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*Full Length Research Paper*

# Investigating the effects of long-term application of compost-like output on wheat yield and N, P and K in kernel and soil under planting

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**In order to investigate the effects of application of 3 and 5 consecutive periods of Compost-Like Output (CLO) on yield and concentration of N, P, K in kernel wheat and soil under planting, a greenhouse experiment was conducted in split plot based on a Randomized Complete Block Design (RCBD) with four replications in 2009. The main plot was six fertilizer levels including: control (without CLO and chemical fertilizer), Chemical Fertilizer (CF) based on soil test, 4 levels of CLO (20 and 40 t/ha without and with half of CF) and sub-plot was applying 3 and 5 continuous periods. The results showed that application of CLO significantly increased yield amendment and concentration of macro-nutrient in grain wheat and soil. Also, regarding the periods of application, it was observed that the application of CLO in five consecutive periods was more effective compared with three consecutive periods. The maximum and minimum amount of N, P kernel and soil after harvesting and number of kernel in spike were produced with application of 40 t/ha CLO with half of CF and control, respectively. The highest amount of 1000- kernel weight was observed in 40 t/ha of CLO treatment. The maximum grain yield was obtained with the application of 5 consecutive periods of 40 t/ha CLO with half of CF. Furthermore, it was observed that between CLO treatments, there was no significant difference in the concentration of k in kernel.**

**Key words:** Consecutive periods, compost-like output, soil, wheat, yield.

## INTRODUCTION

Wheat is considered as one of the most important and strategic crops in the world. There are several ways for increasing wheat production of which one of them is the appropriate application of organic residues (Yassen et al., 2010). Most agricultural soils in Iran are generally low in organic matter (OM), usually less than 1% and as a result, have poor chemical conditions. Therefore, increasing OM in these soils is of prime concern. More than 7.2 million tons of municipal solid waste is generated in Iran annually. With these amounts of waste, 2.5 million tones compost is available, which causes an increase in OM levels of agricultural soils in Iran (Mahmoodabad et al., 2010). Compost-like output is commonly applied to the soils to improve their physical, chemical and biological properties. Field studies with these materials applied as soil amendments have shown that the CLO can be useful in agricultural crop production (Hargreaves et al., 2008).

Gong et al. (2009) and Enke et al. (2010) found that long-term addition of organic manure has the most beneficial effect on grain yield of wheat and maize. Also, Tejada and Gonzalez (2003) showed that compost application in 2-continuous years increased the number of grains/spike, 1000 grain weight and the number of spikes and grain wheat yield. This positive effect was mainly due to a better N supply with the compost application. Compost-N availability (especially, during the first year) is lower, application of CLO compost together with inorganic N is recommended to enhance N availability to

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**Table 1.** Some chemical properties of the soil and compost-like output (CLO) used in the study.

| Characteristic | Soil | CLO |
|---|---|---|
| Texture | Silty clay | - |
| pH | 7.53 | 7.41 |
| EC (dS/m) | 1.18 | 10.19 |
| OC (%) | 2.36 | 22.63 |
| N (%) | 0.23 | 2.03 |
| P (mg/kg) | 14.6 | 4600 |
| K (mg/kg) | 270.06 | 8485.76 |
| Zn(mg/kg) | 1.02 | 103.94 |
| Fe(mg/kg) | 58.47 | 273.26 |
| Mn (mg/kg) | 13.96 | 52.41 |
| Cu (mg/kg) | 5.58 | 37.52 |

crops (Mkhabela and Warman, 2005). Also Mkhabela and Warman (2005), in a 2-year experiment on sweet corn and potato observed that inorganic fertilizer (NPK) and a mixture of compost-like output and inorganic fertilizer produced higher yields than municipal solid waste compost alone.

Yassen et al. (2010) suggested that organic manure application increased the transfer elements between the solid phase and soil solution in addition to higher microbial activity. The activity of soil micro-organisms was higher in the organic farming system, which helped the nutrient uptake.

In wheat plant, Nehra and Hooda (2002), Sing et al. (2002), Tawfik and Gomaa (2005), Zeidan et al. (2005) and Yaduvanshi and Sharma (2008) found that organic manure application significantly enhanced the yield and uptake of N, P and K in wheat. In general, municipal solid waste composts may improve soil properties even better than other manure (Weber et al., 2007). Courtney and Mullen (2008) and Soumare et al. (2003) have shown that applications of municipal solid waste compost bring about an increase in the bioavailability of macronutrients.

It is clear that organic materials play a major role in soil nutrients availability to plants. The objectives of this study were to evaluate the effect of application 3 and 5 consecutive periods of CLO on (i) number of grain in spike, 1000 K-W and kernel wheat yield, and (ii) the concentration of N, P and K in kernel wheat and soil under planting.

## MATERIALS AND METHODS

This project was performed during the period of 2006 to 2009 cropping season in Agriculture Sciences and Natural Resources University of Sari in Iran. The site was characterized by 53°4´W longitude and 36°39´N latitude and 15 m height from the surface of the sea with an average annual temperature of 17.4°C.

A greenhouse experiment was conducted in split plot based on Randomized Complete Block Design (RCBD) with six fertilizers and two years treatment in four replications in 2009. The Main plot was six fertilizers level, $T_0$: control (without CLO and chemical fertilizer), $T_1$: chemical fertilizer (CF) (200 kg urea, 50 kg triple superphosphate, and 100 kg $K_2SO_4$ per ha), $T_2$: 20 ton CLO ha$^{-1}$, $T_3$: 40 ton CLO ha$^{-1}$, $T_4$: 20 ton CLO ha$^{-1}$ + 1/2 $T_1$ and $T_5$: 40 ton CLO ha$^{-1}$ + 1/2 $T_1$, and sub plot was application of 3 and 5 continuous periods.

To investigate the cumulative and residual effects of CLO, fertilizer treatments were added to the soil from 2006 to 2009 for 3 and 5 continuous periods. The fertilizer treatments were used in 12 plots (3 × 12 m$^2$) in research field of Agriculture Sciences and Natural Resources University of Sari from 2006 to 2008. Then, each plot was divided into two sub-plots (3 × 6 m$^2$): The effects of applications of treatments on 3 consecutive periods were studied in one half and in other portion, treatments were applied twice (in spring and autumn 2009) and the effects were investigated on 5 consecutive periods. The compost used during this experiment was supplied from Isfahan composting factory in Iran. Before planting in 2006, soil samples and compost-like output were taken to determine some chemical properties of them. Some properties of soil and compost-like output are shown in Table 1.

During the winter of 2009, after the preparation of the required treatments and filling of the 10-kg pots under the greenhouse conditions, 10 seeds of wheat (N-81-19 cultivar) were sown in each pot and decreased to six plants per pot ten days after planting, keeping soil moisture near the field capacity (FC) during planting period. At the maturity stage, the plants were harvested and their spikes and straws separated. Then, number of kernel per spike, total kernel weight and 1000-kernel weight were determined.

Total N in plant materials was determined according to the modified Kjeldahl method. Concentration of P and K in plant materials was carried out after dry-ashing at 450°C and digestion with HCL (Lester and Birkett, 1999). Phosphorus in plant extracts was determined by a vanado-molybdate colorimetric procedure and potassium in all extracts was estimated using flame photometer.

Immediately after harvesting, soil samples were taken from the 0 to 20 cm layer in each plot. Then, soil samples were air-dried and passed through a 2.0 mm sieve. The following soil analyses were carried out: Total N content was obtained by the Kjeldahl method. Van Reeuwijk (1995) and available phosphorus was determined after the extraction of sodium bicarbonate by Olsen method (Olsen and Sommers, 1990) and extractable K was determined using a 1 N ammonium acetate extraction method (Thomas, 1982).

The experimental data were subjected to analysis of variance (ANOVA) tests with mean separation by the Duncan test using a significance of $p < 0.01$ using SPSS system and MSTATC system for counter effect at the possibility level of $p < 0.05$.

**Table 2.** Analysis of variances for different characteristics of wheat.

| Variable | Df | Mean square | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Number of kernel in spike | 1000 KW | kernel yield | HI | N | P | K |
| Replication | 3 | 44.24 | 17.5 | 1.77 | 1.611 | 0.01 | 0.00 | $4\times10^{-5}$ |
| Amount of application (A) | 5 | 91.68** | 134.7** | 24.46** | $1.341^{ns}$ | 0.18 ** | 0.00 ** | 0.00 ** |
| Error a | 15 | 11.44 | 8.24 | 3.46 | 2.096 | 0.05 | 0.00 | 0.00 |
| Periods of application (B) | 1 | $58.52^{ns}$ | $23.66^{ns}$ | 16.18** | $1.584^{ns}$ | $0.10^{ns}$ | 0.00 ** | 0.00 ** |
| A × B | 5 | $28.32^{ns}$ | $12.95^{ns}$ | 2.78** | $2.098^{ns}$ | $0.08^{ns}$ | $0.00^{ns}$ | $0.00^{ns}$ |
| Error b | 18 | 17.13 | 7.94 | 0.86 | 1.828 | 0.04 | 0.00 | 0.00 |
| Total error | 47 | | | | | | | |
| CV (%) | - | 10.66 | 6.13 | 4.35 | 3.91 | 10.04 | 5.45 | 1.94 |

ns, * and **: Not significant, significant at 0.05 and 0.01 levels, respectively.

## RESULTS AND DISCUSSION

### Compost characteristics

Chemical analyses of the compost are presented in Table 1. The amount of pH, EC and nutrient concentrations in compost used were in the order of those reported by Ontario Ministry of Environment (2004). Since the concentration of nutrients such as N, P and K in this compost is high, it may be useful in agricultural lands.

### Effect on yield and yield component

The application of different amounts of compost-like output had a significant effect on the number of kernel in spike, 1000 kernel weight and yield wheat ($p < 0.01$), but periods of application and the interaction effect of these two factors were statistically significant on kernel yield at ($p < 0.01$) (Table 2).

#### *Number of kernel in spike*

This factor increased significantly with the application of different rates of compost as compared to control treatment. The maximum and minimum number of kernel in spike was observed in 40 t/ha compost + 1/2 NPK ($T_5$) and control ($T_0$) treatment, respectively. It showed 26.5% increase compared with the control treatment and statistically was similar to the group with $T_2$, $T_3$ and $T_4$ treatments (Table 3). Barzegar et al. (2002) reported that application of 50 t/ha compost could increase total seed number per canola plant. An application of compost-like output stimulated plant growth, which could be due to improving soil organic matter (SOM), because SOM influences nitrogen load and mobilization, enhances nutrient cycling, and improves soil physiochemical and microbial properties (Cherifa et al., 2009).

Also the data in Table 3 showed that a combination of compost with half of NPK increased significantly the number of kernel in spike compared to the treatments receiving compost alone. These findings are in accordance with the results reported by Sikora and Enkiri (2000). They noted that when an N-fertilizer was present in a blend with compost, the compost could provide a more crop yield. Also, they observed that there were no significant difference between 3 and 5 consecutive periods of applying fertilizer treatments and there were no significant difference in this factor (Table 3). The results of the current experiment, therefore, suggest that compost-like output applied at the rates used for 3 consecutive periods may supply enough N for wheat grown (Erhart et al., 2005), thereby, leading to an increase in the observed number of kernel in spike.

#### *1000 Kernel weight*

The data in Table 3 showed that, 1000 kernel weight increased with increasing amount of application of CLO in soil. The maximum and minimum amounts of it were observed in 40 t/ha CLO ($T_3$) and control ($T_0$) treatment, respectively. It showed 26.4% increase when compared to control and had no significant difference with $T_5$ (40 t/ha CLO + 1/2 NPK fertilizer) treatment. The yield component of cereals for sample 1000-kernel-weight (TKW) was affected by the nitrogen supply at different developmental stages (Borghi, 1999). Improvements in plant biomass have been reported (Courtney and Mullen, 2008), which were mainly due to the improvement in nutrient availability by composts. Also Kazemini et al. (2010) found that application of compost caused a significant increase in the mean of canola seed weight. Municipal solid waste compost contains more available minerals and organic matter, thus, the application of more compost led to a nutritional surplus in soil which improved the utilization of soil nutrient by roots thereby enhancing the production of more seeds per crop.

#### *Kernel yield*

The application of different amounts of compost-like

**Table 3.** Mean comparison of CLO treatments and periods of application on the yield and yield components of wheat.

| Treatment | Number of kernel in spike | 1000 KW (g) | Kernel yield (g pot) |
|---|---|---|---|
| Control ($T_0$) | 33.5$^c$ | 40.37$^c$ | 15.73$^d$ |
| Chemical fertilizer ($T_1$) | 36.0$^{bc}$ | 41.68$^c$ | 16.18$^{cd}$ |
| 20 ton CLO ha$^{-1}$ ($T_2$) | 40.25$^{ab}$ | 47.02$^b$ | 17.02$^c$ |
| 40 ton CLO ha$^{-1}$ ($T_3$) | 39.50$^{ab}$ | 51.03$^a$ | 18.79$^b$ |
| 20 ton CLO ha$^{-1}$ + 1/2 $T_1$ ($T_4$) | 41.25$^a$ | 47.2$^b$ | 19.01$^b$ |
| 40 ton CLO ha$^{-1}$ + ½ $T_1$ ($T_5$) | 42.38$^a$ | 48.48$^{ab}$ | 20.11$^a$ |
| **Periods of application** | | | |
| 3 consecutive periods (2006-2008) | 37.71$^a$ | 45.258$^a$ | 17.22$^b$ |
| 5 consecutive periods (2006-2009) | 39.92$^a$ | 46.662$^a$ | 24.52$^a$ |

Means followed by similar letters in each column are not significantly different at 0.05 level of probability according to Duncan's multiple range tests.

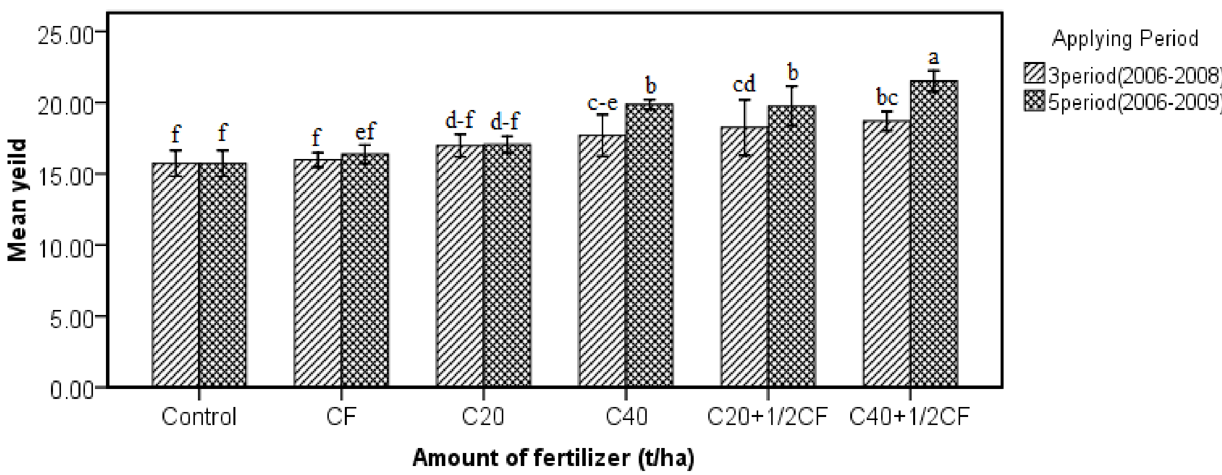


**Figure 1.** Mean comparison of interaction effect of periods and amounts of fertilizer on the yield of wheat (g/pot); means followed by similar letters in each column are not significantly different at 0.05 level of probability according to Duncan's multiple range tests; CF: chemical fertilizer; C: Compost-like output.

output had a significant effect on increasing the kernel yield of wheat when compared to the control. This may be due to the ability of compost to support the growth of plants with micro and macro nutrients needed for their growth. Similar results were obtained by Courtney and Mullen (2008), Wei and Liu (2005) in barley and Soumare et al. (2003) in ryegrass plant.

Also, the results in Figure 1 showed that the application of CLO in five consecutive periods compared with three consecutive periods produced the highest kernel yield. Similar results were obtained by Tejada and Gonzalez (2003). They reported that the wheat yield parameters of the second experimental season were better than those of the first experimental season, due to the residual effect of the organic matter after its application in the first season. In a long-term field experiment (10 years) on different cereals, Erhart et al. (2005) found that crop yield response to the compost applications was low in the beginning and increased slightly for the duration of the experiment and the long-term applications of compost supplied slow-release nitrogen for crop growth. Nitrogen is the key nutrient for plant growth and yields are usually strongly related to nitrogen supply when other nutrients are not limited (Keeling et al., 2003).

In this study, the maximum kernel yield of wheat was observed in the application of 5 consecutive periods of 40 tons CLO + 1/2 NPK (21.51 g in pot), that showed 36.7% increase compared to control treatment. Also, data indicated that between applications of 5 consecutive periods, $T_3$ and $T_4$ treatments did not differ significantly at the 0.05 level of significance and were in a similar statistical group with an application of 3 consecutive periods of $T_5$ treatment (Figure1). Barzegar et al. (2002) in their study on the effect of various organic amendments showed

**Table 4.** Effect of the amount of compost-like output on concentration of nitrogen and phosphor and potassium in kernel.

| Treatment | N (%) | P (%) | K (%) |
|---|---|---|---|
| Control ($T_0$) | 1.94$^{c}$ | 0.15$^{c}$ | 0.47$^{c}$ |
| Fertilizer ($T_1$) | 2.15$^{bc}$ | o.18$^{bc}$ | 0.53$^{a}$ |
| 20 ton CLO ha$^{-1}$ ($T_2$) | 2.12$^{bc}$ | 0.17$^{c}$ | 0.51$^{b}$ |
| 40 ton CLO ha$^{-1}$ ($T_3$) | 2.12$^{bc}$ | 0.19$^{bc}$ | 0.52$^{ab}$ |
| 20 ton CLO ha$^{-1}$ + ½ $T_1$ ($T_4$) | 2.21$^{ab}$ | 0.20$^{ab}$ | 0.52$^{ab}$ |
| 40 ton CLO ha$^{-1}$ + ½ $T_1$ ($T_5$) | 2.41$^{a}$ | 0.21$^{a}$ | 0.52$^{ab}$ |
| **Periods of application** | | | |
| 3 consecutive periods (2006-2008) | 2.11$^{a}$ | 0.17$^{b}$ | 0.50$^{b}$ |
| 5 consecutive periods (2006-2009) | 2.20$^{a}$ | 0.20$^{a}$ | 0.52$^{a}$ |

Means followed by similar letters in each column are not significantly different at 0.05 level of probability according to Duncan's multiple range test.

that the application of organic materials increased wheat yield, aggregate stability, and soil infiltration rate. In another study, it was shown that the application of 50 ton organic matter ha$^{-1}$ increased the wheat and barley yield 1.7 and 2.7 times, respectively (Zhang et al., 2000).

Results also indicated that consecutive multi-years application of CLO as compared to NPK fertilizer can produce the highest yield (Figure 1). These findings are in accordance with the results reported by Wei and Liu (2005).They noted that nutrients from the compost were more effective for the yield increment of Chinese cabbage than that from the common N–P–K fertilizer.

Findings also indicated that when NPK-fertilizer was present in a blend with compost, the compost could provide more kernel yield (Table 3). These results are in a good agreement with that obtained by Sikora and Enkiri (2000) and Wei and Liu (2005). Kavitha and Subramanian (2007) also found that combination of inorganic fertilizer and enriched compost positively influenced the dry matter production of rice at different growth stages. They indicated that when organic manure was applied with inorganic fertilizer, more nutrient uptake occurred in the plant system and as such, more plant biomass was recorded.

## Concentration of macronutrients in kernel

The application of different amounts of compost-like output had a significant effect on the concentration of nitrogen, phosphorous and potassium ($p < 0.01$), but periods of application had significant effects on the amount of P and K at ($p < 0.01$), and the interaction effect of these two was not significant in the amount of N, P and K kernel (Table 2).

### *Nitrogen*

Data in Table 4 indicated that, all treatments tended to increase nitrogen concentration in grain as compared with the control treatment. But, the combination of compost and half of NPK increased significantly the concentration of grain N compared to the treatments receiving compost alone. An enhanced availability of the organic N due to the addition of chemical fertilizer has been reported by several authors (Soumare et al., 2003; Wen et al., 1995). In this study, highest amount of nitrogen in kernel was observed when 40 t/ha CLO + 1/2 fertilizer was used. It showed 13.67% increase compared to control treatment and in a similar group statistically using of 20 t/ha MSW + 1/2 fertilizer. The lowest amount of N in kernel (1.94%) was observed in control treatment (Table 4). These results are in accordance with that obtained by Zeidan et al. (2005), Kavitha and Subramanian (2007) and Mylavarapu and Zinati (2009). Yassen et al. (2010) reported that increasing N concent-ration and its uptake with organic matter application may be attributed to the mineralization of organic minerals and slow release of minerals in an available form from organic manure and may be due to the effect of several organic acids produced during manure decomposition. Also Kropisz and Wojciechowsky (1978) indicated that the combined application of triple-fertilizer NPK and municipal garbage compost slightly increased the N content of several types of crops when compared to the application of mineral fertilizer alone.

Also the results showed that between 3 and 5 consecutive periods of applying fertilizer treatments no significant difference was found in supplying crop N (Table 4). The results of the current experiment, therefore, suggest that compost-like output applied at the rates used for 3 consecutive periods may supply enough N for wheat grown. These results are in accordance with that obtained by Erhart et al. (2005). They showed the long-term value of compost applications for supplying slow-release nitrogen for crop growth.

### *Phosphorous*

Results indicated that the concentration of kernel P increased with increasing compost application rates of 20 to 40 t/ha, especially, in mixture treatments of compost and inorganic fertilizer (Table 4). As a result of this, composts often contain relatively low levels of nutrients compared with complete fertilizer and low mineralization rates which require high application rates to satisfy the complete P requirement of a crop (Wei and Liu, 2005). Also Soumare et al. (2003) observed that the combination of NPK with different doses of compost maintained P concentrations in ryegrass within the sufficiency range. Stable supply of P over a longer period of time from the organic sources and faster release from inorganic fertilizer coupled with stimulating effects of this inorganic phosphorus on the soil microbes increased the P uptake in mixed treatments.

The maximum and minimum amounts of kernel P was obtained in $T_5$ (40 t/ha CLO + 1/2 NPK fertilizer) and $T_0$ (control) treatments, respectively. It showed 40% increase compared to control treatment and maximum treatment was in a similar group statistically with $T_4$ (20 t/ha CLO + 1/2 NPK fertilizer) treatment. Mkhabela and Warman (2005) found that plants fertilized with city compost had higher leaf tissue P compared to those fertilized with inorganic fertilizers, however, leaf tissue P increased with increasing compost application rate. Also Hargreaves et al. (2008) found that the application of organic amendments increased both soil microbial bio-mass and soil enzyme activity. Increasing phosphatase enzyme activity with the addition of low rates of CLO compost (12 and 24 Mg/ha) was reported by Crecchio et al. (2004).

Also, the application of CLO in five consecutive periods compared to three consecutive periods produced the highest concentration of P in kernel (Table 4). This indicated that due to the increase in P and K, the CLO amended soil increased microbial activities and nutrient availability and their uptake as well as root distribution. These results are consistent with those obtained by Mylavarapu and Zinati (2009) and Yassen et al. (2010). Mbaraki et al. (2008) articulated that the main reason for this could be as a result of the increased activity of soil micro-organism and high concentrations of this element left in compost for the plant.

### *Potassium*

Data in Table 4 showed that the application of compost could increase concentrations of K grain, but between CLO different treatments, there were no significant difference. The maximum and minimum amounts of potassium kernel were accumulated in fertilizer ($T_1$) and control ($T_0$) treatment respectively, that showed 11.76% increase as compared to control treatment. The results are also supported by the report of Bengston and Cornette (1973), Duggan and Wiles (1976) that the incorporation of the garbage compost leads to significant increase in plant potassium content. Generally, it has been claimed that potassium is present in compost in an easily assimilated form. Also DeHaan (1981) in a long-term study of CLO compost demonstrated that K was as available in municipal solid waste compost as in mineral K fertilizers. Also, the results showed that application of CLO in five consecutive periods as compared to three consecutive periods produced the highest concentration of K in wheat kernel (Table 4). In the context, Bhattacharyya et al. (2007) found that potassium uptake by rice grain increased with increasing rates and periods of applying compost on the soil. These results are consistent with those obtained by Weber et al. (2007). They said the relatively higher content of different fractions of K in composts might be a possible reason for higher K uptake from treatment receiving compost. Therefore, application of a longer period of time from organic source could be a stable reference of nutrition for crops.

## Effects of treatments on N, P and K soil

According to Figure 2, the application of different amounts of compost-like output had a significant effect on percent of N total soil at ($p < 0.01$), but periods of application and the interaction effect of these two had significant effect on the amount of phosphorus in the soil.

### *Nitrogen*

Application of CLO provides higher percentage of N in soil as compared to control treatment and the percent N in soil increased with increasing the amount of application of CLO in the soil. In general, the maximum percent of N total soil resulted in 40 t/ha CLO + 1/2 fertilizer treatment (0.53%), that showed 103 and 96% increase as compared to control (0.26%) and CF (0.27%) treatment, respectively. Increases in Kjeldahl N with different composts application was observed in studies by Soumare et al. (2003) and Ros et al. (2006). The availability of nitrogen in municipal solid waste compost was estimated at 10% in the first year after application with some reports of N release in the second year after application (DeHaan, 1981; Zhang et al., 2006). Also Hargreaves et al. (2008) reported that, 16 to 21% of the total N in municipal solid waste compost was available as $NH_4NO_3$ six months after application regardless of the soil type. Also, they reported that some studies showed that municipal solid waste compost increased soil N content and that municipal solid waste compost is often less effective in supplying available N in the first year of application to the soil–plant system than inorganic mineral fertilizers. Courtney and Mullen (2008) stated that the application of two agro-industrial composts in loamy sandy soil in Ireland increased significantly its N content

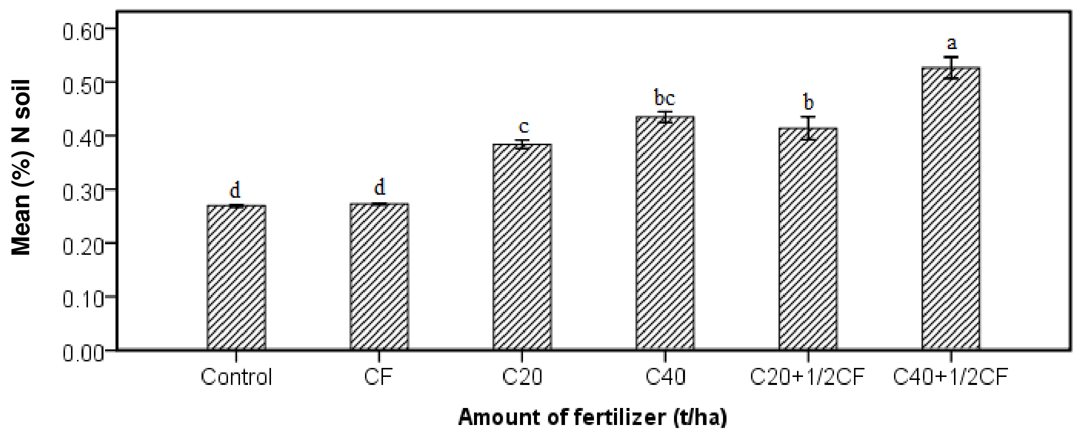


**Figure 2.** Effect of application of different amounts of CLO on N total in soil (%); means followed by similar letters are not significantly different at 0.05 level of probability according to Duncan's multiple range test; CF: chemical fertilizer; C: Compost-like output.

only when applied at 100 t/ha rate.

Results also indicated that when NPK-fertilizer was present in a blend with compost, the compost could provide more of N in soil compared to when compost was applied alone. This result showed a decline in immobilization of N soil by micro-organisms in the decomposition process of organic materials and increased mineralization of N. Mineralization of OM in added composts leads to aa stepwise release of nutrient elements, in particular, N (Weber et al., 2007).

Also in the study, there was no observed significant difference between used periods of CLO on percent of N soil, but in both periods, amending soil with compost only or in combination with inorganic fertilizer increased N soil concentrations (Table 6). These results are consistent with that obtained by Mylavarapu and Zinati (2009). That could be due to applied organic nutrient source and presence of the residual effects of long-term application compost on N soil, because the compost acted as a slow and steady release source of nitrogen on a medium level to soil (Erhart et al., 2005). In some research, increasing soil nitrogen content was observed with applying 5 (Achiba et al., 2009), 4 (Ros et al., 2006) and 2 (Soumare et al., 2003) consecutive years of municipal solid waste compost in soil.

## *Phosphorus*

According to Figure 3, concentration of soil available P increased significantly with increasing compost application rates of 20 to 40 t/ha, especially, in mixture treatments of compost and inorganic fertilizer compared to control treatment. Zhang et al. (2006) reported that municipal solid waste compost could effectively supply P to soil and soil P concentration increasing with increased application rates. In our study, the increase in the level of soil available P with compost dose in clay soil may be due to the increase of organic matter levels which accompanies compost application. Indeed, organic matter is known to increase ion exchange in soils (Mbarki et al., 2008).

Also related to the effect of application of consecutive multi-periods of MSW, it was observed that the amount of P available in soil increased with increasing periods of application of CLO from 3 to 5 (Figure 3). Soumare et al. (2003) and Mkhabela and Warman (2005) found that the amount of P available increased with applying 2-year municipal solid waste compost in soil.

In general, application of 5 successive periods 40 t/ha CLO + 1/2 fertilizer resulted in maximum available P in soil, that showed 31.7% increase compared to control treatment (Figure 3). Similar results were obtained by Warman and Termeer (2005). The increase of available P indicated that compost supplied these nutrients into the soil. Soumare et al. (2003) and Gius-quiani et al. (1988) reported that the addition of urban-waste compost increased soil P solubility. They postulated that the increase in soil P solubility was caused by the formation of phosphohumic complexes that minimized immobilization process and anion replacement of P by humate ion. Phosphatase enzyme activity was also found to increase with the addition of municipal solid waste compost rates (Crecchio et al., 2004). Phosphatase is a P mineralizing enzyme and thus, an increase in its activity may be related to the increased P availability (Hargreaves et al., 2008).

Results of the present study suggest that compost-like output may be as effective as mineral fertilizer in increasing/supplying available soil P (Figure 3) thus, confirming the results of Mkhabela and Warman (2005), Gius-quiani et al. (1988), Jimenez et al. (1993) and Cooperband et al. (2002). This may be attributed to higher microbial activity after the application of compost and consequent release of P during organic matter decomposition. In addition, visual examination of the soil

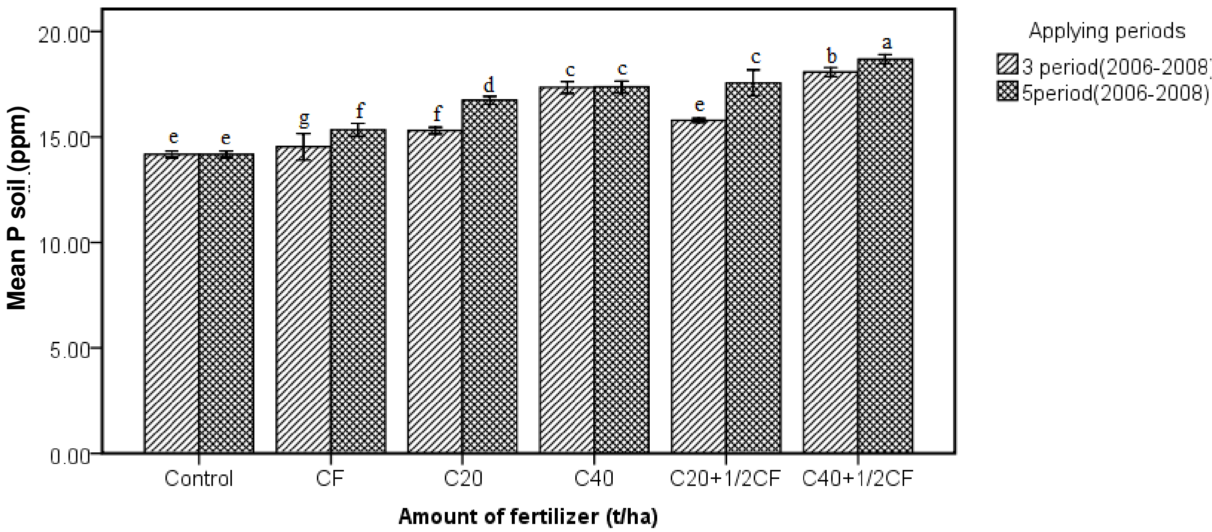


**Figure 3.** Effect of application of different amounts of CLO on the level of available P in soil (ppm); means followed by similar letters are not significantly different at 0.05 level of probability according to Duncan's multiple range test; CF: chemical fertilizer; C: Compost-like output.

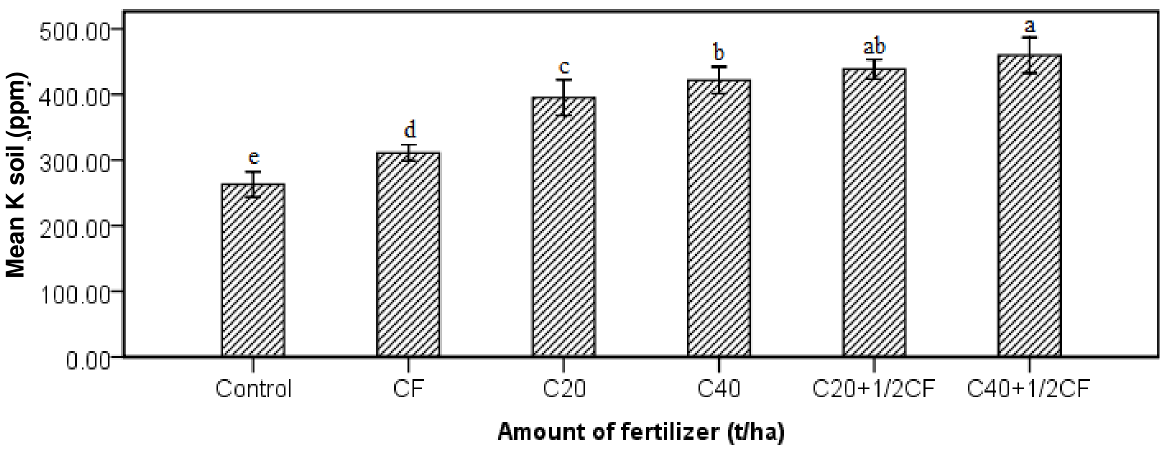


**Figure 4.** Effect of application of different amounts of CLO on level of extractable K soil (ppm); means followed by similar letters are not significantly different at 0.05 level of probability according to Duncan's multiple range test; CF: chemical fertilizer; C: Compost-like output.

during sampling periods suggested more biological activity (earthworms) in all the plots amended with compost as compared to those amended with inorganic fertilizer. The addition of compost material is expected to stimulate organic P mineralizing bacteria and inorganic P solubilizing bacteria (Mkhabela and Warman, 2005).

### *Potassium*

According to Figure 4, the application of fertilizer and CLO significantly increased the exchangeable K content over control. This may be attributed to adsorption of $K^+$ ions on exchange sites of clay minerals (Bhattacharyya et al., 2007). In general, the maximum and minimum amounts of K in soil resulted in 40 t/ha CLO + 1/2 fertilizer and control treatment, respectively. It showed 75% increase compared to control and did not show significant difference with the application of 20 t/ha CLO + 1/2 fertilizer in soil. Also, we observed that when NPK-fertilizer was present in a blend with compost, the compost could provide more extractable K in soil (Figure 4). The mineral NPK fertilizers were active fertilizers whose nutrients were readily available for crops. Composts were slowly-released fertilizers which provided a whole array of nutrients to soil, thereby, suggesting that combined organic and inorganic fertilizer acted as a stable supplier of major plant nutrients in soil. Similar

**Table 5.** Analysis of variances of long-term CLO on N, P, and K in soil.

| S.O.V | Df | Mean square | | |
|---|---|---|---|---|
| | | N (%) | P (ppm) | K (ppm) |
| Amount of application (A) | 5 | ** | ** | ** |
| Periods of application (B) | 1 | ns | ** | ns |
| A × B | 5 | ns | ** | ns |
| CV (%) | | 8.24 | 1 | 6.4 |

ns, * and **: Not significant, significant at 0.05 and 0.01 levels, respectively.

**Table 6.** Effect of periods of application on level of N, P and K in soil.

| Variable | N (%) | P (ppm) | K (ppm) |
|---|---|---|---|
| 3 period (2006-2008) | 0.38 [a] | 15.87[b] | 381[a] |
| 5 period (2006-2009) | 0.38 [a] | 16.64[a] | 382[a] |

Means followed by similar letters in each column are not significantly different at 0.05 level of probability according to Duncan's multiple range test.

results were obtained with the application of CLO in 3 consecutive years by Bhattacharyya et al. (2007). They explained that increase of exchangeable K could be due to the dissolution of K bearing minerals by organic acids and other complex agents produced during the mineralization of organic matters and the decomposition of roots left after the crop harvest. Besides, between the application of CLO in 3 and 5 consecutive periods, there was no significant difference but compared to control soil (263 mg/kg), it had higher content (Tables 5 and 6). Similar results were observed by Bhattacharyya et al. (2007) and Weber et al. (2007). They found that with consistent increasing time and rates of application composts in soil, the contents of exchangeable cations exceeded in soil as compared to control, especially, K.

## Conclusion

Results of the present study indicated that the yearly application of compost-like output to soil during 3 and 5 successive periods improved its fertility due to the reason that composts contains a lot of nutrient that were released to the soil during its decomposition. The best treatment to provide requirement of wheat to macro-nutrient through CLO is the application of 40 t/ha CLO with half of the fertilizer that could produce maximum yield and yield components. This treatment did not show significant difference with the application of 20 t/ha CLO + 1/2 fertilizer on the subject of concentration of N, P and K in grain. In general, to attain the purpose of this study, application of 40 t/ha CLO with half fertilizer for 3 continuous periods even though 2 periods have passed since the last fertilization and or application of 20 ton/ha CLO with half fertilizer for 5 continuous periods is recommended.

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