not detected	270
*Copper (mg/kg)	0.516	0.864	11.164
*Lead (mg/kg)	Not detected	0.022	0.976
*Cadmium (mg/kg)	Not detected	Not detected	0.436

*Extractable.

the control, plots received annual sewage sludge and one plot received synthetic fertilizer applications. The sewage sludge and triple superphosphate (TSP 42%) were applied in November and ammonium nitrate (AN 33%) was applied in April for the two consecutive years. Synthetic fertilizer was applied at one time at 200 kg N/ha/year and 100 kg P_2O_5/ha/year as recommended (225 kg N/ha; 120 kg P_2O_5/ha) N and P_2O_5 application doses for natural pasture (Koç et al., 2005; Hatipoğlu et al., 2005). Application doses for the organic amendments assumed 50% of the total N applied and was available in the year of application (Warman and Termeer 2005). Therefore, the mean rate of the air- dried sewage sludge was calculated based on the N content (Sigua, 2009) applied at 25, 50, 75 and 100 tons per hectare. Considering the average for long years, the experiment area was semi-arid region according to the drought index (Table 1). The maximum application doses were likened to 98.8 ton/ha applied in a semi-arid rangeland (Fish, 1995). It was assumed that with these applications doses, plots received half of 32.5, 81.3, 162.5 and 325 kg N ha^{-1} ya^{-1} for the first year of experiment. For phosphorus application, sewage sludge plots received 5.8, 11.6, 17.4 and 23.2 kg P_2O_5 ha^{-1} ya^{-1}, respectively. Each treatment was replicated three times in a randomized complete block design.

The experiment was formed as 18 plots. Soil samples were taken from three different points of each plot and then these soils were

Table 3. Soil pH at two depths as affected by two year application of four sewage sludge treatments and one of synthetic fertilization.

Parameter	Soil depth					
	0-20 cm			20-40 cm		
	2007	2008	Average	2007	2008	Average
Control	8.28ab	7.91a	8.09a	9.21a	9.10a	9.15a
SF (TSP+AN)	8.67a	7.83a	8.25a	9.18ab	8.81ab	8.99ab
SS1	8.42ab	7.71a	8.07ab	9.29a	9.09a	9.19a
SS2	8.30ab	7.70a	8.00ab	9.06ab	9.00a	9.03ab
SS3	8.32ab	7.31b	7.81b	9.30a	8.37b	8.83bc
SS4	8.16b	7.92a	8.04ab	8.89b	8.53b	8.71c
Average	8.36A	7.73B	8.04	9.15A	8.81B	8.98

*Means with different letters in a column are significantly different ($p < 0.05$).

mixed to form sample of that plot. By this way, soil sample represented the plot from where it was taken from in a more efficient way. Samples were taken from the 0 to 20 (surface soil) and 20 to 40 (subsoil) cm depths by using steel auger on the 15th November 2007 and 2008. Soil samples were kept in deep freezer until they were analyzed, in order to avoid nitrogen loss by mineralization resulted from microbial activity. The content of soil N and P in the surface soil and subsoil were insufficient according to the pastureland (Alparslan et al., 1998). The physicochemical properties of the sewage sludge and the soil of the study area in various depths are given in Table 2.

The samples were air-dried and passed through a 2 mm mesh sieve prior to chemical extraction of the soil nutrient. Soil analyses were conducted at the University of YYU Soil Science Department Laboratory. Soil pH was determined by using 1:2 soil to water ratio (Kaçar, 2009). Total N was analyzed using Kjeldahl method. Available P was extracted with sodium bicarbonate (0.5 M $NaHCO_3$) at pH 8.50 as described (Olsen, 1954) and analyzed using a spectrophotometer (Spekol 1300). Texture was determined using the hydrometer method (Bouyoucos, 1965).

Statistical analysis was performed by ANOVA at a significance level of $p < 0.05$ with SPSS v. 17.0. Comparison of means was determined by the “post-hoc” Duncan’s multiple range test.

RESULTS

Effect of sewage sludge and synthetic fertilizer on soil pH

The effect of sewage sludge and synthetic fertilizer applications on the surface soil pH was insignificant when compared to the control in 2007, however, a significant ($P < 0.05$) decrease occurred in SS_4 application with respect to SF. In year 2008, decreases in the pH levels were determined in both the control and applications plots compared to those in 2007. Also, in 2008, except for SS_4 by sewage sludge applications, a gradual decrease occurred compared to the control and SF. Nevertheless, the decrease obtained by the SS_3 dose of sewage sludge was significant ($p < 0.05$) compared to all the other applications. In 2008, the surface soil pH decreased significantly compared to 2007. In 2007, while the effect of sewage sludge on subsoil pH was insignificant compared to the synthetic fertilizer by SS_4 application, its effect was significant ($P < 0.05$) compared to the control. In 2008, the effect of SS_3 and SS_4 applications on pH was insignificant compared to the synthetic fertilizer and was significant compared to the control and other sewage sludge doses. In light of all applications, in 2008, significant decrease in the level of subsoil pH occurred compared to 2007. According to the average of the two years, the lowest pH level was obtained from SS_3 and SS_4 applications. Generally, it is observed that SS_1 and SS_2 doses of sewage sludge increased the pH level of the subsoil compared to the synthetic fertilizer, although, this increase was insignificant (Table 3).

Effect of sewage sludge and synthetic fertilizer on soil total N

In 2007, all the doses of sewage sludge and synthetic fertilization significantly increased the surface soil total nitrogen content compared to the control. SS_l, SS_3 and SS_4 doses of sewage sludge increased soil total nitrogen significantly compared to the synthetic fertilizer ($p < 0.05$). In 2008 applications, although, except for SS_2 dose, gradual increase was obtained compared to control; only the increase that occurred in the SS_3 dose was significant ($p < 0.05$). However, in spite of the repeated applications of all the treatment in year 2008, significant decreases occurred in the soil total nitrogen. Generally, when the years were considered separately, sewage sludge, except for the SS_2 dose, increased the surface soil nitrogen when compared to the chemical fertilizer and the control (Table 4).

While in the first year of the experiment, the increase that sewage sludge doses made in subsoil nitrogen was significant compared with the synthetic fertilizer and control, in the second year, it was insignificant except for the dose SS_4. In year 2008, in spite of the repeated sewage sludge and synthetic fertilizer applications, decreases occurred in subsoil nitrogen compared with

Table 4. Soil nitrogen (%) at two depths as affected by two year application of four sewage sludge treatments and one of chemical fertilization.

Parameter	Soil depth					
	0-20 cm			20-40cm		
	2007	2008	Average	2007	2008	Average
Control	0.071d	0.070b	0.071d	0.070e	0.090b	0.080d
SF (TSP+AN)	0.095c	0.072b	0.084c	0.071e	0.081b	0.076d
SS1	0.112b	0.076b	0.094b	0.095c	0.083b	0.089c
SS2	0.088c	0.070b	0.079cd	0.082d	0.081b	0.081d
SS3	0.137a	0.109a	0.123a	0.108b	0.091b	0.099b
SS4	0.139a	0.088b	0.113a	0.144a	0.104a	0.124a
Average	0.107A	0.081B	0.094	0.095A	0.088B	0.092

*Means with different letters in a column are significantly different (p < 0.05).

Table 5. Soil phosphorus (mg/kg) at two depths as affected by two year application of four sewage sludge treatments and one of chemical fertilization.

Parameter	Soil depth					
	0-20 cm			20-40cm		
	2007	2008	Average	2007	2008	Average
Control	34.46bc	16.80c	25.63c	61.38b	117.73b	89.56b
SF(TSP+AN)	17.21c	166.93a	92.07a	81.90ab	136.90ab	109.40ab
SS1	35.39bc	33.67bc	34.53c	59.23b	136.60ab	97.92ab
SS2	57.10a	69.20b	63.15b	113.58a	130.11ab	121.85a
SS3	63.35a	70.47b	66.91b	101.82ab	140.00ab	121.31a
SS4	47.91ab	163.60a	105.76a	64.47b	154.07a	109.27ab
Average	42.57B	86.78A	64.65	80.40B	136.04A	108.22

*Means with different letters in a column are significantly different (p < 0.05).

the control, except for the doses of SS_3 and SS_4. Only the SS_4 dose increased the subsoil nitrogen significantly ($P < 0.05$) with respect to the control. According to the average of two years, with the increasing sewage sludge doses, the increase that occurred in the subsoil nitrogen were significant. By application of synthetic fertilization, subsoil nitrogen was not affected compared with the control in 2008 and the average of the two years. The rate of nitrogen in the SF plots was less than the control plot (Table 4). In spite of the repeated application of treatment, the rate of subsoil nitrogen in the 2008 average was significant ($P < 0.05$); less than the 2007 average.

Effect of sewage sludge and synthetic fertilization on soil available phosphorus

In the first application year, significant increase was observed in the surface soil available phosphorus by the sewage sludge application compared with the synthetic fertilizer and control. The lowest amount of surface soil available phosphorus occurred in the synthetic fertilizer treatment. However, in the second year, the highest amount of surface soil available phosphorus resulted from synthetic fertilizer and SS_4 applications. In year 2008, the increase found in the amount of surface soil available phosphorus was significant with respect to that determined in year 2007. On the other hand, in year 2008, the surface soil available phosphorus decreased in the control and SS_1 plots compared with year 2007. At the average of the years, the highest increase in the amount of surface soil phosphorus occurred in SS_4 and synthetic fertilizer applications and this increase was significant with respect to other doses of sewage sludge applications and the control. In general, as the doses of sewage sludge increased, a gradual increase occurred in the surface soil available phosphorus (Table 5).

In year 2007, by sewage sludge application, there occurred an increase in amount of subsoil phosphorus. In spite of the increasing amount of sewage sludge, a significant decrease was observed in the amount of subsoil phosphorus. In 2007, low doses of sewage sludge increased the amount of available P of the subsoil, but increasing sewage sludge amount decreased the amount of available P significantly ($P < 0.05$).

In 2007, the highest amount of subsoil available phosphorus was found in SS_2 dose. However, this increase was insignificant with respect to SS_3 dose and synthetic fertilizer application and was significant when compared with other doses and the control. By sewage sludge applications, in year 2008, the amount of subsoil phosphorus increased, yet, this increase was significant only in SS_4 dose with respect to the control. In 2008, there occurred an increase in the amount of subsoil phosphorus contrary to the surface level one in the control plot. The increase found in the amount of subsoil phosphorus in 2008 was significant when compared with the first year. When the average of two years was investigated, the increase by the increasing doses of sewage sludge that caused the amount of subsoil phosphorus was insignificant; yet the highest increase was obtained in the SS_2 dose. However, the increase that SS_2 and SS_3 doses caused with respect to the control was significant (Table 5).

DISCUSSION

In alkaline pasture area having intense vegetation, in spite of the synthetic fertilization having alkaline characteristic, a decrease occurred in the soil pH with respect to the control. The decrease of surface soil and subsoil pH in the synthetic fertilizer and control parcels in 2008 can be explained by the fact that increasing root mass caused an increase in the soil organic material and so this caused an increase in soil humidity and a decrease in soil pH (Olff et al., 1993).

In the yearly cut study area which was protected from early spring and late fall grazing, a rapid and early growth was formed in the second year (observational). In 2008, the decrease in pH formed in both soil depths in the control parcel can be attributed to the increased root mass, because through season long, growth in the topsoil and subsoil was found to be proportional to each other (Imbert and Houle, 2001). Maximum pH decrease was obtained on topsoil by the application of 75 ton ha^{-1} dose of sewage sludge and in subsoil by the application of 100 ton ha^{-1} dose. Angin and Yağanoğlu (2009) and Navas et al. (1998) stated that, pH value of alkaline soil decreased by high amount of sewage sludge application. High dose applications of sewage sludge promote pH decrease by increasing the soil humidity (Navas et al., 1998). In similar manner, Keramati et al. (2010) reported that sewage sludge reduced soil pH. Other than the previously stated reasons, sewage sludge having low pH value (6.2) can be put forward as the major factor.

In 2007, the increase in surface and subsoil nitrogen that sewage sludge applications formed was significant compared to the synthetic fertilizer and control. In the applications of the year 2008 and the average of the two years, maximum nitrogen rate was obtained from SS_3 dose in the surface soil and from SS_4 dose in the subsoil.

Surface and subsoil nitrogen decreased significantly in year 2008. While the synthetic fertilizer application provided a slight increase in the surface soil nitrogen compared to SS_2 dose, all other doses of sewage sludge provided increases in nitrogen at a higher rate compared to the synthetic fertilizer in both soil depths. Yet, all the doses of sewage sludge contained lower amounts of nitrogen with respect to synthetic fertilizer. This fact supports our hypothesis of extending the availability duration of nitrogen and so depending on this extension of the green herbage period, this hypothesis is the fundamental basis for our study. In spite of the low nitrogen content, even one year after the application, the soil nitrogen was found more in both depths (especially in subsoil) depending on the sewage sludge doses with respect to synthetic fertilizer. This fact points out that the risk of sewage sludge based soil nitrogen to be leached is low (van Nieker et al., 2005). Moreover, in both depths of soil, soil nitrogen did not increase proportional to the increasing doses of sewage sludge; as Sigua (2009) indicated, this situation is related to the decrease in mineralization rate contrary to increasing amount of organic mass and therefore, related to decrease in the released nitrogen rate.

In 2008, the decrease in surface soil nitrogen occurred in all the application plots evaluated as increased surface soil biomass had increased nitrogen intake. Because the nitrogen that synthetic fertilizer contained is in the inorganic form, it is ready for absorption by plant or for removal by leaching out (van Nieker et al., 2005). Same researcher indicates that while the sewage sludge based nitrate nitrogen begins to be transformed in available form after 28 days, inorganic nitrate nitrogen was transformed in available form only after 24 h. Except for the first year of the experiment, there was not an increase in the soil nitrogen in both depths compared with the control and this fact supports the hypothesis previously stated.

Moreover, the seven-month period passed between the applications and getting samples, can be accepted as a long term for removal of nitrogen applied in the nitrate form from the soil depths from which the samples were taken. In fact, nitrogen in nitrate form moves much more rapidly in soil profile compared to organic nitrogen (Shukla et al., 2010). In year 2008, in spite of the repeated synthetic N application, there occurred a decrease in surface soil nitrogen and an increase in subsoil nitrogen. The pH level of the experiment area was between 7.3 and 9.2 and this values can be accepted as quite ideal when the optimal pH values are $2<pH>12$ which Batziaka et al. (2008) indicated for nitrogen usefulness and mobility. Therefore, both the property of nitrogen in nitrate to be leached out rapidly and the pH value of soil can be put forth as the factors facilitating the leaching of nitrogen to the subsoil.

The application of sewage sludge and phosphorus fertilization to the surface, contrary to the known method, is supposed to be influential in the low amount of available phosphorus at the surface and subsoil in year 2007. Besides this, despite the increasing doses of sewage sludge, the decrease formed in the amount of subsoil phosphorus, in 2007, can be explained by the fact that climatic factors of semi-arid ecology did not generate the sufficient environment (temperature, rainfall, and etc.) for high mineralization rate. Warman and Tarman (2005) indicated that the amount of available phosphorus could not be adequate in soils to where the organic material was newly applied and this was resulted from mineralization.

The inverse relationship found between the increase in organic mass and availability of nutrient elements (Sigua, 2009), can be asserted as a reason of the increasing doses of sewage sludge to the decreased amount of the available phosphorus in the first year. Additionally, the six month pluvial winter term passed between the first application time of sewage sludge and triple super phosphate and plants' early growing periods facilitated the rapid and easy absorption of mineralized available phosphorus by plants and this fact can be evaluated as a factor decreasing the surface available phosphorus. The botanic composition of the pasture under the pressure of early grazing and run over, in year 2007, was dominantly consisted of plants having shallow root and growing rapidly in early spring (*Juncus* spp., *Carex ve Bromus* spp.).

The increase in the amount of available phosphorus in surface soil, in year 2008, supports this approach. Nyamangara and Mzezewa (2000) reported that accumulation of P in topsoil can result in deficiency during dry periods when the topsoil is dry; plants have to derive their nutrients from the sub soil. This situation supports our findings that rapidly growing shallow root plants also decreased surface soil available phosphorus. The increase in the amount of available phosphorus in surface soil, in line with the application doses, in 2008, was thought to be resulted from the repeated applications in 2008 in addition to those in 2007. Factors as legumes and other deep rooted plants found in low ratios (especially in sewage sludge parcels, observational), the application of sewage sludge in high doses (Nyamangara and Mzezewa, 2000), the low absorption capacity of loamy experiment soil (Iskandar and Syers, 1980) can be indicated as a reason for increase in the amount of subsoil available phosphorus in year 2008. In year 2008, the maximum increase in subsoil available phosphorus was determined from the highest sewage sludge application dose as Singh and Agrawal (2008) indicated.

Conclusion

Sewage sludge application decreased the pH of alkaline experiment soil of both depths in significant levels in a particularly short term; two years. Especially, the decreased occurred in year 2008 was more remarkable.

Not only in the control plot, but also in the plot with ammonium nitrate, the pH of pasture soil was decreased in both depths in 2008. In year 2008, repeated application of 100 ton da^{-1} ya^{-1} dose of sewage sludge did not affect the total nitrogen rate and the pH of the surface soil as expected. Although, sewage sludge doses contain less nitrogen than synthetic fertilizer does, it provided more increase in the total nitrogen in both soil depths. While the synthetic fertilizer increased the amount of the surface soil available phosphorus more than the other applications except the 100 ton da^{-1} ya^{-1} dose of sewage sludge did, it did not cause a significant increase in sthe ubsoil phosphorus. In the second year of the experiment, sewage sludge applications also increased the amount of subsoil available phosphorus. Although, sewage sludge contains fewer amounts of nitrogen and phosphorus than the chemical fertilizer does, it kept more total nitrogen and available phosphorus in various depths of soil at the end of the growing season; this indicates that it is an important organic fertilizer for sustainable pasture meadow management. Therefore, it can offer an important solution to the problem of not being able to keep plant nutrient elements in the root region for a long time; this problem is one of the fundamental ones confronted in increasing yield and providing sustainability at great areas like pastures and meadows.

In this study, although, higher amounts of nitrogen and phosphorus were obtained by high sewage sludge doses, in the long term applications, the risk of nitrate and eutrophication could increase. In order to determine the most appropriate sewage sludge dose that can be applied to semi-arid region pastures and meadows, long term studies involving the mineralization process are necessary.

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