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Effects of compost interactions on the alterations in mineral biochemistry, growth, tuber quality and production of *Solanum tuberosum*

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Abstract Incorporation of compost in soil will not only protect the environment, but also take advantage of the nutrients and organic matter contained in the compost to enhance soil fertility and crop production. Field experiments were carried out during the 2006/2007 and 2007/2008 growing seasons at the College of Food and Agriculture Farm, United Arab Emirates University. The experiments were established in randomized complete block design (RCBD) with four replications. The plot dimension was 3.2 m × 2.8 m, with four rows per plot. The treatments were designed to study the effect of compost rates on the potato production and soil fertility properties. Five rates of compost were investigated (control, 40, 80, 120 ton compost per hectare; and inorganic fertilizers (250 kg N · ha⁻¹, 250 kg P₂O₅ · ha⁻¹ and 300 kg K₂O · ha⁻¹)). Results of the first growing season 2006/2007 showed that marketable tuber yield, plant height and specific gravity were greater in compost amended soil than in non-amended soil even if inorganic fertilizers were added. Application of 120 ton compost per hectare gave the highest total tubers number, marketable tuber yield, height and specific gravity.

Keywords compost, soil fertility, tuber quality, minerals, crop production, *Solanum tuberosum*

1 Introduction

Potato, *Solanum tuberosum* L., is the most important agronomic root and tuber crop in the world. Today, potato

is grown in more than 130 countries and over a billion people worldwide eat it, making it the third most important food crop in the world after rice and wheat. It is a major source of inexpensive energy. Potato produces more food per unit of water than any other major crops. Potato is also an excellent source of complex carbohydrates. No other crop can match the crop in its production of food energy and food value per unit area (Nevain et al., 2007). It contains significant amounts of vitamins B and C and other minerals. Moreover, potato is used in many industries, such as French fries, chips, starch and alcohol production (Mehdi et al., 2009). Potato indeed could become an important food crop, as it can be planted in dry areas not suitable for rice, and it is a potential crop for the United Arab Emirates. It is mainly produced on sandy soil under irrigation. This type of soil is characterized by low organic matter and fertility. Under these conditions, compost may be a key factor for improving the soil fertility and increasing potato production.

The recycling and further use of organic residues in soils represents an attempt to alleviate the serious environmental problems caused by residue accumulations (Sonia et al., 2008). Moldes et al. (2007) claimed that the application of mature compost at reasonable rates improved plant growth and soil physical properties, and increased the available soil nutrient levels. The use of compost in agriculture in most countries of the world is gradually increasing as a result of the promising results achieved through their experiences with its management. Compost application to the soil has several beneficial effects on crop yield and soil fertility by improving and increasing soil organic matter, water holding capacity, nutrient contents, soil aggregation, and microbial activity (Griffin and Porter, 2004; Elisabetta and Nicola, 2009). Also, compost application has positive effects on the crop yield, root system and stimulation of plant-growth due to hormones (García-gil et al., 2000). Moreover, use of compost as a fertilizer in agriculture is a convenient method of disposal. A field study was

Received September 14, 2009; accepted October 19, 2009

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conducted by Bresson et al. (2001) to assess the impact of composts from four sources and ammonium nitrate (AN) applied at different rates in the spring on soil moisture and inorganic N in spring wheat production (*Triticum aestivum* L. 'Messier'). They indicated that large amounts of compost raised soil moisture content of the sandy loam by 3%–5%, particularly under dry climatic conditions. Similar results were obtained by Hopkins and Stark (2003) who found that soil water content was increased by compost compared to the control treatment.

Another study conducted by Kleinhenz and Cardina (2003) showed that compost application increased the yield of potato tubers by 13%–14%. Moreover, weed densities and biomass were very low in two seasons. Also, Henderson (2000) indicated that compost addition increased potato tuber yield above the maximum yield obtained with nitrogen application. Moreover, compost application in an intensive 3-year potato rotation provided benefits for potato productivity and both soil physical and biological properties. A recent three-year study was done by Hopkins and Stark (2003) at the University of Idaho in which they evaluated the effect of three rates of phosphorus (0, 60, or 120 lbs $P_2O_5 \cdot ha^{-1}$) applied in the mark-out band with and without humic acid (which is a compost product) at a 10:1 v/v ratio. They found that petiole phosphorus (P) concentrations during tuber bulking increased by an average of 0.03% with the addition of humic acid. In addition, humic acid application increased total yield and gross return. The aim of our present research was to evaluate the effect of different rates of compost on the potato production and soil fertility properties.

2 Materials and methods

Two field trials were conducted during the 2006/2007 and 2007/2008 growing seasons at the experimental farm of the College of Food and Agriculture, United Arab Emirates University, Al-Ain. The experiments were established in randomized complete block design (RCBD) with four replications. Plot dimension was 3.2 m × 2.8 m, with four rows per plot. The treatments were designed to study the effect of compost rate on the potato production and soil fertility properties. Five rates of compost used: zero compost application (control); 40 ton compost per hectare; 80 ton compost per hectare; 120 ton compost per hectare; and inorganic fertilizers (250 kg $N \cdot ha^{-1}$, 250 kg $P_2O_5 \cdot ha^{-1}$ and 300 kg $K_2O \cdot ha^{-1}$). The potato cultivar (Jelly-medium maturity) was used in the experiment. The compost was applied to all plots and incorporated uniformly into soil prior to sowing. Representative compost and soil samples were then taken for chemical analysis (Table 1).

During the growing season, plant height, leaf area and chlorophyll content were determined. At harvesting, potato tubers were graded visually into marketable (> 3.5 cm in diameter) and cull (< 3.5 cm, bruised, green or sprouted

Table 1 Preliminary analysis of the compost

parameter	compost
O.M/%	50–60
moisture/%	25
pH	6.5–7.5
N/%	2.3
P/%	1.65
K/%	1.76

tubers). Marketable and total tuber yield were determined by weight. Potato tuber samples were collected from all treatments to determine the dry matter and specific gravity. Plant samples from each plot were taken at maturity stage for chemical analysis. Plant samples were analyzed for the following constituents: total nitrogen; total phosphorus; potassium; micronutrients and heavy metals.

As for the statistical analysis in our study, MSTATC PROGRAM (Michigan State University, USA) was used. Data for each trait were analyzed for a randomized complete block design (RCBD). Analysis of variance was used to determine the main effect of compost rate. Comparisons between means were made using Least Significant Differences (LSD) at 0.05 probability level.

3 Results and discussion

3.1 Effect of compost application on growth parameters

The first growing season 2006/2007 results showed that marketable tuber yield increased significantly ($P < 0.05$) with increasing compost rate (Fig. 1). The addition of 120 ton compost per hectare gave the highest marketable tuber yield ($14.21 t \cdot ha^{-1}$). Also, application of 40 and 80 ton compost per hectare increased the marketable tuber yield to 10.41 and $11.26 t \cdot ha^{-1}$, respectively. Marketable tuber yield was greater in compost amended soil than in non-amended soil even if inorganic fertilizers were added.

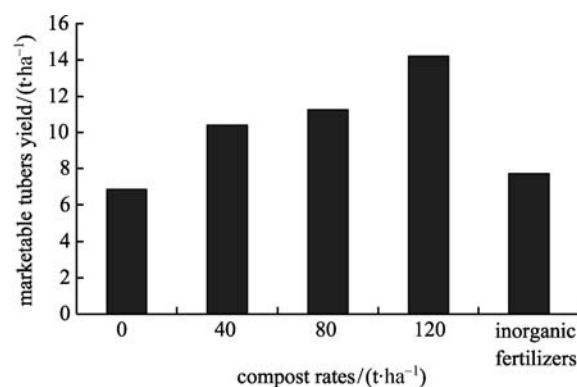


Fig. 1 Effect of different rates of compost on marketable tubers yield in the first growing season 2006/2007

Number of marketable tuber in the first growing season 2006/2007 increased with the increasing of compost rate. The marketable tuber number increased from 90030 tuber per hectare when 120 ton compost per hectare was applied (Fig. 2, Plate 1).

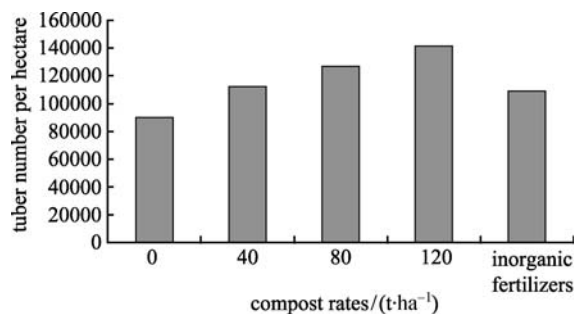


Fig. 2 Effect of different rates of compost on the number of marketable tubers in the first growing season 2006/2007



Plate 1 Effect of different rates of compost on the marketable tubers

Specific gravity is an important quality parameter associated with processing of tubers. The higher the specific gravity, the higher the recovery rate and the better the quality of the processed product. There is a very high correlation between the specific gravity of the tuber and starch content and also the percentage of dry matter or total solid (Henderson, 2000). The specific gravity in the first growing season 2006/2007 was clearly affected by the compost applications (Fig. 3). The treatments (control, 40 ton compost per hectare and inorganic fertilizers) had the lowest specific gravity, whereas, the addition of 80 ton compost per hectare increased the specific gravity but was less than the addition of 120 ton compost per hectare, which gave the highest specific gravity.

Plant height in the first growing season 2006/2007 was significantly affected by the compost application (Fig. 4). The highest plant was reached when 120 ton compost per hectare was applied. Whereas, the lowest plant height was found when no compost or fertilizers were applied.

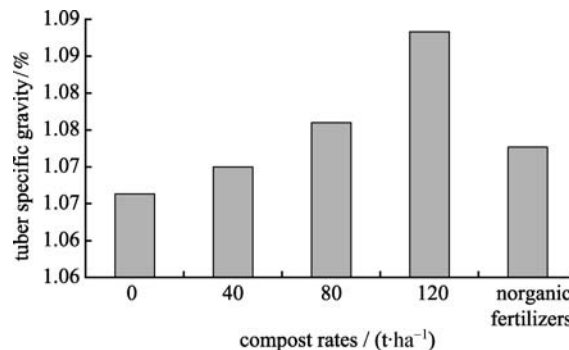


Fig. 3 Effect of different rates of compost on tuber specific gravity in the first growing season 2006/2007

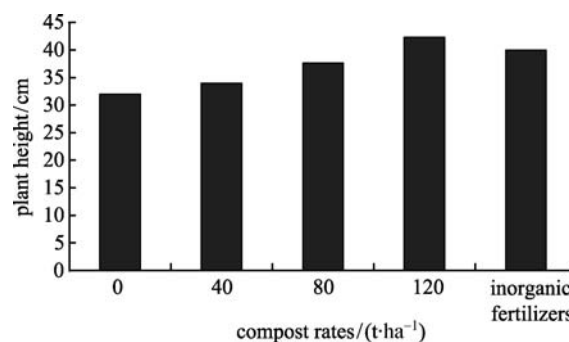


Fig. 4 Effect of different rates of compost on plant height in the first growing season 2006/2007

3.2 The effect of compost on the tubers nutrient concentration

Table 2 and Table 3 show the results of macro- and micro-nutrients contents in tuber tissues. No significant differences were found in tuber analysis regarding N, P, K in the first growing season and compost rates. Whereas, there were significant differences between treatments in the second growing season in terms of phosphorus and potassium. Micronutrients significantly increased with compost application in both growing seasons. Furthermore, no accumulation of heavy metals was absorbed in tuber tissues.

3.3 Effect of compost on soil properties

The nutrient content of the soil was significantly increased with increasing compost rates (Table 4 and Table 5). N, P, K, Cu, Fe, Mn and Zn also increased with increasing compost rates. Also, organic matters were strongly affected by the compost application, just because organic matter was an important factor for improving soil and plant growth. On the other hand, compost application did not affect the soil pH and soil salinity. In addition to that the heavy metals levels in the organically amended soil were within the normal range for agricultural soils (Mkhabela and Warman, 2005).

Table 2 Effect of different compost rate on the macronutrients concentrations in tissue tissues

compost rates/(t·ha ⁻¹)	N/%		P/%		K/%	
	2006/2007	2007/2008	2006/2007	2007/2008	2006/2007	2007/2008
0	1.25	1.33	0.30	0.32b	2.57	2.07a
40	1.30	1.26	0.31	0.29d	2.47	1.98c
80	1.34	1.26	0.33	0.32a	2.37	2.04ab
120	1.37	1.30	0.25	0.30c	2.39	1.99bc
inorganic fertilizer	1.35	1.29	0.26	0.28e	2.21	1.99bc
<i>P</i> _{0.05}	NS	NS	NS	*	NS	*

Note: Values followed by different small letters represent significance at 0.05 probability levels according to LSD test (the same as below)

Table 3 Effect of different compost rate on the micronutrient and heavy metals concentrations in tissues

item		0 t·ha ⁻¹	40 t·ha ⁻¹	80 t·ha ⁻¹	120 t·ha ⁻¹	inorganic fertilizer	<i>P</i> _{0.05}
Cu/(mg·L ⁻¹)	2006/2007	7.4b	10.6a	9.8ab	11.1a	7.4b	*
	2007/2008	0.26c	0.61b	0.80a	0.81a	0.13d	NS
Fe/(mg·L ⁻¹)	2006/2007	86	242	96	76	109	NS
	2007/2008	213ab	258a	212ab	186b	230ab	*
Mn/(mg·L ⁻¹)	2006/2007	6.41	6.68	5.2	4.86	5.72	NS
	2007/2008	11.15ab	6.75bc	8.10bc	5.75c	12.65a	NS
Zn/(mg·L ⁻¹)	2006/2007	20.00c	28.60b	28.87b	34.57a	20.07c	**
	2007/2008	16.35c	21.90b	28.85a	28.80a	15.85c	**
Cd/(mg·L ⁻¹)	2006/2007	0	0	0	0	0	NS
	2007/2008	9.1	9.6	8.7	9.1	8.85	NS

Table 4 Effect of different compost rate on the macronutrients concentrations, soil pH, electrical conductivity and organic matter in the soil

compost rates/(t·ha ⁻¹)	N/%	P/(mg·L ⁻¹)	K/(mg·L ⁻¹)	pH	EC/(ms·m ⁻¹)	OM/%
0	0.04c	67.2	85.4c	8.3c	0.24b	0.69d
40	0.14b	54.8	162.6bc	8.4bc	0.56b	1.53c
80	0.15b	25.4	175.1b	8.4ab	0.51b	2.31b
120	0.37a	63.9	322.4a	8.5a	1.44a	4.04a
inorganic fertilizer	0.05c	54.8	124.0bc	8.3c	0.31b	0.86d

Note: EC stands for Electrical conductivity.

Table 5 Effect of different compost rate on the micronutrient and heavy metals concentrations in the soil

compost rates/(t·ha ⁻¹)	Cu/(mg·L ⁻¹)	Fe/(mg·L ⁻¹)	Mn/(mg·L ⁻¹)	Zn/(mg·L ⁻¹)	Cd/(mg·L ⁻¹)
0	0.91c	7.80c	4.21c	2.97c	0.05c
40	2.97b	42.70bc	6.29b	8.88b	0.21b
80	3.95b	64.74b	7.24b	9.82b	0.24b
120	8.24a	210.86a	11.17a	11.36a	0.55a
inorganic fertilizer	1.26c	10.70c	4.36c	4.25c	0.06c

The high economic value of potato has become a reality throughout different parts of the globe. However, the yield loss due to diseases, improper plant protection measures, abiotic constraints and overall side-effects from modern organic and synthetic fertilizers are the main hindrances to the economic production of this crop. Therefore, in order to overcome these problems, at least better plant protection strategies should be applied. In this context, application of

compost from municipal garbage can be an alternative for organic fertilizers. Research has shown that a number of factors contribute to increased biomass production, namely greater photosynthesis, higher water use efficiency, depression of respiration and delayed leaf senescence due to various plant hormone and growth regulator treatments. Comparatively few studies have investigated the effect of compost prepared from municipal garbage on

potato. It has been demonstrated that tuber hierarchy can alter in response to environmental changes (Heidmann et al., 2008). The potato plant, however, may also be affected by low irradiance and other common abiotic factors (Oumèma et al., 2006). Intercropping conditions may additionally affect temperature within the canopy and induce a beneficial microclimate for potato growth (Gustave et al., 2008). Potato may produce 90% of its nodal roots by the fourth leaf stage thanks to the abundant carbon resources in the planted tuber while the emergence of nodal roots in maize is progressive and usually synchronous with that of leaves.

In our studies, the results of the first growing season 2006/2007 showed that marketable tuber yield, plant height and specific gravity were greater in compost amended soil than in non-amended soil even if inorganic fertilizers were added. This was possibly due to the fact that compost increased soil organic matter, water holding capacity, nutrient contents, soil aggregation, root system and microbial activity (Mamo et al., 2000; Carter et al., 2001; John et al., 2002). Similar results were obtained by Kleinhenz and Cardina (2003) who showed that compost application increased the yield of potato tubers by 13%–14%. Also, Mamo et al. (2000) indicated that compost addition increased potato tuber yield above the maximum yield obtained with nitrogen application. Moreover, compost application in an intensive 3-year potato rotation provided benefits for potato productivity and both soil physical and biological properties.

Our present study has shown very clearly that substantial stimulation of potato tuber yield and quality of tubers can be expected to result from compost applications. Consequently, these encouraging results demonstrate that application of compost can be considered as an alternative and effective means of fertilization in cultivated potato. It can be used to complement and supplement conventional fertilization methods for crop improvement.

Acknowledgements This work was financially supported by the Research Affairs at the UAE University (contract No. 1-1-6-11/07). We thank Mr. Raseed Abdelftah for his indispensable technical support. Also we thank Al Ain compost plant for their assistance in providing us with the compost.

References

- Bresson L M, Koch C, Le Bissonnais Y, Barriuso E, Lecomte V (2001). Soil surface structure stabilization by municipal waste compost application. *Soil Science Society of America Journal*, 65: 1804–1811
- Carter M R, Sanderson J B, Macleod J A (2001). Influence of compost on the physical properties and organic matter fractions of a fine sandy loam throughout the cycle of a potato rotation. *Canadian Journal of Soil Science*, 84: 211–218
- Elisabetta L, Nicola S (2009). In vitro and in vivo assessment of the potential of compost and its humic acid fraction to protect ornamental plants from soil-borne pathogenic fungi. *Scientia Horticulturae*, 122: 432–439
- García-gil J C, Plaza C, Soler-rovira P, Polo A (2000). Long-term effects of municipal solid waste compost application on soil enzyme activities and microbial biomass. *Soil Biology & Biochemistry*, 11: 1907–1913
- Griffin T S, Porter G A (2004). Altering soil carbon and nitrogen stocks in intensively tilled two-year rotations. *Biology and Fertility of Soils*, 39: 366–374
- Gustave N M, Jean F L, Xavier D (2008). Shoot and root competition in potato/maize intercropping: Effects on growth and yield. *Environmental and Experimental Botany*, 64: 180–188
- Heidmann T, Tofteng C, Abrahamsen P, Plauborg F, Hansen S, Battilani A, Coutinho J, Doležal F, Mazurczyk W, Ruiz J D R, Takáč J, Vacek J (2008). Calibration procedure for a potato crop growth model using information from across Europe. *Ecological Modelling*, 211: 209–223
- Henderson A (2000). Potatoes: measurement of specific gravity. *Agriculture Notes*, Knoxville
- Hopkins B, Stark J (2003). The Idaho potato conference, Idaho, USA, January, 22–23
- John M F, Alison D, James I B, Michael B J (2002). The effects of elevated concentrations of carbon dioxide and ozone on potato (*Solanum tuberosum* L.) yield. *Agriculture, Ecosystems and Environment*, 88: 11–22
- Kleinhenz M D, Cardina J (2003). XXVI International Horticultural Congress: Potatoes, Healthy Food for Humanity: International Developments in Breeding, Production, Protection and Utilization. Mais, France. *ISHS Acta Horticulturae*, 619
- Mehdi S, Derek H L, Bernie J Z, Zhiming Z, Ralph C M (2009). Evaluation of nitrogen supply rate Measured by in situ placement of plant root simulatorTM probes as a predictor of nitrogen supply from soil and organic amendments in potato crop. *American Journal of Potato Research*, 86: 356–366
- Mkhabela M S, Warman P R (2005). The influence of municipal solid waste compost on yield, soil phosphorus availability and uptake by two vegetable crops grown in a Pugwash sandy loam soil in Nova Scotia. *Agriculture Ecosystem and Environment*, 106: 57–67
- Moldes A, Cendon Y, Barral, M T (2007). Evaluation of municipal solid waste compost as a plant growing media component, by applying mixture design. *Bioresource Technol*, 98: 3069–3075
- Nevain A S M, Ariena H C B, Anne D D, Oscar J V, Aad J T, Tjou-Tam N N, Sin A, Janse J D (2007). Potato brown rot incidence and severity under different management and amendment regimes in different soil types. *European Journal of Plant Pathology*, 119: 367–381
- Oumèma N E, Radhia G, Darasinh S, Mohamed A T, Georges D, Noureddine D, Lilia L (2006). Production of potato intraspecific somatic hybrids with improved tolerance to PVY and *Pythium aphanidermatum*. *Journal of Plant Physiology*, 163: 1321–1332
- Sonia M, Nehla L, Henda M, Naceur J, Chedly A (2008). Contrasting effects of municipal compost on alfalfa growth in clay and in sandy soils: N, P, K, content and heavy metal toxicity. *Bioresource Technology*, 99: 6745–6750