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*Full Length Research Paper*

# Effect of municipal wastewater with manure and fertilizer on yield and quality characteristics of forage in corn

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**In order to study the effects of wastewater with two kinds of fertilizers (manure and chemical fertilizer) on yield and quality characteristics of forage in corn, a field experiment was conducted in the University of Zabol in Iran during 2007 growing season. The experiment was conducted in split plot design with three replications. The treatment were comprised of two levels of irrigation water ($W_1$ = Well water and $W_2$ = Wastewater) in the main plot and five levels of fertilizer ($F_1$ = Control; $F_2$ = Manure, 30 ton/ha; $F_3$ = Manure, 15 ton/ha; $F_4$ = NPK: 350, 200 and 100 kg/ha; and $F_5$ = NPK: 175, 100 and 50 kg/ha) in the sub plot. Results showed that irrigation with wastewater significantly increases the fresh and dry forage yield of corn than well water. Treatment of treated wastewater also had a significant influence on crude protein content, ash percentage and macro elements (N, P and K) contents in corn forage ($P < 5\%$). But wastewater had no significant effect on Fe, Mn and Zn elements content. The highest fresh and dry forage yield and the most crude protein content, ash percentage and macro elements (N, P and K) contents were obtained from $F_4$ (NPK: 350, 200 and 100 kg/ha) treatment. However, the highest Fe, Mn and Zn elements content were obtained from $F_2$ (Manure: 30 ton/ha) treatment.**

**Key words:** Treated wastewater, manure, chemical fertilizer, yield, quality, corn.

## INTRODUCTION

The continuous growth of world population along with industrial and agricultural activities for increasing the food supply and the consecutive droughts in recent years has caused the consumption of existing water resources to reach their maximum in the dry belt zone. Iran is among the Middle East countries, which will experience 20 to 25 percent drop in annual rainfall in 2050 as compared to its 1961-1990 average annual rainfall (Abedi and Najafi, 2001). In addition, Iran is among the countries in which the per capita water consumption is beyond the international standards. Consequently, where the country is suffering severely from the shortage of consumptive water and critical problems of water resources exist, the problem is serious. It is inevitable and necessary to pay attention to the abnormal consumption of water resources (Najafi, 2002).

The use of treated wastewater for agricultural irrigation is an old and popular practice in agriculture (Feigin et al., 1991). Irrigation with treated wastewater has been used for three purposes: (i) complementary treatment method for wastewater (Bouwer and Chaney, 1974), (ii) the use of marginal water as an available water source for agriculture (Bouwer and Idelovitch, 1987; Al-Jaloud et al., 1995; Tanji, 1997), and (iii) the use of wastewater as nutrient source (Bouwer and Chaney, 1974; Vazquez-Montiel et al., 1996) associated with mineral fertilizer savings and high crop yields (Smith and Peterson, 1982; Feigin et al., 1991).

The beneficial effects of using sludge on agriculture have been proven by numerous researchers. It has been shown that sewage sludge application improves the physical, chemical and biological properties of soil (Aggelides and Londra, 2000; Benitez et al., 2001; Selivanovskaya et al., 2001; White et al., 1997). Nutrients contained in sludge increase plant biomass and yield (Brofas et al., 2000; Cogger et al., 2001; Snyman et al., 1998). Reed et al. (1991) reported that sludge and nitrogen fertilizer applications as the source of applied

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**Table 1.** Chemical analysis of water, wastewater and soil of experiment.

| Parameter | Unit | Water | Wastewater | Soil |
|---|---|---|---|---|
| pH | - | 7.2 | 7.95 | 7.2 |
| EC | Ds $m^{-1}$ | 2.2 | 3.1 | 1.8 |
| N | Meq $l^{-1}$ | - | 23.12 | 0.027 |
| K | Meq $l^{-1}$ | 6.7 | 25.27 | 317 |
| P | Meq $l^{-1}$ | - | 11.1 | 1.56 |
| Ca | Meq $l^{-1}$ | 11.43 | 6.2 | 12.1 |
| Fe | Mg $l^{-1}$ | 0.015 | 0.10 | 0.03 |
| Zn | Mg $l^{-1}$ | 0.015 | 0.015 | 1.615 |
| Mn | Mg $l^{-1}$ | 0.03 | 0.05 | 0.32 |

**Table 2.** Chemical analysis of cattle manure.

| Mn (mg $kg^{-1}$) | Zn (mg $kg^{-1}$) | Fe (mg $kg^{-1}$) | K (%) | P (%) | N (%) |
|---|---|---|---|---|---|
| 372 | 93 | 7431 | 1.47 | 76 | 21 |

nutrient did not affect the grain and silage yield of corn, indicating that the fertilizer value of sludge was comparable to that of commercial fertilizers. Pedreno et al. (1996) found that tomato yield was clearly favored by sewage sludge fertilization and noted that the difference was observed from other organic fertilizer treatments. Erfani et al. (2001) showed that utilization of treated municipal wastewater has caused an increase in the yield as compared to irrigation with the well water. The results of this research also showed that microbial contamination of the fruits increased by using the treated wastewater.

The aim of this research is to study the effects of wastewater with two kinds of fertilizers on yield and quality characteristics of forage in corn.

## MATERIALS AND METHODS

This experiment was conducted in 2007 cropping season at Agriculture Research Center of Zabol University. The site lies at longitude 61º29' and latitude 31º2' and the altitude of the area is 487 m above sea level. It has a warm dry climate with the mean minimum, mean maximum and average air temperatures of 18, 41 and 29ºC, respectively. The soil characteristics of Agriculture Research Center is sandy-loam in texture, pH = 7.4 and E= 1.8 $ds.m^{-1}$ (The soil properties prior to the experiment has shown in Table 1). The experimental design was split plot, using randomized complete block design with tree replication. The treatment were comprised of two levels of irrigation water ($W_1$ = Well water and $W_2$ = Wastewater) in the main plot and five levels of fertilizer ($F_1$ = Control; $F_2$ = Manure, 30 ton/ha; $F_3$ = Manure, 15 ton/ha; $F_4$ = NPK: 350, 200 and 100 kg/ha and $F_5$ = NPK: 175, 100 and 50 kg/ha) in the sub plot. The average values of physical and chemical characteristics of the water and treated wastewater are reported in Table 2. In this study, the total manure (the chemical analysis of cattle manure has been showed in Table 2) for both irrigation were applied prior sowing and for chemical fertilizer, 50% N and total P and K fertilizers were applied to the sowing seeds.

Experiment plots were seeded with hybrid corn KoSc 704 at 30 kg/ha with 70 cm row to row distance and 22 cm between plants. Corn was planted manually in June 2007. After planting, irrigation was applied as required during the growing season. The corn was harvested in stage of dough seed in November 2007. Data collected (obtained by combining the five center rows at each experiment unit) includes: fresh forage yield, dry forage yield (were measured after drying samples at 70ºC for 48 h in an air oven) (Schurman and Goedewaagen, 1971; Veli et al., 1991), the macro elements (N, P and K) content in forage (N, P and K were measured by Kejeldal method, Spectrophotometer and Atomic absorption, respectively). The micro elements (Fe, Mn and Zn) content in forage of corn (Fe, Mn and Zn were measured by dry ash and mixture to hydro fluoride acid), crude protein (was measured by Kjeldal method) and ash percentage (was determined by burning the plant tissues in temperature of 500 - 550ºC in electrical kiln) (Wilson, 1983). The data were analyzed using MSTATC software; mean comparison was done using Duncan Multiple Comparison at 5% probability level.

## RESULTS AND DISCUSSION

### The fresh and dry forage yield

The effect of fertilizer and irrigation treatments was significant on fresh and dry forage yield of corn ($P < 5\%$) (Table 3). Mean comparison showed that the use of wastewater in comparison with well water irrigation, result in the increase of fresh and dry forage yield (8.25% fresh forage and 23.14% of dry forage) (Table 5). The increase of fresh and dry forage yield of corn could be related to the amount of enough nutritious elements in wastewater (such as N, P and K). Alizadeh et al. (2001) reported that irrigation treatment with wastewater in all the growth stages cause the most biological yield of corn to be achieved. The highest fresh and dry forage yields of corn obtained from $F_4$ (NPK: 350, 200 and 100 kg/ha) treatment (91237.5 kg/ha fresh forage yield and 19447.6 dry forage yield) are as shown in Table 5. The fertilizer percentage

**Table 3.** Analysis of variance for yield and quality characteristics of forage.

| S.O.V | df | Fresh forage yield | Dry forage yield | Crude protein | Ash |
|---|---|---|---|---|---|
| | | Mean Square | | | |
| Replication | 2 | 41.50$^{ns}$ | 19.81$^{ns}$ | 0.41$^{ns}$ | 2.35$^{n.s}$ |
| Irrigation | 1 | 11941.52* | 2956.21* | 41.17* | 110.63$^{n.s}$ |
| Error a | 2 | 2130.74 | 871.45 | 85.25 | 339.74 |
| Fertilizer | 4 | 8391.23* | 1002.31* | 63.50* | 561.31$^{*}$ |
| Interaction | 4 | 5586.41* | 1452.78* | 32.11 | 963.97 |
| Error b | 14 | 991.84 | 126.54 | 7.09 | 18.49 |
| CV | - | 16.3 | 10.8 | 21.32 | 14.08 |

*, ** Significantly different at the 5% and 1% levels of probability, respectively; $^{n.s}$ non significant.
df = Degree of freedom.

**Table 4.** Analysis of variance for macro and micro elements content in forage.

| S.O.V | df | N | P | K | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|
| | | Mean Square | | | | | |
| Replication | 2 | 0.014$^{ns}$ | 0.04$^{ns}$ | 1.16$^{ns}$ | 93.6$^{ns}$ | 14.3$^{ns}$ | 6.42$^{ns}$ |
| Irrigation | 1 | 2.45* | 0.008* | 0.74* | 381.4$^{ns}$ | 85.6$^{ns}$ | 29.83$^{ns}$ |
| Error a | 2 | 1.17 | 0.003 | 4.89 | 417.2 | 136.7 | 65.42 |
| Fertilizer | 4 | 2.07* | 0.011 | 1.96* | 458.7* | 124.9* | 32.70* |
| Interaction | 4 | 2.16* | 0.025* | 0.94* | 725.1$^{ns}$ | 306.8$^{ns}$ | 84.91$^{ns}$ |
| Error b | 16 | 4.1 | 0.091 | 6.07 | 528.7 | 399.7 | 100.7 |
| CV | - | 14.8 | 19.3 | 13.1 | 20.7 | 24.5 | 19.1 |

*, ** Significantly different at the 5 and 1% levels of probability, respectively; $^{n.s}$ non significant.
df = Degree of freedom.

**Table 5.** Mean comparison for forage yield, crude protein content and ash percentage.

| Treatment | Fresh forage yield (kg ha$^{-1}$) | Dry forage yield (kg ha$^{-1}$) | Crude protein (%) | Ash (%) |
|---|---|---|---|---|
| **Irrigation** | | | | |
| $W_1$ | 79344.6 b | 12489.5 b | 9.93 b | 15.21 b |
| $W_2$ | 86479.3 a | 16249.3 a | 17.37 a | 1852 a |
| **Fertilizer** | | | | |
| $F_1$ | 66972.4 d | 10621.7 d | 12.37 d | 15.12 c |
| $F_2$ | 78431.6 c | 13911.7 c | 15.06 c | 16.61 b |
| $F_3$ | 74211.8 c | 4776.3 c | 14.62 c | 16.05 b |
| $F_4$ | 91237.5 a | 19447.6 a | 22.37 a | 17.39 a |
| $F_5$ | 84319.7 b | 17281.1 b | 19.31 b | 17.13 a |

Mean followed by similar letters in each column, are not significantly different at the 5% level of probability.

decreased; the rate of fresh and dry forage yield of corn also decreased to the lowest, its amount in $F_1$ (without fertilizer application) treatment (669724 kg/ha fresh forage yield and 10621.7 dry forage yield). This shows that fertilizer caused the increase of fresh and dry forage yields of corn because of increasing availability of essential elements (NPK) of plant growth. Hasanzadeh et al. (2001) presented similar results in the evaluation of chemical, organic and mixture fertilizers effects on the quantity and quality characteristics of sunflower.

The interaction effect of fertilizer and irrigation treatments was significant on fresh and dry forage yield of corn (P<5%) (Table 3). The mean comparison of interaction effects showed that the highest amount of fresh and dry forage yield obtained from $W_2F_4$ (wastewater and NPK: 350, 200 and 100 kg/ha) treatment, which was equal to 88858 kg/ha fresh forage yield and 17848 kg/ha dry forage yield and the lowest amount of it, achieved from

**Table 6.** Mean comparison for macro and micro elements content in forage.

| Zn (mg kg$^{-1}$) | Mn (mg kg$^{-1}$) | Fe (mg kg$^{-1}$) | K (%) | P (%) | N (%) | Treatment |
|---|---|---|---|---|---|---|
| | | | | | | **Irrigation** |
| 13.1 a | 28.9 a | 83.9 a | 2.1 b | 0.18 b | 1.11 b | $W_1$ |
| 14.7 a | 30.1 a | 86.4 a | 3.6 a | 0.26 a | 2.78 a | $W_2$ |
| | | | | | | **Fertilizer** |
| 6.9 c | 19.7 c | 73.4 c | 2.2 c | 0.14 d | 1.98 d | $F_1$ |
| 17.8 a | 38.4 a | 93.4 a | 3.3 b | 0.22 b | 2.41 c | $F_2$ |
| 13.1 b | 35.1 a | 84.2 b | 2.4 c | 0.18 c | 2.34 c | $F_3$ |
| 11.8 b | 26.9 b | 81.9 b | 3.9 a | 0.32 a | 3.58 a | $F_4$ |
| 7.6 c | 24.2 b | 77.2 bc | 3.0 b | 0.24 a | 3.09 b | $F_5$ |

Mean fallowed by similar letters in each column, are not significantly at the 5% level of probability.

$W_1F_1$ (well water and without fertilizer application) treatment (which was equal to 73008kg/ha fresh forage yield and 10556 kg/ha dry forage yield) (Table 7).

## The macro elements (N, P and K) content in forage

The results of statistical analysis showed that the effect of fertilizer and irrigation treatments was significant on macro elements (N, P and K) contents (P < 5%) (Table 4). Table 6 showed the highest macro elements (NPK) content in forage of corn obtained from treatment of irrigation with wastewater (2.78, 0.26 and 3.6% for N, P and K, respectively). The increase of macro elements (NPK) content in forage of corn could be related to the amount of these nutritious elements in wastewater. Alizadeh et al. (2001) showed that, the irrigation with wastewater in all of growth stages cause the increase of nitrogen and other macro elements content in corn. Among fertilizer treatment, $F_4$ (NPK: 350, 200 and 100 kg/ha) treatment cause the increase of N, P and K content in forage, and correspond to dry forage yield with decrease of fertilizer amounts from N, P and K content that has been decreased in forage of corn and has reached the lowest of its amount in $F_1$ (without fertilizer application) treatment (Table 6). In this condition, the use of fertilizer, made the NPK elements available for plant and consequently causes the increase of their absorption by plant. Parhamfar (2006) in a research also presented the same results on this matter.

The interaction effect of fertilizer and irrigation treatments was significant on macro elements (NPK) content in forage of corn (P < 5%) (Table 4). The mean comparison of interaction effects showed that the highest amount of macro elements (NPK) content in forage obtained from $W_2F_4$ (wastewater and NPK: 350, 200 and 100 kg/ha) treatment (3.18, 0.29 and 3.75% for N, P and K, respectively) and the lowest amount of it achieved from $W_1F_1$ (well water and without fertilizer application) treatment (which was equal to 1.54, 0.12 and 2.15% for N, P and K, respectively) (Table 7).

## The micro elements (Fe, Mn and Zn) content in forage

Fertilizer treatment had significant effect on micro elements (Fe, Mn and Zn) content in forage of corn (P < 5%). But irrigation treatments and interaction effects were not significant on it (Table 4). Alizadeh et al. (2001) in evaluation of corn irrigation effect with wastewater showed that wastewater has no significant effect on micro and heavy elements content in corn forage. The other researchers showed that the similar results were related to the lack of wastewater effect on micro and heavy elements content in different several plants as well (Barbarick et al., 1998; Selivanovskaya et al., 2001; Snyman et al., 1998). As shown in Table 6, the most micro elements content achieved from $F_4$ (NPK: 350, 200 and 100 kg/ha) treatment (93.4, 38.4 and 17.8 mg/kg for Fe, Mn and Zn, respectively) and with decrease of manure amounts from Fe, Mn and Zn content has been decreased in forage of corn and has reached the lowest of its amount in $F_1$ (without fertilizer application) treatment (73.4, 19.7 and 6.9 mg/kg for Fe, Mn and Zn, respectively) (Table 6). The increase of micro elements content in corn forage in condition of using manure could be because of the existence of enough amounts of these elements in manure. Rezainejad and Afyuni (2000), in evaluation of organic matters, effect on soil chemical characteristics, and elements uptake by corn and its yield, reported that organic fertilizer cause a significant increase of soil organic matter and the ability of Zn, Fe and Cu uptake in soil. In this case, manure had the most effect on corn yield.

## Crude protein content and ash percentage of forage

The result of statistical analysis, showed that irrigation

**Table 7.** Mean comparison of interaction effects for yield, quality characteristics and macro elements content.

| Treatment | Fresh forage yield (kg ha$^{-1}$) | Dry forage yield (kg ha$^{-1}$) | Crude protein (%) | Ash (%) | N (%) | P (%) | K (%) |
|---|---|---|---|---|---|---|---|
| $W_1F_1$ | 73008.4 e | 10556.3 c | 9.62 d | 15.27 d | 1.54 d | 0.12 c | 2.15 c |
| $W_1F_2$ | 78887.6 c | 13200.1 bc | 11.00 d | 15.96 cd | 1.76 d | 0.16 bc | 2.70 b |
| $W_1F_3$ | 76777.4 d | 13632.5 b | 10.75 d | 15.52 a | 1.72 d | 017 bc | 2.25 c |
| $W_1F_4$ | 85290.2 b | 15668.4 ab | 14.62 bc | 16.72 bc | 2.34 bc | 0.25 a | 3.00 b |
| $W_1F_5$ | 81831.5 bc | 14885.7 ab | 13.12 c | 16.54 c | 2.10 c | 0.22 ab | 2.55 bc |
| $W_2F_1$ | 76741.3 d | 13435.8 bc | 14.87 bc | 16.96 b | 2.38 bc | 0.20 b | 2.90 b |
| $W_2F_2$ | 82455.9 bc | 15080.2 ab | 16.18 b | 17.42 ab | 2.59 b | 0.24 a | 3.45 a |
| $W_2F_3$ | 80345.1 c | 15512.9 ab | 16.00 b | 16.98 b | 2.56 b | 0.22 ab | 3.00 b |
| $W_2F_4$ | 88858.5 a | 17848.1 a | 19.87 a | 18.10 a | 3.18 a | 0.29 a | 3.75 a |
| $W_2F_5$ | 85399.7 b | 16765.5 a | 18.31 a | 17.85 a | 2.93 a | 0.25 a | 3.40 a |

Mean followed by similar letters in each column, are not significantly different at the 5% level of probability.

and fertilizer treatment have significant effect on crude protein content and ash percentage of forage ($P < 5\%$) (Table 3). Table 5 showed that the highest crude protein content and ash percentage of forage were obtained from treatment of irrigation with wastewater. The increase of crude protein content and ash percentage of forage of corn could be related to suitable amount of nitrogen element in wastewater. Alizadeh et al. (2001) showed that, the irrigation with wastewater in all of growth stages leads to increase of nitrogen and other macro elements content in corn. Also, in spite of the fact that ash percentage showed the amount of minerals in plant tissue, the irrigation with wastewater leads to increase of ash percentage in this treatment.

Among fertilizer treatments, the consumption of complete fertilizer (NPK: 350, 200 and 100 kg/ha) leads to increase of crude protein content and ash percentage of corn forage and according to dry forage yield with decrease of fertilizer amounts from crude protein content and ash percentage has been decreased in forage of corn and has reached the lowest of its amount in $F_1$ (without fertilizer application) treatment (Table 5). In this condition, the use of fertilizer made the NPK elements available for plant and consequently causes the increase of their absorption by plant. The interaction effect of fertilizer and irrigation treatments was significant on crude protein content and ash percentage of corn forage ($P < 5\%$) (Table 3). The mean comparison of interaction effects showed that the highest amount of crude protein content and ash percentage of forage obtained from $W_2F_4$ (wastewater and NPK: 350, 200 and 100kg/ha) treatment (19.78% crude protein content and 18.10% ash percentage) and the lowest amount of it was achieved from $W_1F_1$ (well water and without fertilizer application) treatment (which was equal to 9.62% crude protein content and 15.27% ash percentage) (Table 7).

## Conclusions

The results in this experiment showed that irrigation with wastewater significantly increase the fresh and dry forage yield of corn than well water. Also the crudest protein content, ash percentage and macro elements (N, P and K) contents in corn forage were obtained from irrigation with wastewater. This increase could be related to the amount of enough nutritious elements in wastewater (such as N, P and K). Furthermore, among fertilizer treatments the highest fresh and dry forage yield and the most crude protein content, ash percentage and macro elements (N, P and K) contents were obtained from consumption of total chemical fertilizer (NPK: 350, 200 and 100 kg/ha). However, the highest Fe, Mn and Zn elements content in corn forage was obtained from consumption of total manure (30 ton/ha).

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