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Effect of Two Organic Amendments on Growth, Ions and Water Use Efficiency of Maize Plants Grown in Sandy Soil

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Abstract: The effects of wheat straw, bone meal and their combinations on maize plants were investigated in a pot experiment. Incorporation of wheat straw into sandy soil reduced shoot growth criteria of maize plants as compare with control plants. This effect was increase with increasing the straw level. On the other hand, root growth was improved with the straw addition. Bone treatments greatly improved shoot and root growth of the used plants. Combination treatments (straw+bone) added more increase in plant growth. Total chlorophyll and carotenoids content was reduced in response to straw additions. Bone treatments either alone or in combination with straw appeared to improve the level of these pigments in maize leaves. On many occasions, the straw treatments decreased C, N, P, Ca, S, Mg and Fe content of maize plants. The addition of bone to the soil, generally, increased N, P and Ca, whereas decreased C level of maize plants. Although, the addition of straw appeared to conserve soil water, it reduced the estimated WUE. Bone application either alone or in combination with wheat straw markedly increased WUE of maize plants. The WUE was positively correlated with N, Ca and P content of the used amendments. Total soil bacterial, actinomycetal and fungal count was increased in response to all used organic amendments in relation with control soil. The highest microbial count was recorded with the straw 2 + bone 2 treatment. It can be concluded from this study that the application of bone either alone or in combination with wheat straw is benefit for maize growth. But, the addition of the straw alone has a negative effect on shoot growth at least in short application experiments.

Key words: Bone, chlorophyll, efficiency, ions, maize, microflora, sand, straw

INTRODUCTION

Improvement of sandy soil and desert is one of the most important tasks facing mankind at present. Reversal of sandy soil fertility depletion is required to increase agricultural production and may be achieved through the use of inorganic and organic inputs (Sanchez and Leakey, 1997). Use of inorganic fertilizers is constrained by inadequate supply, high price, unstable prices of agricultural produce (Kayuki and Wortmann, 2001) and its environmental impact. The application of organic amendments to soil is increasing as both an environmentally favorable waste management strategy and a means of improving soil organic matter content in low-fertility soils (Flavel and Murphy, 2006; Tejada *et al.*, 2006, 2007).

Considerable research has shown the benefits of using organic amendments to improve soil physical (water holding capacity, porosity and bulk density), chemical (pH, electrical

conductivity and nutrient content) and biological properties such as soil microbial populations and plant growth (Stemmer *et al.*, 1999; Rahman *et al.*, 2005; Flavel and Murphy, 2006; Tejada *et al.*, 2006).

The influence of organic matter on soil properties depends on amount, type and size of added organic materials (Barzegar *et al.*, 2002). The C:N ratio of the added organic amendment has a large influence on its subsequent decomposition and determine if net mineralization or immobilization of N occurs, whereas net immobilization of N generally occurs at C:N ratio >20-30:1 (Hodge, 2003). Organic matter decaying in soil immobilize N. A proportion of this N will eventually be remineralize, but the immobilization can prevent or retard the loss of nitrate from the soil leading to improved economy of N fertilizer and decreasing the risk of contaminated ground water (Cheshire *et al.*, 1999).

The beneficial effect of crop residue is well established and with the introduction of combine harvesters in developed countries cereal straw remains, either as mulch or is incorporated into the soil (Rahman *et al.*, 2005). In this regard, Stemmer *et al.* (1999) found that maize straw was more decomposed and protected within soil inorganic compounds when mixed into the soil than when applied on the soil surface. They attributed this to high contact between the soil microflora and plant residues. However, the addition of crop residues into the soil results in enhanced microbial activity which causes N depletion and suppression of plant growth (Al-Hamdi *et al.*, 2001).

A principle constituent of bone is calcium phosphate which may provide important minerals to growing plants (Traveset *et al.*, 2001) and a remediation treatment for metal contaminated soil (Hodson *et al.*, 2000; Hodson and Valsami-Jones, 2000). However, few studies have been devoted to the consequences of animal bone incorporation in the soil on plant growth and the results are contradictory. Plant growth may be improved (Montagu and Goh, 1999; Traveset *et al.*, 2001) or reduced (Chitdeshwari and Savithri, 2000) with bone meal addition. Furthermore, the combined effect of wheat straw and animal bone on plants grown in sandy soil was not evaluated before. Therefore, this study was undertaken to evaluate the effects of wheat straw and bone meal addition to sandy soil on maize plants growth, some plant physiological criteria and soil microflora.

MATERIALS AND METHODS

Plant Materials and Growing Conditions

In these experiments, wheat straw and cow bone ribs were cut to small pieces, air dried and used as organic amendments for sandy soil (pH 7.5; CaCO₃ 0.003%). Before addition, the animal bone was ground to fine powder. Plastic pots (15 cm diameter) were filled with sandy soil (1.5 kg pot⁻¹) and allocated into 7 treatments according to the incorporated amendment (12 replicates in each one) as shown in Table 1.

Healthy and equalize grains of maize (*Zea mays* L. var single 10) were surface sterilized with 0.001 M HgCl₂ solution for 10 min and washed thoroughly with distilled water. Then 6 grains were sown in each pot. The pots were kept in a greenhouse at the Faculty of

Table 1: Experimental treatments and the added amendments

Treatments	Amendments added to the soil pot ⁻¹
Control	0.0
Straw 1	10 g wheat straw
Straw 2	20 g wheat straw
Bone 1	10 g bone
Bone 2	20 g bone
Straw 1 + bone 1	10 g wheat straw + 10 g bone
Straw 2 + bone 2	20 g wheat straw + 20 g bone

Education (at Al-Arish, Egypt), where the plants were subjected to natural day/night conditions during the summer season (14 h day; 39±3 mid day temp.). After 12 days the plants were thinned to 4 pot⁻¹. Irrigation to field capacity was carried out when soil water content had fallen to 60% of its initial value. After one month of sowing, samples were taken for growth and biochemical analyses.

Measurements of Leaf Area

Leaf area was measured by Digital Planimeter KP-90 N (PLAKOM).

Determination of Photosynthetic Pigments

Photosynthetic pigments (chlorophyll a, chlorophyll b and carotenoids) were extracted rapidly from the 1st upper fully expanded leaf in ammoniacal acetone and their concentrations were determined spectrophotometrically using the equations of Hendry and Price (1993).

Determination of Metallic Ions and Phosphorus Concentration

Ions in dry shoots and roots were extracted by the acid digestion method. Ca, Mg and Fe were determined using the atomic absorption spectrophotometer Perkin-Elmer 2380. Phosphorus was determined by the ammonium molybdate colorimetric method as recommended by Rorison *et al.* (1993).

Determination of Total C, N and S Concentration

C, N and S concentration of dry shoots and roots was determined using CHNS Analyzer (Elementar vario III, Germany).

Microbial Count

Total microfloral count of soil samples was carried out using the appropriate common media for isolating and culturing fungi, bacteria and actinomycetes. These media were potato dextrose agar, nutrient agar and starch nitrate respectively (Scharlau, 2000).

Estimation of Water Use Efficiency

Water Use Efficiency (WUE) was estimated using the following equation (Kramer and Boyer, 1995):

$$WUE = \frac{\text{Shoot dry weight (g)}}{\text{Total water used (kg)}}$$

Statistical Analysis

The experiment was a completely random design. The main effect of factors (wheat straw and animal bone) and their interaction (straw×bone) were evaluated by general linear model (two way ANOVA) using SPSS program. Tests for significant differences between means at $p = 0.05$ were given by LSD test. Correlation coefficient between the amendment constitutions and the other main results was also estimated.

RESULTS

Chemical Composition of Used Organic Amendments

Results for wheat straw and animal bone chemical analyses are presented in Table 2. Wheat straw had a higher carbon and S concentration than bone meal. On the other hand,

Table 2: Chemical analyses of wheat straw and animal bone

Constituents	Concentration (%)	
	Wheat straw	Animal bone
C	43.52	25.920
N	0.31	4.540
S	0.33	0.010
P	0.42	2.960
Ca	0.03	0.240
Mg	0.22	0.440
Fe	0.05	0.048

the bone was rich in N (14 fold), P, Ca and Mg elements as compared with wheat straw. The two organic amendments appeared to have the same level of Fe content. The C:N ratio of wheat straw was about 140:1, whereas that of bone was about 6:1.

Changes in Growth Parameters

Addition of wheat straw significantly reduced maize shoot fresh and dry weights as well as total leaf area in relation with control plants (Table 3). This effect was more elicited with the highest straw level. Conversely, bone meal treatment either alone or in combination with wheat straw markedly improved these criteria. Shoot length and leaves number was not affected by straw additions. Bone application, over all conditions, significantly increased these parameters in maize plants in relation with control plants.

Table 3: Effect of wheat straw and bone meal on growth parameters of maize plants grown in sandy soil

Treatments	Parameters						
	Shoot length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Root length (cm)	Root fresh weight (g)	Root dry weight (g)	Leaves No. plant ⁻¹
Control	14.81	1.33	0.16	28.00	1.21	0.12	6.25
Straw 1	15.25	1.00	0.13	35.75	1.87	0.19	6.00
Straw 2	14.00	0.76	0.11	43.50	2.10	0.19	5.75
Bone 1	21.75	1.79	0.21	35.00	1.94	0.16	6.63
Bone 2	24.71	2.20	0.23	35.25	3.15	0.24	7.13
Straw 1 + bone 1	22.14	2.30	0.25	39.00	3.49	0.26	6.71
Straw 2 + bone 2	24.88	2.65	0.30	39.25	4.33	0.29	6.71
LSD (p≤0.05)	2.38	0.18	0.02	5.44	0.47	0.03	0.53

Concerning root growth, all straw and bone treatments significantly increased root length and fresh and dry weights in comparison with control plants. It is clear from the obtained results that the bone additions improved the growth criteria of maize plants and the effect was more efficient with the dual treatment of straw 2 + bone 2.

Shoot and root dry weights were positively correlated ($r = 0.8-0.95$; $p \leq 0.01$) with N, P and Ca concentration of the used amendments. Shoot dry weight was negatively correlated ($r = -0.7-0.9$; $p \leq 0.01$) with S and non significantly correlated with C, Mg and Fe level of the added amendments. On the other hand, root dry weight was positively correlated ($r = 0.9-0.95$; $p \leq 0.01$) with C, Mg and Fe and non significantly correlated with S level of the used amendments.

Changes in Photosynthetic Pigments

Wheat straw application significantly reduced total chlorophylls and carotenoids concentration in maize leaves in relation with control plants (Fig. 1). This effect increased with increasing the straw level. Conversely, bone treatments significantly increased these pigments over the control level. Total carotenoids content was not affected, whereas total

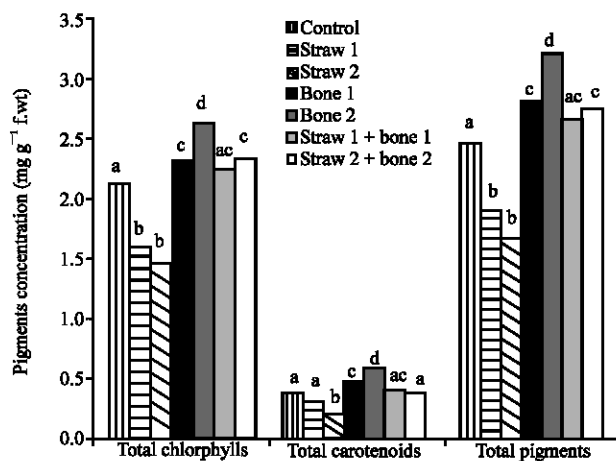


Fig. 1: Effect of wheat straw and bone meal on photosynthetic pigments concentration of maize plants grown in sandy soil. Bars in grouping labeled with the same letter(s) are not significantly different at $p \leq 0.05$

chlorophyll was increased in response to the dual treatments. Statistically, the interaction (straw $\times$ bone) was significant for total chlorophylls. This may point to the non significant effect of the dual treatment, straw 1+bone 1, on chlorophylls content. Total photosynthetic pigments followed the same patterns of changes that obtained for total chlorophylls.

Chlorophyll and carotenoids contents were positively correlated ($r = 0.8-0.9$; $p \leq 0.01$) with N, P and Ca and negatively correlated ($r = 0.8-0.9$; $p \leq 0.01$) with S concentration of the added soil amendments. A non significant correlation appeared with the other amendment constitutions.

Changes in Metallic Ions and Phosphorus Content

It can be seen from the results (Fig. 2a, b) that the addition of wheat straw significantly decreased total P and Ca concentration of maize shoot as compared with control plants. Addition of bone improved the P level of these plants and on some occasions this compensated the control values. Conversely, this treatments significantly increased Ca content of maize shoots. The dual treatment, straw 2 + bone 2, clearly increased the P and Ca level of maize shoots in relation with control plants.

Generally, both organic amendments significantly increased P content of maize roots in relation with control plants and the effect was more pronounced with the straw treatments. Except for the combination treatment, straw 2 +bone 2, all used straw and bone treatments decreased Ca content of maize roots. The straw treatments appeared to reduce Mg and Fe ions concentration of maize shoots in comparison with control plants (Fig. 2c, d). The application of bone either alone or in combination with straw non significantly increased the concentration of these ions. In root, all used amendments appeared to decrease the Mg and Fe level of these plants and the effect was more elicited with the straw 2 treatment.

The estimated results of correlations between plants ion contents and the amendment constitutions were not regular and sometimes misleading.

Changes in C, N and S Content

Figure 3a-c show that all straw and bone treatments decreased to some extent C level in maize shoots. However, the results for C% of roots were not regular. The application of

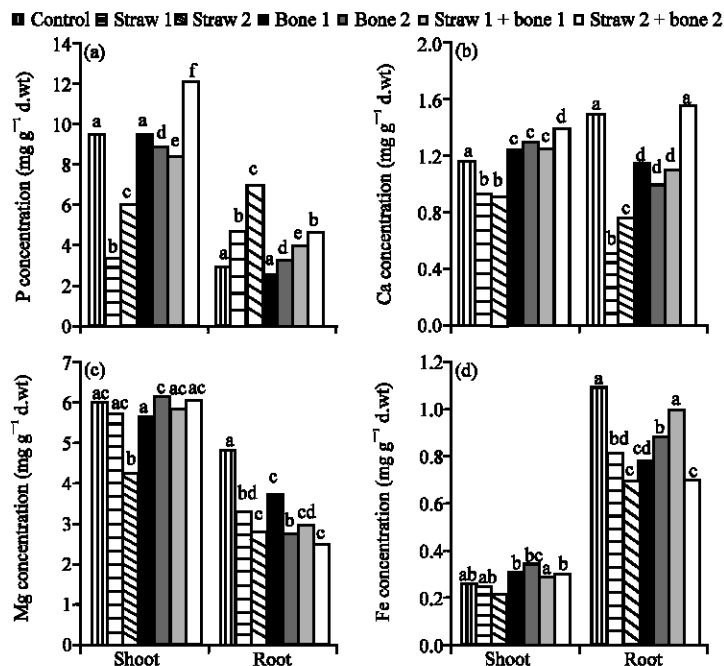


Fig. 2: (a-d) Effect of wheat straw and bone meal on metallic ions and phosphorus concentration of maize plants grown in sandy soil. Bars in grouping labeled with the same letter(s) are not significantly different at $p \leq 0.05$

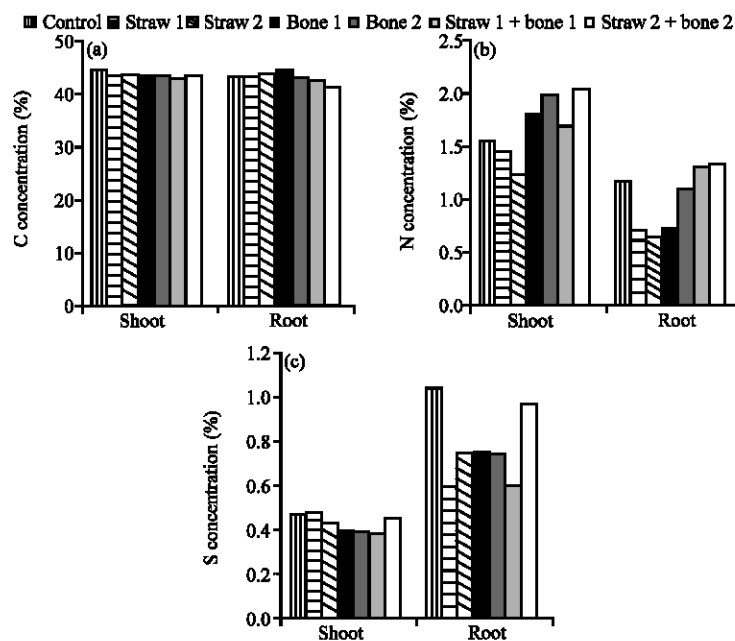


Fig. 3: (a-c) Effect of wheat straw and bone meal on C, N and S concentrations of maize plants grown in sandy soil

straw and bone treatments caused a little increase in C concentration of roots, whereas the dual treatments, straw+ bone, appeared to reduce the C% as compared with control plants.

Clearly, the addition of wheat straw reduced N% of maize shoots and roots in relation with control plants. On many occasions, bone treatment either alone or in combination with wheat straw increased N concentration of these plants. In general, all used organic amendments appeared to decrease S% of these plants shoot and root as compared with control values.

Shoot N content was positively correlated ($r = 0.8-0.86$; $p \leq 0.01$), whereas root N was non-significantly correlated with N, P and Ca of the used amendments. On the other hand, shoot and root N was negatively correlated ($r = -0.82$; $p \leq 0.01$) S level of the added organic matter.

Changes in Water Use Efficiency (WUE)

It can be seen from the results (Fig. 4), that the addition of wheat straw significantly reduced WUE of maize plants in relation with control plants. The higher level of straw induced more reduction than the lower one. On the other hand, bone treatments drastically increased the WUE over the control values and the effect increased with increasing the bone level. The dual treatments appeared to add more increase in WUE. It should be mention that the total applied water per plant was found to be 325 cm³ for control and bone treatments and 287 cm³ for straw and straw + bone applications.

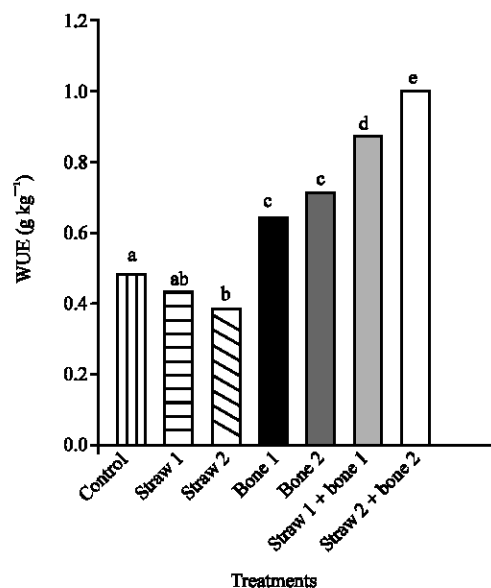


Fig. 4: Effect of wheat straw and bone meal on water use efficiency (WUE) of maize plants grown in sandy soil. Bars in grouping labeled with the same letter(s) are not significantly different at $p \leq 0.05$

water use efficiency was positively correlated ($r = 0.93$; $p \leq 0.01$) with N, Ca and P level and negatively correlated ($r = -0.73$; $p \leq 0.02$) with S concentration of the added soil amendments. Non-significant correlations appeared with the other amendment constitutions.

Changes in Soil Microbial Count

The obtained results (Fig. 5a-c) show that both organic amendments significantly increased the count of soil actinomycetes, bacteria and fungi in comparison with control soil. The combination treatments added more increase and the effect were more elicited with the straw 2+bone 2 treatment.

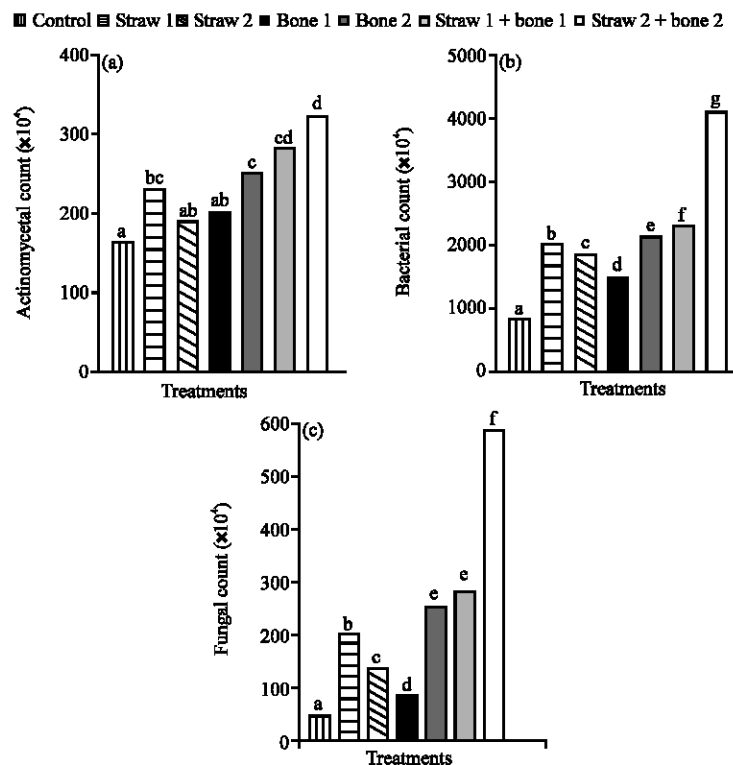


Fig. 5: (a-c) Effects of wheat straw and bone meal on soil microbial count (cell g⁻¹ soil dry weight). Bars in grouping labeled with the same letter(s) are not significantly different at $p \leq 0.05$

The count of all evaluated soil microorganisms were significantly correlated ($r = 0.77-0.9$; $p \leq 0.01$) with N, S, P, Ca, Mg and Fe level of the used amendments. Only soil bacterial count was positively correlated ($r = 0.81-0.9$; $p \leq 0.01$), whereas fungal and actinomycetal count were non-significantly correlated with C content of the applied amendments.

DISCUSSION

The addition of wheat straw to sandy soil reduced shoot growth criteria of maize plants and the effect increased with increasing the straw level. This is consistent with the general reputation that the incorporation of crop residues into the soil cause N depletion and suppression of plant growth (Harper, 1977; Al-Hamdi *et al.*, 2001). It is clear from the results that the straw has C:N ratio about 140 and this high ratio may be the reason of suppressed plant growth. In this respect, Moraghan *et al.* (2003) found that the incorporation of low-N mature wheat straw decreased the availability of soil N probably due to immobilization associated with straw decomposition and consequently reduced sugarbeet growth.

Root growth of maize plants was improved with the addition of wheat straw in relation with control plants. Although, these results may be complicated with the results of shoot growth, it could be explained by the fact that the addition of the straw materials decrease soil mechanical impedance (Bengough *et al.*, 2006) and enhance microbial activity which may produce some root growth stimulating agents (Compant *et al.*, 2005).

The application of animal bone markedly improved both shoot and root growth of maize plants. In this study, the C:N ratio of bone materials was about 6:1 which is considerably lower than the C:N ratio of >20-30 where net immobilization of N occurs (Bartholomew, 1965; Hodge, 2003). Thus, this organic material is expected to be decomposing and releasing available N, P and Ca for maize plants. Additionally, maize plants may capable of absorbing organic N (Okamoto and Okada, 2004). This is consistent with Traveset *et al.* (2001), who found that the bone compost significantly increased seed germination of *Rubus spectabilis* as compared with control. The combination treatments added more increase in plant growth and the effect was more pronounced with the straw 2+bone 2 treatment. This effect could result from increased microbial activity and available nutrients, as well as decreased soil mechanical impedance.

Total chlorophyll and carotenoids was reduced with the addition of wheat straw. This may be due to shoot N deficiency, whereas the straw was poor in N as appeared from the obtained results. On the other hand, bone treatments greatly improved these photosynthetic pigments and N level in maize plants. The role of nitrogen in chlorophyll biosynthesis is well known and chlorophyll content is often used as a plant N status indicator (Okamoto and Okada, 2004; Olivier *et al.*, 2006).

On many occasions, the wheat straw treatments decreased N, P, Ca, S, Mg and Fe content of maize plants. This appeared to be due to the low level of these ions in the straw materials and may reflect the competition between the growing plants and soil microflora. In this context Tejada *et al.* (2006) found that the application of organic amendments increased both soil microbial biomass and soil enzyme activity. It is widely documented that the reduction of chlorophylls content was accompanied with a reduction of C photo-assimilate content of growing plants (Aldesuquy and Gaber, 1993; Ibrahim, 1999; Younis *et al.*, 2000). This could explain the observed reduction of C% of maize shoots which was associated with chlorophylls decrease due to straw additions. The addition of bone to the soil, generally, increased N, P and Ca content of maize plants. This is expected results, whereas the bone materials had a high level of N, P and Ca ions. Conversely, the application of bone decreased C% of maize plants and this may due to enhanced plant growth. The results appeared to be far from those of Browaldh (1992) who found that the addition of bone ash decreased total N and P content of bean plants.

Although, the application of wheat straw appeared to decrease the total applied water, it reduced WUE of maize plants. This reduction is mainly due to decreased shoot growth. The bone treatments greatly increased the estimated WUE. This increment resulted from enhanced shoot dry weight. The combination treatments added more increase in WUE and this resulted from soil water conservation as well as improved shoot growth. Again, the bone is rich in nutrients mainly N, Ca and P which enhanced plant growth and consequently increased plant WUE. This is in a good conformity with the results of many authors who found that N fertilization increases WUE on N-deficient soils (Viets, 1962; Olsen *et al.*, 1964; Al-Kaisi and Yin, 2003).

The results clearly show that soil bacterial, fungal and actinomycetal count was increased in response to all straw and bone treatments. The positive effect of organic amendments addition on soil microflora is widely documented (Höflich *et al.*, 2000;

Tejada *et al.*, 2006, 2007). According to Tejada *et al.* (2006), this increase is due to a direct (microbial growth whereas the organic matters act as an energy source of microorganisms) and indirect effect (improvement of plant growth which increase root exudates). In this regard, Lazarovits *et al.* (2000) found that the addition of bone meal and soymeal lead to an increase in soil microorganisms populations by up to 100 fold following applications. The nutrient content (N, P and Ca) was higher in bone than in the wheat straw amendment and these nutrients may have increased the quantity and activity of microorganisms (Marin, 2004). Thus, the highest bone level (bone 2) and its combination with wheat straw added more increase in soil microflora.

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