Iraqi J. Agric. Res. Vol.17 No.1 pp.246-254 Dec./2012

SHORT -TERM COMPOST EFFECT ON SOIL PHYSICAL PROPERTIES AND PLANT GROWTH OF TOMATO IN A SALINE SOIL

N. A. Abbas* J. Kelly**
R. Murray C. Grant****

ABSTRACT

Using recycled water over 32 years in the Northern Adelaide Plains (NAP) has made its clay soil saline, sodic and lacking in organic matter. This study was conducted to examine the effects of compost on improving soil physical properties and plant growth characteristics of tomatoes grown on typical NAP soils. Compost was added to the NAP soil irrigated with two water irrigation qualities (recycled water (EC 1.5 dS/m), mains water (EC 0.62 dS/m). An experiment was laid out as a factorial randomized complete block design, lasted three months. It appeared that compost had a slight positive impact on soil physical properties, this might be due to the short term action of compost application. In relation to plant growth, adding compost resulted in a significant improvement in plant productivity. However, this improvement decreased with increasing salinity, Irrigated tomato yield with mains water increased by 38%, while irrigated tomato yield with recycled water increased by 24%. These findings suggest that compost could reduce the adverse effects of salinity on soil physical properties and plant growth of tomato. Further studies are required to examine the long term action of compost.

Keywords: Saline soil, Recycled water, Compost, Soil physics, Plant growth, Plant productivity.

INTRODUCTION

Due to the rapid increase in human population worldwide, water is becoming extremely scarce in many parts in the world, in particular in arid and semi-arid areas (4). In response to this scarcity, wastewater reclamation and reuse is becoming an increasingly accepted practice worldwide for agricultural production, the greatest consumer of fresh water the world over (3), so it is a nation that is an excellent candidate for reclaimed water use and thus the conservation of fresh water. Nevertheless, reclaimed water poses several threats to agricultural sustainability over the long term; one of the greatest of these is salinity. Salinity is the major agent in the destruction of soil structure and reduction of agricultural productivity, in particular when elevated sodium is present in the soil (6). The Australian state of South Australia is experimenting with the use of recycled water as part of its Northern Adelaide Plains Water Reclamation Scheme which provides water for irrigation to horticultural producers. Salinity has been recognized as a critical issue inhibiting the development of the Northern Adelaide Plains (NAP) in the long term because its soil has become saline, sodic and lacking in organic matter after using recycled water for more than 32 years (15). Leaching is one way of overcoming the effect of salinity; however, it may be expensive (17) and can have negative effects. In areas that have a shallow water table, for example, such as the NAP (23), leaching may contaminate ground water and cause water-logging. Composts

Part of M. Sc thesis of the first author.

* Ministry of |Water Resources- Baghdad, Iraq.
** Adelaide Univ. – Australia.

Received : Joule/2012
Accepted : Oct../2012

have shown to improve plant productivity via improvement of soil physical properties and nutrient availability for plant growth (13, 12, 2). This study was to determine the effectiveness of compost adding to the NAP saline soil ($Ec_{1:5}$ 3.9 dS/m) on improving the soil physical properties and plant productivity, using two water qualities (mains water, Ec 0.62 dS/m, and recycled water, Ec 1.5 dS/m).

MATERIALS AND METHODS

Location, soil and crop details

A pot experiment was conducted in a glass-house at the Waite Campus of the University of Adelaide, Adelaide, Australia. Seedlings (10 cm high) of the tomato variety (*Lycopersicon esculentum* L.) were planted on 30 September 2011 for compost experiment. A clay soil was collected from the NAP, blended and steam sterilized before use to ensure that it was free of plant pathogens. Twenty white plastic 20 L buckets (inside dimensions: height= 38.5 cm, top diameter= 28.5 cm, bottom diameter= 24.5 cm) were lined at the bottom with 1 kg of stones covered by geo-textile fabric to prevent blockage of drainage holes. Ten of these pots were then filled with 22 kg of the soil and other ten pots were filled with 17 kg of soil. Finally, a mixture of 5 kg of soil was mixed with 200 mL of compost (to simulate a rate of 30 m^3/ha) and added to the top of the soil (figure1).

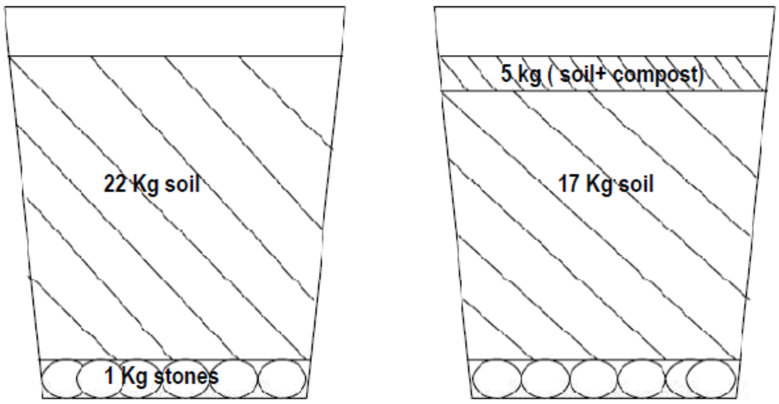

Figure 1: Procedure of filling the pots.

Experimental design and treatments

The experiment was laid out as a factorial randomized complete block design. There were two treatments tested. Irrigation salinity (recycled water (EC 1.5 dS/m), mains water (EC 0.62 dS/m) and compost treatment (30 m^3/ha of compost and control (without compost) (Figure 2).Each treatment was replicated five times.

Replication 1	Replication 2	Replication 3	Replication 4	Replication 5
Control +Recycled	Compost+Recycled	Compost +Mains	Control+ Mains	Control +Recycled
Compost+Recycled	Control+ Mains	Control +Recycled	Compost +Mains	Compost+Recycled
Control+ Mains	Compost +Mains	Compost+Recycled	Control +Recycled	Compost +Mains
Compost +Mains	Control +Recycled	Control+ Mains	Compost+Recycled	Control+ Mains

Figure2: A sketch of experimental design, control, without compost.

Soil samples and analysis

Soil pH was 8.23 and electrical conductivity of soil: water extract at a ratio of 1:5 ($Ec_{1:5}$) was 3.9 dS/m before the experiment commenced. At the end of the experiment $Ec_{1:5}$ of soil irrigated with mains water was 2.1dS/m and $Ec_{1:5}$ of soil irrigated with recycled water was 3.2 dS/m. The texture of soil was 52% clay, 5% sand and 20% silt. Soil physical properties were examined, as described by Brady & Weil (9), after the plants harvested on December 12, 2011 (three months after planting). Bulk density and volumetric water content at field capacity of intact soil cores (3 replications) were measured on pots of soil with or without compost added, and irrigated with mains water or recycled water. Total porosity was calculated from the mean bulk density assuming an average particle density of 2.65 g/cm^3; volumetric air content was calculated by difference between total porosity and volumetric water content. Saturated hydraulic conductivity (K_{sat}) of undisturbed soil (with or without compost applied) in pots at the end of the experiment (110 days) using recycled or mains water (3 replications) was measured.

Properties of the NAP irrigation water

Two types of water were used in the experiment, mains water which its source from Happy Valley Reservoir and artificial recycled water to simulate class A recycled water (CARW) used in the NAP. The source of recycled water in the NAP is from the Bolivar Wastewater Treatment Plant that collects waste water from urban areas and then produces CARW. Water quality properties of mains water and artificial recycled water are shown in Table 1.

Table 1: Mains and artificial recycled water properties

properties	Mains water	Artificial recycled water
pH	7	8
TDS (mg/L)	397	960
EC (dS/m)	0.62	1.5
Sodium (mg/L)	71	230
Calcium (mg/L)	30	43
Magnesium (mg/L)	19	33

Fertilization requirements

The fertilizer requirement of the crop was supplied using 15 gm of "Hortico All Purpose Compound Fertilizer" (N: 12.2%; P: 5.1%; K: 13.7%; Ca: 4.5%; Mn: 1.1%; B: 0.02%; Zn: 0.01%) to each pot before the first irrigation event. The fertilizer was buried in three different places in each pot 5 cm below the soil surface around the edge of the pot to provide nutrients. At week 12, soluble calcium was sprayed directly on tomato leaf tissues as Blossom End Rot (BER) incidence appeared on the fruits due to calcium deficiency. Insect control, "Chemspray Garden Insect Spray" was applied at 5 mL/L of water as soon as the first sign of pest infestation appeared and then (two-three) sprays a week with (Mavrik) 10 mL/L of water as the plants were affected by thrips and white fly.

Compost analysis

Stable compost was provided by Gro Company, derived from various cellulose materials, manures, seagrass, vegetable matter and whey. Compost contains an average of (N: 1.12%, P: 0.67%, K: 0.9%, OM: 35%), compost pH was 6.5 and Ec was 0.83 dS/m.

Collecting data

Growth and development parameters such as plant height, number of leaves and dry biomass (70 C, 48 h) of above-ground growth were recorded. Water Use Efficiency (WUE) for biomass production was measured by the weight of above-ground dry biomass per plant divided by the total amount of water applied during the experiment. Reproductive parameters such as number and weight per fruit from each plant were recorded from fruits harvested over different dates as they ripened on the plants.

Data analysis

The data collected was subjected to an analysis of variance using two way ANOVA model procedure for a factorial randomized complete block design, employing Gens tat version 5.

RESULTS AND DISCUSSION

Soil physical properties

Soil physical properties (as measured by bulk density, total porosity, and volumetric water (and air) contents at field capacity) are summarized in Table 2, which show that soil treated with mains water had slightly greater bulk density (thus lower total porosity) than soil treated with recycled water; these differences, however, were not statistically significant at P=0.05. Compost tended to improve soil physical properties. Although statistically not significant, bulk density was smaller and volumetric water content was slightly lower, consequently total soil porosity and volumetric air content were higher with compost (Table 2). K_{sat} with compost was slightly greater compared to its control (Figure 3). Lakhdar et al. (17), report that soil organic matter binds fine soil particles together, this results in a decrease in bulk density and an increase in soil porosity thus K_{sat}. Significant decreases in bulk density and increases in soil porosity and K_{sat} following long term compost application have intensively reported by many authors (7, 10,11,16,19,22). In current study, a significant improvement in soil physical properties following compost application was not expected in such a short time (approximately 3 months duration of experiment) as this improvement is usually associated with improved soil aggregation. So the findings of this study suggest that if the rate of compost is great enough, such improvements can be achieved more quickly.

Table2: Mean Bulk density, Volumetric water content at field capacity, Total porosity and volumetric air content as affected by Salinity x Compost interactions

Factor	Irrigated with Mains water*				Irrigated with Recycled water*			
	Bulk density (g/cm^3)	Volumetric water content (cm^3/cm^3)	Total porosity (cm^3/cm^3)	Volumetric air content (cm^3/cm^3)	Bulk density (g/cm^3)	Volumetric water content (cm^3/cm^3)	Total porosity (cm^3/cm^3)	Volumetric air content (cm^3/cm^3)
Compost	1.09	0.32	0.56	0.24	1.06	0.27	0.57	0.30
No compost	1.12	0.35	0.55	0.20	1.10	0.32	0.57	0.25
LSD (5%)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

* $EC_{1:5}$ for soil irrigated with Mains water = 2.1 dS/m; irrigated with Recycled water = 3.2 dS/m at the end of the experiment. LSD, least significant differences, n.s, no significant.

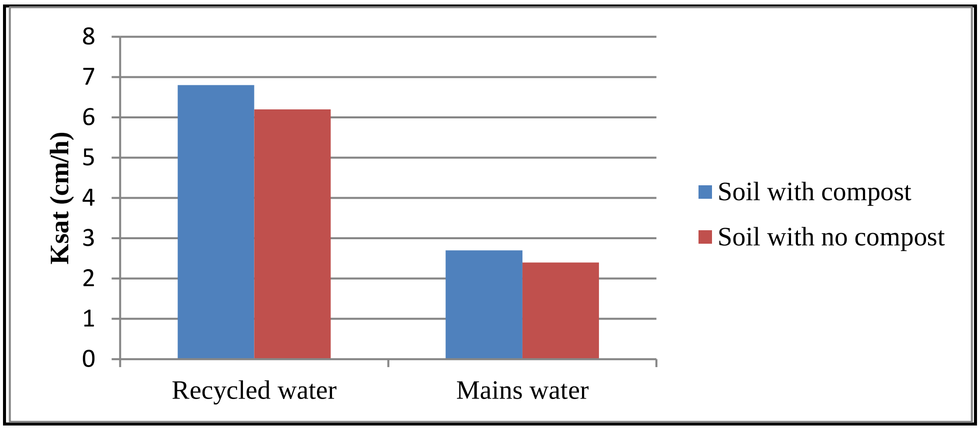

Figure 3: Mean saturated hydraulic conductivity as affected by salinity X compost interactions, the coefficient of variation (cv) ≈ 0.27.

Plant growth

A significant effect of compost was observed on both vegetative and reproductive growth parameters regardless of irrigation water quality (salinity). From a vegetative growth perspective, plant height, number of leaves per plant, and above-ground dry biomass were all significantly greater in soils treated with compost (at P=0.05) compared to those with no compost for both sources of irrigation water. Furthermore, the benefits of compost were reduced in the pots irrigated with recycled water (Table 3), which means there was a significant interaction between the effects of water quality and compost. All reproductive growth parameters: fruit number, weight per fruit, and total weight of fruits per plant were significantly increased when compost was added to the soil regardless of water quality (Table 4). The incidence of blossom end rot (BER), due to Ca deficiency, was significantly lower for compost plant. As for the vegetative growth the effects of compost were somewhat moderated when recycled water was used for irrigating, which implies a strong interaction between the effects of water quality and compost. The positive impacts of compost on plant growth of tomato have been reported by other authors. Atiyeh et al. (5), Abbasi et al. (1) and Özenç (18), who reported that addition of organic matter offers great tomato growth and yield enhancement.

Table 3: Mean Vegetative growth characteristics for tomato as affected by Salinity x Compost interactions.

Factor	Mains water*			Recycled water*		
	Height (cm)	No. leaves /plant	Dry bio-mass (g)	Height (cm)	No. leaves /plant	Dry bio-mass (g)
Compost	197.6	17.9	67	174.2	15.1	55.1
Control	167.5	13.0	58	140.6	12.9	50.4
LSD (5%)	12	1.4	4.5	12	1.4	5

* $EC_{1:5}$ for soil irrigated with Mains water = 2.1 dS/m; irrigated with Recycled water = 3.2 dS/m at the end of the experiment. LSD, least significant differences.

Table 4: Mean Reproductive growth characteristics for tomato as affected by Salinity x Compost interactions

Factor	Mains water*				Recycled water*			
	No. fruits / plant	Weight / fruit (g)	Total weight (kg)	No. Fruit with BER*	No. fruits / plant	Weight / fruit (g)	Total weight (kg)	No. Fruit with BER*
Compost	32	95	3	0.75	27	79	2.1	1.5
Control	29	72	2.2	1.12	25	66	1.7	2.3
LSD (5%)	1.4	9	0.3	0.63	1.4	9	0.3	0.63

* $EC_{1:5}$ for soil irrigated with Mains water = 2.1 dS/m; irrigated with Recycled water = 3.2 dS/m at the end of the experiment. BER*, Blossom end rot. LSD, least significant differences

Greater WUE for above ground biomass with compost application was observed for both mains water plants and recycled water plants (Table 5). For nutrients accumulation in tomato leaves, compost was found to decreased Na concentration and increased other nutrients such as Mg, K and P (Table 5). Na tomato leaf tissues concentrations reduced due to compost treatment for both water sources, however, the effect of compost on Na concentrations was not statistically significant with increasing salinity (recycled water). Higher Mg and P leaf tissue concentrations were evident when compost added regardless of water quality. K concentration in the leaf tissues was higher in soil treated with compost and mains water; however, it was not affected by compost in soil irrigated with recycled water. The accumulation of Ca in the leaf tissues was not affected by both compost and water quality treatment. Possible explanation is that the foliar application of a foliar liquid fertilizer containing Ca was applied due to BER incidence. This might make the effect of compost and water quality treatment on the concentration of Ca unnoticeable. In this experiment, we observed that the root systems with compost had greater length, thicker diameter and higher root hair density than those in no compost treatment (Figure 4). Such improvements may have resulted in improved permeability of the root membrane. This may, in turn, increase water and nutrient uptake for plant and reduce sodium ingress into the plant due to enhanced salt exclusion. Roots act as highly effective filters excluding as much as 95% of salt (8). Additionally, more nutrients accumulation in leaf tissues might be because compost improves cation exchange capacity of the soil (CEC), hence its ability to store nutrients, this increases nutrient availability in the root zone. As for vegetative and reproductive growth the effects of compost were reduced in the pots irrigated with recycled water.

Table 5: WUE for biomass production and salt accumulation in tomato leaves, according to Wheal et al. (24), as affected by water quality and compost treatment

Factor	Mains water*						Recycled water*					
	WUE (g.biomass/L)	Na (g/kg)	Ca (g/kg)	Mg (g/kg)	K (g/kg)	P (g/kg)	WUE (g.biomass/L)	Na (g/kg)	Ca (g/kg)	Mg (g/kg)	K (g/kg)	P (g/kg)
Compost	1.38	9.0	27.7	8.75	25.2	2.73	1.14	13.4	28.0	8.40	23.0	2.55
Control	1.19	13.2	28.0	8.10	23.0	2.55	1.04	13.7	28.5	8.15	23.7	2.40
LSD (5%)	0.09	0.75	n.s	0.2	0.8	0.12	0.09	n.s	n.s	0.20	n.s	0.12

* $EC_{1:5}$ for soil irrigated with Mains water = 2.1 dS/m; irrigated with Recycled water = 3.2 dS/m at the end of the experiment. n.s, no significant

Figure 4: The effect of compost on root growth, (*Left*) root grown with compost, (*Right*) root growth with no compost.

The benefits of compost were observed to decrease with increasing salinity (Table 3, 4). For vegetative growth, dry biomass per plant treated with recycled water was 55.1g versus to 67 g dry biomass per plant irrigated with mains water when compost added. Regarding reproductive growth, in soil irrigated with recycled water the number of fruits per plant was 27 and weight per fruit was 79 g while with mains water the number of fruits was 32 and weight per fruit was 95 g. This may be because of that increasing salinity causes a reduction in the rate of soil organic matter decomposition and in the mineralization of C and N (21, 20, 14). This, in turn, reduces nutrients releasing from compost and hence nutrient availability to the plants. Table (5) shows that more nutrients accumulated in the leaf tissues of plants irrigated with mains water compared with those treated with recycled water when compost added.

CONCLUSION

Adding compost to the NAP silane soil favoured soil physical properties and plant growth. Organic matter stimulated soil physical properties. However, the short term action of compost was not enough to show a significant improvement in soil physical properties. The plants responded considerably to compost treatment. Furthermore, this positive response decreased with increasing salinity. Irrigated tomato yield with mains water increased by 38%, while irrigated tomato yield with recycled water increased by 24%. Further studies are required to determine long term action of compost on soil physical properties and plant productivity.

REFERENCES

1- Abbasi, P. A.; J. Al-Dahmani; F. Sahin; H. A. J. Hoitink and S. A. Miller (2002).Effect of Compost Amendments on Disease Severity and Yield of Tomato in Conventional and Organic Production Systems, Plant Disease, 86 (2):156-161.

2- Abdurrahman H.; F. Buyuksonmez; F. M. Kiziloglu and M. Y. Canbolat (2004). Reclamation of Saline-Sodic Soils with Gypsum and MSW Compost, Compost Science & Utilization, 12(2):175.

3- Asano, T. and W. W. Eckenfelder (1998). Waste water reclamation and reuse. Technomic Pub, Co, Lancaster, Pa, pp. 300-424.
4- Asano, T. (2002).Water from (waste) water- the dependable water resource", Water Science and Tech., 45, pp. 24.
5- Atiyeh, R. M.; N. Arancon; C. A. Edwards and J. D. Metzger (2000).Influence of earthworm-processed pig manure on the growth and yield of greenhouse tomatoes, Bioresource Technology,75(3):175-180.
6- Ayers, R. S. and D. W. Westcot (1976). Water quality for agriculture, FAO, Rome.
7- Benbi, D.K.; C. R. Biswas; S. S. Bawa and K. Kumar (1998).Influence of farmyard manure, inorganic fertilizers and weed control practices on some soil physical properties in a long-term experiment", Soil Use and Management, 14(1):pp. 52-54.
8- Bhattarai, S. P. (2005). The physiology of water use efficiency of crops subjected to subsurface drip irrigation, oxygation and salinity in a heavy clay soil", ph.D thesis, Central Queensland University.
9- Brady, N.C. and R. R. Weil (2008).The nature and properties of soils, Pearson Prentice Hall, Upper Saddle River, N. J., pp.246-277.
10- Bronick, C.J. and R. Lal (2005).Soil structure and management: a review, Geoderma,124,
11- Courtney, R.G. and G. J. Mullen (2008). Soil quality and barley growth as influenced by the land application of two compost types, Bioresource Tech., 99(8): 2913-2918.
12- de Brito Alvarez, M.; S. Gagne and H. Antoun (1995). Effect of Compost on Rhizosphere Microflora of the Tomato and on the Incidence of Plant Growth-Promoting Rhizobacteria, Applied and Environmental Microbiology, 61(1):194-199.
13- Debosz, K.; S. O. Petersen; L. K. Kure and P. Ambus (2002). Evaluating effects of sewage sludge and household compost on soil physical, chemical and microbiological properties, Applied Soil Ecology, 19(3):237-248.
14- Gómez, I. (1992). The Influence of Saline Irrigation and Organic Waste Fertilization on the Mineral Content (N, P, K, Na, Ca and Mg) of Tomatoes, J. of the Sci. of Food and Agric., 59(4):483.
15- Keremane, G. B. and J. McKay (2007). Successful wastewater reuse scheme and sustainable development: a case study in Adelaide,Water and Environment, 21:83-91.
16- Khaleel, R.; K. R. Reddy and M. R. Overcash (1981).Changes in Soil Physical Properties Due to Organic Waste Applications: A Review1, J. of Environment Quality, 10(2):133,1:3-22.
17- Lakhdar, A.; M. Rabhi; T. Ghnaya; F. Montemurro; N. Jedidi and C. Abdelly (2009).Effectiveness of compost use in salt-affected soil", J. of hazardous materials, 171,no. 1-3:29-37.
18- Özenç, D. B. (2006). Effects of Composted Hazelnut Husk On Growth of Tomato Plants, Compost Science & Utilization, 14(4): 271.
19- Qadir, M.; A. Ghafoor and G. Murtaza (2001).Use of saline–sodic waters through phytoremediation of calcareous saline–sodic soils, Agric. Water Management, 50(3):197-210.
20- Rietz, D.N. and R. J. Haynes (2003).Effects of irrigation-induced salinity and sodicity on soil microbial activity, Soil Biology and Biochemistry, 35(6): 845-854.

21- Saison, C.; V. Degrange; R. Oliver; P. Millard; C. Commeaux; D. Montange and X. Le Roux (2006). Alteration and resilience of the soil microbial community following compost amendment: effects of compost level and compost-borne microbial community, Environmental microbiology, 8(2):247-257.

22- Shepherd, M. A.; R. Harrison and J. Webb (2002). Managing soil organic matter – implications for soil structure on organic farms, Soil Use and Management, 18:284-292.

23- Stevens, D. P.; M. J. McLaughlin and M. K. Smart (2003). Effects of long-term irrigation with reclaimed water on soils of the Northern Adelaide Plains South Australia, Soil Res., 41: 933-948.

24- Wheal, Fowles and Plmer (2011). Analytical methods, vol.3, no. 12, pp. 2854-2863.

التأثير القصير الأمد للسماد العضوي على الخواص الفيزيائية ونمو نبات الطماطة في تربة ملحية

نهله عبد عباس* جم كللي**

روبرت مري** كاميرون كرانت**

الملخص

تمت دراسة اثر الاسمدة العضوية النباتية في تقليل التاثيرات السلبية للملوحةعلى التربة وعلى نمونبات الطماطة . اجريت الدراسة في الترب المالحة والتي تم تجهيزها من السهول الشمالية لمدينة اديلايد/استراليا وباستخدام نوعين من مياه الري: المياه المعادة بملوحة 1.5 dS/mم والمياه العذبة 0.62 dS/m.التجربة استغرقت ثلاثة اشهر. لتحديد معنوية النتائج تم استخدام التصميم العشوائي الكامل متعدد العوامل. النتائج أظهرت أن اثر الأسمدة النباتية لم يكن معنوياً على تحسين الخصائص الفيزيائية للتربة.سبب ذلك قد يعزى الى قصر وقت التجربة . ولكن اثر الأسمدة النباتية كان معنوياً في نمو نبات الطماطة وإنتاجها. هذه النتائج تظهر بان الأسمدة النباتية تقلل من تأثير الملوحة في النبات، اذ ان إنتاجية الطماطة كان قد ازداد بمعدل 38% في التربة المروية بالمياه العذبة و24% في التربة المروية بالمياه المالحة نتيجة لإضافة الأسمدة النباتية. وهذا يعني ان إضافة الأسمدة النباتية قد زاد من مقاومة النبات للملوحة. نوصي بإجراء المزيد من الدراسات مطلوبة لدراسة تأثير السماد النباتي العضوي على نمو النبات والخصائص الفيزيائية للتربة على المدى الطويل.

جزء من رسالة ماجستير للباحث الأول.

*وزارة الموارد المائية – بغداد، العراق.

* * جامعة اديلايد – استراليا.