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# THE EFFECTS OF SEWAGE SLUDGE TREATMENT ON TRITICALE STRAW YIELD AND ITS CHEMICAL CONTENTS IN RAINFED CONDITION

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## ABSTRACT

This study was carried out to evaluate the effects of different of sewage sludge doses on some yield traits and straw chemical contents in triticale (*Triticosecale wittmack*, Cv Mikham-2001).The field study was designed in randomized complete blocks (RCB) with 7 sewage sludge treatments (0, 5, 10, 15, 20, 25, 30 t $ha^{-1}$) and 1 conventional inorganic fertilizer treatment (N, P) with 3 replicates.According to the results of this study, sewage sludge significantly increased grain filling period (day), plant height (cm), straw yield (t $ha^{-1}$) and biological yield (t $ha^{-1}$), except harvest index (%). The highest straw yield was obtained from the highest sewage sludge dose (30 t $ha^{-1}$). Similarly, sewage sludge significantly increased the mineral (N, P, Mg, Mn and Fe) contents of triticale straw in dose dependent manner. Also, sewage sludge did not increase heavy metal (Al, Cd, Ch, Ni, Pb and Cu) concentrations in triticale straw. It was concluded from the results that application of sewage sludge at the rate of 30 t $ha^{-1}$ was more beneficial in terms of better growth, higher straw yield and some yield traits of triticale under low input soil compared to control and inorganic fertilizer. At the rate of 30 t $ha^{-1}$sewage sludge application could be substituted for conventional inorganic fertilizer for optimum triticale growth in marginal lands. Also, for agricultural practices, straw material obtained by the rate of 30 t $ha^{-1}$ application may be recommended for animal feeding operations without any heavy metal risk.

**Key words:** Triticale, heavy metal, straw yield, sewage sludge.

## INTRODUCTION

Triticale is a hybrid crop between rye and wheat and also having higher production values compared to wheat and barley (Yagmur and Kaydan, 2007) in marginal areas having insufficiency of water and minerals. Recently, triticale cultivation has become an important crop in grain and forage production (McGoverin *et al*., 2011). Triticale has been used for different purposes, as grain, straw and silage. Triticale has been grown as a silage crop by farmers with other forage crops.In general, straw materials are available in large quantities, approximately half the harvestable vegetation of the crop. These straw materials have been used for feeding ruminants, bedding materials in animal barns, and, nowadays, generating bioenergy (Larsen *et al*., 2012).

The benefits of using sewage sludge as fertilizer has been proven by numerous studies. In many countries, sewage sludge has been used in large amount to increase cereal production due to its mineral and organic matter content for optimum plant growth. Moststudies showed that sewage sludge improves the physicaland chemical properties of poor soils and increases their fertility. Pagliai *et al.* (2004) observed that sewage sludge increased water holding capacity of soil. Depending upon origin, sewage sludge has similar concentrations as inorganic fertilizer for optimum plant growth. Benitez *et al*. (2001) and Aggelides and Londra (2000) demonstrated that sewage sludge increased crop production by increasing biomass (Cogger *et al*., 2001). In the another study, sewage sludge increased spike fertility, biomass, straw yield and grain filling time in wheat (Jamil *et al*., 2006)

Main problems in sewage sludge usage would be the presence and accumulation of heavy metals in soils, affecting negatively plant growth and causing biosecurity problems. However, Reed *et al*. (1991) reported that the heavy metal content of sewage sludge varied to depending on its origin. Mostly, in the heavy metal content of sewage sludge were observed in high amounts in a heavy industry area. Bozkurt *et al.*(2010) reported that, when applied, sewage sludge did not cause toxicity in apple trees. However, long-term sewage sludge application may result in the accumulation of heavy metals in the soil and plant (Bell *et al*., 1991).

There has been a limited study in triticale production with sewage sludge application by testing whether sewage sludge can be substituted for inorganic mineral fertilizers or not. Therefore, the present study was carried out to examine the effects of different rates of sewage sludge on triticale straw yield and nutrient contents in marginal experimental area being fairly low in organic matter content (generally about 1 %) and medium phosphorus, low nitrogen.

## MATERIALS AND METHODS

**Experimental area:** This current research was conducted in a field condition of Van province in Turkey(38°-55' N; 42° – 05' E, 1725 m above sea level).

**Plant material:** Triticale variety Mikham-2001 was used as a plant material that has environmental tolerance compared to other cereals, moreover it has higher yields in poor soil conditions.

**Sewage sludge**: Dried sewage sludge was obtained from the Campus of Yuzuncu Yıl University Waste Water Unit. Aerobically stabilized sewage sludge was dried in holding pools.

**Soil preparation and experimental design:** The plots were plowed one year ago in spring season. Second plowing was done in opposite directions before planting in early September in 2009.Field study was conducted in winter season in 2009-2010. The experimental design was randomized complete blocks (RCB) in the field condition with 7 sewage sludge treatments including negative control (0 (negative control), 5, 10, 15, 20, 25, 30 t $ha^{-1}$) and 1 positive control (inorganic fertilizer),and three replications with a total number of 24 plots. Negative control plot (0 t $ha^{-1}$) was not including any additional nutrients.

Each plot was 6 $m^{-2}$sowing area sized 1. 20 m x 5 m. Treatments included: one dose of mineral fertilizer that it contains nitrogen and phosphorus (80 kg N $ha^{-1}$ +70 kg P $ha^{-1}$) as a positive control and seven sewage sludge doses (0-negative control, 5, 10, 15, 20, 25, 30 t $ha^{-1}$).As a positive control, conventional inorganic fertilizer plots were fertilized at seeding time with 150 kg $ha^{-1}$$(NH_4)_2HPO_4$ (18 % N and 46 % $P_2O_5$) and 250 kg $ha^{-1}$$(NH_4)_2SO_4$ (21 % N) was applied as a top dressing before ear emergence. Sewage sludge and mineral fertilizer were applied with a hand and mixed into the top 1-5 cm of soil. Sewage sludge applications were completed 30-d prior to sowing time.

**Sowing and agricultural applications:** Triticale was sown on October 20, 2009. Seeds were hand-drilled at depths of 5 cm (4-5 cm) and spaced approximately 1 cm apart along each row at a rate of 100 seeds per meter. The distance between each row was 20 cm (500 seeds $m^{-2}$). Each plot was sown 2 meters away from each other due to limit the mixing of treatments.

**Plant measurements:** The grain filling period (day) was estimated as the difference between the dates of anthesis and maturity. Plant height was measured as the height of the tallest culm of approximately 15 plants from the soil surface to the tip of the spike, awns excluded. Biological yield (t $ha^{-1}$) and straw yields (t $ha^{-1}$) were measured at harvest time. Four central rows were harvested in the beginning of July, 2010. Harvested material was air dried and weighed to record biological yield and straw yield which were calculated per hectare basis. Harvest index (%) was measured as the ratio of the grain yield of the biological yield.

**Straw, soil and sewage sludge nutrientsanalysis:** Straw materials, soil and sewage sludge were analyzed based on Kacar (1984) and AOAC (Helrich, K. (Ed.), 1990)as following: The triticale strawwere analyzed to determine plant nutrients and heavy metal concentrations. Separately, the straw samples were washed with de-ionized water, dried at 60 °C and, finally, ground. N concentration in strawwas analyzed by using of the Kjeldahl method. P was analyzed by using of the spectrophotometer. Some plant nutrient and heavy metals (K, Mg, Fe, Mn, Cd, Cr, Ni, Cu, Pb and Zn) were analyzed by using flame atomic absorption spectrophotometer apparatus with graphite furnace (AAS). The crude protein was found by the formulae N x 6.25 (1/0.16 = 6.25) to convert the analyzed nitrogen content into crude protein content.

In the analysis of soil, the texture was determined by Bouyoucous' hydro-metric method, pH value in 1/2.5 soil/water suspension, lime by calcimetric methods, organic matter by the modified Walkley Black method, salt content by Richards, total nitrogen by Kjeldahl method, available phosphorous by the method of Olsen, potassium, calcium and magnesium by extracted with 1 N neutral ammonium acetate, total elements and heavy metals by atomic absorption spectrophotometry (AAS).

The sewage sludge chemical properties are shown in Table 1. Sewage sludge samples were air dried. In the analysis of sewage sludge, organic matter was determined by the modified Walkley Black method, pH in 1/2.5 soil/water suspension, total nitrogen by Kjeldahl method, total phosphorus by wet digestion of dried and ground subsamples in a HNO3-perchloric acid mixture, total macro and microelements and heavy metals by atomic absorption spectrophotometry (AAS).

Table 1 shows the physical and chemical characteristics of sewage sludge and experimental soil. The sewage sludge has high organic matter, low pH and rich in nutrients. Experiment soil was low in organic matter, nitrogen and alkaline, sandy-clay loam texture, rich in potassium and calcium content,and medium phosphorus (Kacar, 1984).

**Climatic description:** Table 2 illustrates the climatic data of the experimental region. During the experiment, from October to July in 2009-2010 years, rainfall was observed higher in the autumn and winter seasons compared to the data belonging to long term period (1954-2010).

**Statistical analysis:** The data were analyzed by MSTATc statistical software. Means were compared by Least Significant Difference test (LSD) in the same software.

**Table 1.The physical and chemical characteristics of sewage sludge and soils in different levels(on DM basis).**

| Properties | 0-20 cm | 20-40 cm | Sewage sludge |
|---|---|---|---|
| Texture | Clayey-loam | Clayey-loam | Organic material |
| $CaCO_3$ (%) | 4.7 | 4.9 | 5.8 |
| pH | 8.20 | 8.19 | 6.55 |
| EC mS $cm^{-1}$ | 2.76 | 2.66 | 3.42 |
| Organic material(%) | 0.98 | 0.81 | 45.5 |
| P (ppm) | 6.79 | 5.51 | 2120.5 |
| N (%) | 0.069 | 0.057 | 1.30 |
| K (ppm) | 214 | 229 | 2589.3 |
| Ca (ppm) | 1459 | 1871 | 9856.3 |
| Mg (ppm) | 149 | 181 | 4985.6 |
| Cu (ppm) | 1.00 | 1.15 | 10.9 |
| Zn (ppm) | 0.60 | 0.60 | 250.5 |
| Fe (ppm) | 6.93 | 7.52 | 15.7 |
| Mn (ppm) | 26.8 | 28.1 | 68.5 |
| Ni (ppm) | 0.329 | 0.444 | 75.5 |
| Cd (ppm) | 0.056 | 0.056 | 0.355 |
| Pb (ppm) | 0.601 | 0.576 | 0.895 |
| Cr (ppm) | 0.20 | 0.22 | 95.2 |

**Table 2. Climatic data of Van province in 2009-2010(LTM, 1954-2010 years)**

| Months | Rainfall (mm) | | Temperature ($^0$C) | | Moisture (%) | |
|---|---|---|---|---|---|---|
| | LTM | 2009-2010 | LTM | 2009-2010 | LTM | 2009-2010 |
| September | 15.4 | 46.0 | 16.3 | 9.5 | 55.2 | 48.9 |
| October | 49.6 | 15.9 | 10.3 | 12.6 | 63.2 | 46.8 |
| November | 47.5 | 91.1 | 4.3 | 4.3 | 67.0 | 61.1 |
| December | 32.1 | 34.8 | -1.1 | 2.0 | 69.0 | 63.6 |
| January | 41.9 | 51.6 | -3.6 | 0.1 | 69.0 | 63.4 |
| February | 35.4 | 71.1 | -3.5 | 1.4 | 64.0 | 65.6 |
| March | 46.2 | 38.3 | 0.5 | 5.8 | 57.0 | 58.9 |
| April | 57.5 | 46.3 | 7.0 | 8.4 | 50.0 | 62.2 |
| May | 40.5 | 69.8 | 13.0 | 13.3 | 44.0 | 61.2 |
| June | 16.8 | 41.0 | 17.8 | 19.8 | 41.0 | 43.6 |
| July | 5.5 | - | 22.0 | 24.0 | 43.0 | 34.3 |
| Total rainfall | 323.4 | 505.9 | - | | - | |
| Total rainfall | 323.4 | 505.9 | - | | - | |
| Mean | | | 7.5 | 9.2 | 56.58 | 55.41 |

## RESULTS AND DISCUSSION

In the present study, sewage sludge treatments enhanced straw yield and nutrient contents compared to control and inorganic fertilizer. Table 3 shows some yield traits of triticale grown in sewage sludge and mineral fertilizer treated soil. Data analysis showed that sewage sludge affected positively all measured parameters, except harvest index (%).These effects were higher than that of conventional fertilizer on the mentioned parameters. Grain filling period ($day^{-1}$) was increased significantly in dose dependent manner ($P<0.05$). The longest grain filling period 36-d was obtained by the highest dose of sewage sludge treatment (30 t $ha^{-1}$). On the other hand, the shortest grain filling period was obtained in the rate of 0 t $ha^{-1}$ sewage sludge application as control plots. It could be explained by the fact that sewage sludge reduced the negative effects of drought during grain filling period, thus, grain filling period would have been elongated. It could be attributed to that sewage sludge contains higher amount of organic materials enhancing soil water holding capacity. (Pagliai *et al*., 2004). Therefore, a sufficient amount of water in the soil may had extended the grain filling period.

Sewage sludge increased significantly plant height in dose dependent manner($P < 0.05$) compared to those of control and conventional inorganic fertilizer. The maximum plant height (97 $cm^{-1}$) was observed with the highest sewage sludge treatment (30 t $ha^{-1}$).This can be explained as sewage sludge added plots contained sufficient moisture and nutrients for supporting triticale growth and development. Akdeniz *et al.*(2006) reported that sorghum plant showed increases its height in the growing season, when sewage biosolids were added to soil. Also, in similar ecological condition, Yagmur *et al.* (2005) observed that plant height in lentil was increased by application of sewage sludge.

Biological yield and straw yield were tended to increase in sewage sludge and conventional inorganic fertilizer plots. The highest biological yield and straw yield were obtained from the highest sewage sludge dose. The obtained biological yield and straw yield were increased by mineral fertilizer application, but not to as much as sewage sludge did(Table 3). The higherstraw yields(7.73 t $ha^{-1}$ and 7.55 t $ha^{-1}$)were obtained respective higher sewage sludge application doses (30 t $ha^{-1}$ and 25 t $ha^{-1}$, Table 3). These yields were not statistically different between each other, suggesting that 25 t $ha^{-1}$ sewage sludge application dose would be sufficient for straw yield. On the other hand, the control plots produced the lowest straw yield in average 3.45 t $ha^{-1}$. Sewage sludge and mineral fertilizer increased harvest index compared to control without any statistical significance (Table 3). The increases in straw and biological yields most likely are associated with higher nutrient contents of sewage sludge compared to control soil. It was previously evidenced that sewage sludge increased leaves dimensions, leaf area index, dry matter, tillering capacity andplant height in barley (*Hordeum vulgare* L) and in oat (*Avena sativa* L) (Bouzerzour *et al.,* 2002). Tamrabet *et al*. (2009) determined the increases in yield components and straw yield by sewage sludge application, reporting that a 30 t $ha^{-1}$ sewage sludge dose was as much as efficient that of a 66 kg $ha^{-1}$inorganic fertilizer on durum wheat traits. Ahmed *et al*. (2010) observed that sewage sludge application enhanced soil fertility and crop yield in barley compared to control soil. Also, the amended sewage sludge to cultivated soils induced an increase in crop yield by contributing to disposal of and recycling of this waste material (Ripert *et al*., 1990) and attributing to the beneficial effects on soil structure and to the nutrient contains (Tamrabet *et al*., 2009).

**Table 3. Some yield parameters of triticale grown in sewage sludge and inorganic fertilizer treated soils.**

| | Treatments | Grain filling period ($day^{-1}$) | Plant height (cm) | Straw yield (t $ha^{-1}$) | Biological yield (t $ha^{-1}$) | Harvest İndex (%) |
|---|---|---|---|---|---|---|
| | + Control (inorganic fertilizer) | 34.0 b | 87.3 cd | 4.913 e | 8.27 c | 34.0 |
| | 0 T $ha^{-1}$ (-Control) | 32.0 c | 73.0 e | 3.455 f | 5.16 d | 33.4 |
| Sewage sludge | 5 t $ha^{-1}$ | 34.0 b | 84.0 d | 5.335 de | 7.76 c | 33.0 |
| | 10 t $ha^{-1}$ | 35.6 ab | 85.0 cd | 5.736 cd | 8.53 bc | 33.6 |
| | 15 t $ha^{-1}$ | 34.6 ab | 89.0 bc | 5.989 c | 9.20 b | 34.6 |
| | 20 t $ha^{-1}$ | 35.0 ab | 92.0 b | 6.855 b | 11.01 a | 35.6 |
| | 25 t $ha^{-1}$ | 34.6 ab | 96.0 a | 7.555 a | 11.16 a | 34.6 |
| | 30 t $ha^{-1}$ | 36.0 a | 97.0 a | 7.733 a | 11.33 a | 35.1 |
| LSD (P<0.05) | | 1.857 | 4.268 | 0.596 | 0.913 | ns |
| F values | | 4.063* | 30.558** | 52.86** | 49051** | ns |

* P < 0.05; ** P < 0.01; ns: not significant; different letters indicate means significantly different (Least Significant Difference Test, LSD).

Crude protein and mineral contents of triticale straw are presented in Table 4. Data analysis confirmed that the straw protein content was significantly affected by sewage sludge treatments in dose dependent manner. The straw protein content varied between 3.24 and 5.08 % (Table 4). The highest straw protein content (5.08 %) was obtained in the 30 t $ha^{-1}$ sewage sludge rate. This can be explained that sewage sludge was rich in nitrogen content. On the other hand, the lowest protein content (3.24 %) was observed in the control (0 t $ha^{-1}$) plots. Even, mineral fertilizer application increased significantly straw protein over control. And straw protein ratio was 4.88 % in average in positive control (fertilizer) plots. These results show that sewage sludge was more effective than mineral fertilizer on protein content in triticalestraw. Yagmur *et al.* (2005) reported that crude protein content in lentil was higher in all sewage sludge amended treatments compared to control plots and fertilized plots with inorganic fertilizer.

Table 4 shows mineral nutrients in straw for sewage sludge treatments. Data analysis showed that sewage sludge affected significantly all measured plant nutrients (N, P, Mg, Mn, Fe), except potassium. The increases in straw mineral contents were evaluated separately. Total nitrogen in triticale straw was increased in dose dependent manner and higher than that of conventional fertilizer. The highest sewage sludge addition (30 t ha$^{-1}$) to soil caused the higher nitrogen content in straw compared to control and mineral fertilizer (Table 4). These observed results show that sewage sludge applications were more effective than mineral fertilizer on straw N concentration. Akdeniz *et al.* (2006) reported that N uptake was increased with the highest sewage sludge dose. The results when evaluated for straw phosphorus concentration, straw phosphorus was affected significantly higher in mineral fertilizer in comparison to all sewage sludge rates and negative control. In other words, the highest straw P concentration was obtained by mineral fertilizer. In this study, although the treatment of sewage sludge did not provide a significant increase in phosphorus content of the straw compared to inorganic fertilizer. The benefits of using sewage sludge as phosphorus fertilizer has been proven by numerous studies. It was seen on the literature, P concentrations in tomato plant were increased with increasing sewage sludge doses (Önal *et al.,* 2003). Yagmur *et al.* (2005) reported that nitrogen concentration in lentil was higher in all sewage sludge amended treatments in comparison to control. Moreover, P content was normally high in biosolid and mineral fertilized plots compared to control plots as obtained in the sewage sludge amended plots. There was no difference between all treatments with respect to potassium concentrations of triticale straw. This may be attributed to adequate potassium concentrations of the experimental soil for optimum plant growth. Similarly, sewage sludge application did not affect the potassium content of plant tissue (Cogger *et al.,* 2001).

**Table 4. Crude protein and mineral contents of triticale straw.**

| | Treatments | Crude protein (%) | Nitrogen (N, %) | Phosphorus (P, ppm) | Potassium (K,ppm) | Magnesium (Mg, ppm) | Manganese (Mn, ppm) | Iron (Fe, ppm) |
|---|---|---|---|---|---|---|---|---|
| | +Control (inorganic fertilizer) | 4.88 ab | 0.74 a | 2.56 a | 3.99 | 0·181 abc | 87·20 c | 243·0 bc |
| | 0 t ha$^{-1}$ (- Control) | 3.24 c | 0.51 c | 1.30 c | 3.53 | 0·166 bc | 88·23 bc | 144·5 c |
| Sewage sludge | 5 t ha$^{-1}$ | 3.75 c | 0.60 bc | 1.92 b | 3.80 | 0·154 c | 89·87 bc | 287·0 ab |
| | 10 t ha$^{-1}$ | 4.46 b | 0.71 ab | 1.91 b | 4.14 | 0·182 abc | 88·83 bc | 223·2 bc |
| | 15 t ha$^{-1}$ | 4.58 ab | 0.74 a | 1.62 bc | 3.93 | 0·191 abc | 89·61 bc | 278·9 ab |
| | 20 t ha$^{-1}$ | 4.99 ab | 0.78 a | 1.83 bc | 3.79 | 0·213 ab | 86·61 c | 307·2 ab |
| | 25 t ha$^{-1}$ | 4.67 ab | 0.75 a | 2·10 ab | 3.72 | 0·221 a | 96·10 ab | 305·1 ab |
| | 30 t ha$^{-1}$ | 5.08 a | 0.80 a | 2·09 ab | 3.77 | 0·211 ab | 100·06 a | 360·5 a |
| LSD (P<0.05) | | 0.588 | 0.135 | 0.564 | Ns | 0.055 | 8.561 | 103.4 |
| F values | | 18.691$^{**}$ | 5.99 $^{**}$ | 3.948 $^{*}$ | Ns | 3.322$^{*}$ | 2.715$^{*}$ | 3.670$^{*}$ |

$^{*}$ P < 0.05; $^{**}$ P < 0.01; ns: not significant; different letters indicate means significantly different (Least Significant Difference test, LSD)

Straw Mg, Mn and Fe contents were significantly affected by the application of sewage sludge. It was observed that the highest sewage sludge dose increased the highest level these nutrients in triticale straw. Similar results were found by many researchers. For example, Önal *et al*. (2003) reported that magnesium level of tomato plant was increased by the increasing rates of sewage sludge. Akdeniz *et al.* (2006) pointed out that sewage sludge tended to increase plant Mg concentration. Also, Bozkurt *et al*. (2010) reported that sewage sludge application to soil significantly increased Mg, Fe and Mn contents in apple leaves.

Table 5 shows the zinc levels of straw produced in sewage sludge treated soil. Although it has been detected slightly higher in sewage sludge compared to control plots, the observed of zinc (Zn) concentration in straw was similar among sewage sludge application doses and control plots (- and +). The zinc contents in straw changed between 8.07 and 10.0 ppm. In the study, observed zinc content in straw was below unhealthy levels. Andersson and Petersson (1981) demonstrated that zinc concentration in wheat grain should be < 34 mg kg$^{-1}$ for it to be suitable for human consumption.

Results showed that some yield traits of triticale and nutrient concentrations of its straw were significantly affected by sewage sludge application in dose dependent manner without causing the accumulation of heavy metals straw(Al, Cd, Ch, Ni, Pb and Cu) (Table 5). All sewage sludge doses did not increasethe heavy metal contents of straw.This would be advantage for plant growth and development. High heavy metal concentrations in the soil will decrease the essential mineral concentrations, followed by growth retardation in plants. Ciecko *et al.* (2001) pointed out that soil with high cadmium content decreased nitrogen, potassium, magnesium, calcium and sodium contents in triticale. In the current study, nitrogen and phosphorus contents of triticale straw were increased by sewage sludge applications compared to control plots. Heavy metal contents of triticale straw (Al, Cd, Ch, Ni, Pb and Cu) produced from sewage sludge added to soil were similar to those control plots. According to Koupaie and Eskicioglu (2015), high dose and repeatedly applied sewage sludge into soil increased soil and plant tissue heavy metal concentrations, causing health for human who consume agricultural products produced on this kind of lands. Positively, in the present study, sewage sludge applications did not increase heavy metals contents of triticale straw. However, as it appeared from the result of the experiment in this research, there is a good potential for the sludge to be used for agricultural application. In addition to the present low Cu concentration in the straw would be related to the less mobility in soil subjected by sewage sludge due to the stable link of Cu's form with organic matter, thus decreasing availability (Zhu and Alva, 1993). Similarly, Usman *et al.* (2012) reported that sewage sludge, when applied to the alkaline soil, precipitates heavy metals in lower concentration. The straw nickel concentrations in the current study, was below the harmful levels, as found in maize by Melo *et al*. (2007). Similarly, the maximum amount of 40 t ha$^{-1}$ sewage sludge treatment did not reach any harmful levels in examined components (Bouzerzour *et al*., 2002). Heavy metals can also enter the photosynthetic apparatus by decreasing the photosynthetic pigment damaging chloroplast structure and inducing changes in the lipid and protein composition of the thylakoid membrane leading to lipid peroxidation related to the generation of toxic oxygen species (Wang, *et al*., 2009). Commonly this situation directly reduces all yield traits. Whereas, in this study the yield traits were positively affected by the application of sewage sludge. The negative effects of heavy metals on plant growth were not found in the study.

**Table 5. Heavy metal concentrations of triticale straw (ppm).**

| Treatments | | Zinc (Zn) | Cadmium (Cd) | Chromium (Cr) | Aluminum (Al) | Copper (Cu) | Lead (Pb) | Nickel (Ni) |
|---|---|---|---|---|---|---|---|---|
| +Control (inorganic fertilizer) | | 9.88 | 0.418 | 3.90 | 151.2 | 4.147 | 0.119 | 2.10 |
| Sewage sludge | 0 t ha$^{-1}$ (- Control) | 8.07 | 0.412 | 5.32 | 155.4 | 2.471 | 0.155 | 3.81 |
| | 5 t ha$^{-1}$ | 10.00 | 0.394 | 5.42 | 184.5 | 3.847 | 0.125 | 3.22 |
| | 10 t ha$^{-1}$ | 8.80 | 0.384 | 4.53 | 141.6 | 3.320 | 0.164 | 2.03 |
| | 15 t ha$^{-1}$ | 8.44 | 0.539 | 4.79 | 180.8 | 2.650 | 0.131 | 2.61 |
| | 20 t ha$^{-1}$ | 9.10 | 0.292 | 5.27 | 163.9 | 3.247 | 0.128 | 2.79 |
| | 25 t ha$^{-1}$ | 9.27 | 0.292 | 5.10 | 151.9 | 3.257 | 0.138 | 3.10 |
| | 30 t ha$^{-1}$ | 9.86 | 0.339 | 3.78 | 175.6 | 3.290 | 0.173 | 2.27 |
| LSD (P<0.05) | | ns | ns | ns | Ns | ns | ns | ns |
| F values | | ns | ns | ns | Ns | ns | ns | ns |

ns: not significant

**Conclusion:** A 30 t sewage sludge application per ha increased straw yield more than 100 % compared to negative control treatment, nearly 60% compared to positive control, suggesting that sewage sludge may be used as N, P, Mg, Mn and Fe sources and used instead of conventional inorganic fertilizer. Marginal lands like a low input soils can be reorganized with using sewage sludge by considering its possible heavy metal presence before using. Commonly, high dose and repeatedly applied sewage sludge increases soil and plant tissue heavy metal concentrations. For this reason, higher doses and the long-term use of sewage sludge should be avoided.

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