Archives of Agronomy and Soil Science, 2003, Vol. 49, pp. 105–110

CHANGES IN SOIL PROPERTIES FOLLOWING A 40- AND 20-YEARS APPLICATION OF ORGANIC WASTE

VERÄNDERUNGEN DER BODENEIGENSCHAFTEN BEI 40- UND 20-JÄHRIGER ANWENDUNG VON ORGANISCHEN ABFÄLLEN

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(Received 28 September 2002)

Soils of Kuwait contain little plant nutrients and organic matters to support plant growth and development. Soils water holding capacities are very small and need continuous irrigation to maintain water availability. Addition of organic matter in various soils of Kuwait in different time duration were observed and investigated. The effect of organic matter on soil physical and chemical properties were analysed and compared within the soil solution. High variation of macro and micronutrients were distinguished among different soil treatments with organic matter application. Plant nutrients increased in the soil solution with organic matter application enormously. Soil physical properties improved by the decreasing of soils bulk densities and increasing soil water holding capacities. Organic materials are available from many sources in Kuwait, mostly from animal, industrial and municipal waste. These materials can be utilized more efficiently for soil improvement and plants production. Most of organic materials in Kuwait are buried for disposal in limited and very expensive land. Converting organic materials to soils conditioners and fertilizer will improve soil capabilities and save the limited water resources available for irrigation.

Keywords: nutrient; organic; soils; Kuwait; solution; density; irrigation

INTRODUCTION

Soils of Kuwait are mostly sandy with limited organic matter, having very low contents of plant nutrients and high amounts of calcareous materials. The soils water holding capacities are very small, soil water evaporation is very high, particularly in the summer season (3–5 m), and the infiltration rates are very extreme (0.50–1.00 m/hour) (Abdal and Al-Qallaf, 1993). Agricultural production in the arid environment of Kuwait faces many obstacles and problems; due to limitation of water resources and soils low nutrient contents. Farmers mostly grow vegetables and forage crops for local consumption. The yields of most crops are low and the qualities are inferior. High amounts of irrigation water resources are utilized for minimum crop production. Farmers usually apply animal

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ISSN 0365-0340 print © 2003 Taylor & Francis Ltd
DOI: 10.1080/0365034031000079784

manure as organic matters to improve soil productivity. Fertilizer application in Kuwait is practiced without referring to any scientific findings related to soil fertility or crop nutrient requirements. The crops response is minimum because quantities are not scientifically recommended and interference of the high amounts of calcareous materials within the soils profiles. Calcareous soils of Kuwait interact with plant nutrients applied to the soil within soil solutions. Most of the macronutrients and the micronutrients generally fix with calcium cation (Abdel Rahman *et al.*, 1996).

Various organic matter sources are obtainable in Kuwait that can be used to improve soils capabilities. Different agricultural industries, chiefly in dairy, poultry, sheep, and camel husbandry's, produces large amounts of manure that can be utilized as organic matters to improve soil properties (Larney and Janzen 1996). Meanwhile, enormous quantities of municipal wastes are produced within the state that can be converted to beneficial materials for agricultural production. Large amounts of municipal waste are buried in huge limited land sites, that should be utilized as organic matters for crop production and soil improvement. Municipal waste in Kuwait can be converted to good organic matter for soil conditioning and plant growth and development. Tremendous benefits can be achieved by the utilization of municipal organic waste management to improve soil fertility and reduction of land use for burying the waste. The paper discusses the benefits of organic use in various soils to improve soil fertility and soil tilth in various locations in Kuwait.

MATERIAL AND METHODS

Various soil samples were collected from different depths (0–2, 0–5, 5–10, 10–15 cm) from three locations within the Wafra farm area in Kuwait (longitude 46.30–49.00 and latitude 28.30–30.06). The temperature means range between 46.2°C in summer and 6.9°C in winter (Annual Statistics Abstract, 1998). The average rainfall is 115 mm/year and the evaporation averages 14.1 mm/d in summer. The soils were treated by organic waste application (sheep manure) at various time intervals (0, 20, 40 years). Three soils (aridsol) were compared in Kuwait for the effects of organic matter application with duration of time. The duration was from zero timed application, 20 years time application and 40 years time application of organic matter. The organic matter added annually to the topsoil as broadcast at the rate of 2 t/ha. The soil of zero treatment was virgin soil and treated as the control while the other two treatments were cultivated with vegetable crops and forges over the years. The sampling was replicated four times for soil collection and three for soil analysis. The experimental unit size was 20 m^2 with four replication and randomized complete design. The samples were subjected for physical and chemical analysis to compare soils improvements and soils reactions with organic matter application. Samples were examined for soils bulk densities, water retention, water need for irrigation, texture, organic matter contents, macro and micro-element contents according to the monograph of methods of soil analysis by the American Society of Soil Science.

RESULTS

The application of organic matter has significant effect on soils bulk densities, particularly after 40 years application (Table I). The application of organic matter also

improves the soil tilth by decreasing soils bulk densities. Sandy soils usually have high bulk densities, the addition of organic matter increase soil surface area (Kamau *et al.*, 1996). Soils water-holding capacities in both points, field capacities and wilting points, were significantly different among three soils (Table II). At field capacities soils water retention increased more than seven fold at 20 years of organic matter application, at the same time the soil water retention for 40 years of organic matter application increased ten-fold. Improvement of the soils water holding capacities is a very important factor for crop production in an arid environment. Since water is very limited for agricultural production the soils surface areas are very small. The use of organic matter in Kuwait did improve soil water retention significantly (Table II).

TABLE I Chemical characteristics of soil amendments

Element	*Percentage*
Nitrogen	1
Phosphorus	0.09
Potassium	1
Calcium	2
Magnesium	0.03
Sulphur	0.01

TABLE II Effect of organic matter contents on soils physical conditions

Duration (years)	*Bulk density*	*Field capacity (%)*	*Wilting points (%)*	*Texture*	*Carbon (%)*
0	1.70 g/cm^3	1.91	0.55	Sand	1.00
20	1.67 g/cm^3	14.36	2.81	Sand	2.10
40	1.33 g/cm^3	20.96	4.92	Sand	3.08

TABLE III Effect of organic matter application to Kuwait soils total content of micronutrients (mg/kg)

Duration (years)	*Soil depth (cm)*	*Fe*	*Mn*	*Zn*	*B*	*Cu*
0	0–2	2.46a*	0.92a	0.63a	0.20a	0.23a
20	0–2	7.01b	6.79b	3.43b	0.38a	0.52b
40	0–2	42.94c	20.58c	20.52c	7.07b	17.09c
0	0–5	2.73a	0.97a	0.09a	0.03a	0.17a
20	0–5	3.92a	4.04b	2.97b	0.40b	0.46b
40	0–5	36.88b	14.85c	17.21c	5.69c	5.03c
0	5–10	2.06a	0.90a	0.31a	0.29a	0.24a
20	5–10	11.60b	4.08b	1.70b	0.60b	0.49b
40	5–10	43.84c	15.25c	21.89c	1.08c	4.23c
0	10–15	2.61a	0.61a	0.18a	0.23a	0.35a
20	10–15	28.97b	4.10b	1.20b	0.54b	0.42a
40	10–15	42.75c	14.27c	18.83c	0.58b	4.23b

*Mean figures within a column, which are followed by the same letter, are not significantly different at the 5% level, Duncan's multiple range test.

DISCUSSION

Micronutrient deficiency in Kuwait can be noticed in many plant leaves colouring or chlorosis and stunt growth. The high contents of calcareous materials within soil profiles interfere with the availability of micronutrients to the plants' roots. The application of organic matter improves the soil's contents of micronutrients and the plant's growth and development (Dierolf *et al.*, 1997). Significant differences were noticed in soils total contents of micronutrient elements (Fe, Mn, Zn, B, and Cu) in the three treated soils with organic matter (Table III). Iron contents through all soils profiles are distinctively different in all three treatments of organic matter application. Immense increases of iron nutrients were provided by organic matter with all soil horizons. Forty years of organic matter application increases the soil's contents of iron in topsoils of Kuwait more than seventeen-fold. The high contents of calcareous materials provide good storage capacities for iron and decreases the iron toxicity in high contents of organic matter application (Table I). Although, with the long duration of organic matter, application in Kuwait indicate a high content of micronutrient elements, but the availability comparative to plants' roots are low, mostly due to a high content of calcareous materials. Manganese contents increase enormously in all soils profile with the application of organic matter. Topsoils with 40 years application of organic matter contain more than twenty-fold of manganese element. The high accumulation of manganese can be noticed in all soil profiles. Zinc accumulations exceeded both the iron and manganese content in all soils with added organic matter. Over thirty-fold dilatation of zinc contents were recognized with all soils horizons. Boron element content also increased, but not as much as other micronutrients within the soil profile. This may be due to calcareous fixation of this element by calcareous materials in Kuwait soils, since the calcium and sodium borate's are reasonably soluble (Bowman and Halvorson, 1998). Copper contents increase in all soils profile as much as the iron, zinc and manganese. Correlation of organic matters application to the coarse texture of Kuwait soil reveal high release of micronutrients in the soil solution, and undoubtedly is an important fertility factor.

Calcium contents significantly decreased in 40 years application of organic matter compared to other treatments. At the same time calcium contents within the 40 years treatment have increased through the soils lower horizons and decreased in the other treatments (Table IV). Continuous water irrigation and organic matter reactions within the soils increase calcium cation solubility. Calcium concentration with constant farming moved to the lower soil profiles. Magnesium concentration in the soil solution increased in all soil profiles with the application of organic matters. Potassium, phosphorous and sulphur were highly increased in all soils horizons with the continuous application of organic matters (Table V). Application of organic matters in different soils of Kuwait improved nutrient contents of the soils.

CONCLUSIONS

The soil of Kuwait is poor with organic matter and plant nutrients and needs a heavy application of fertilizer and organic materials to improve soils productivity. Organic materials are available in large quantities in Kuwait from animal and municipal wastes. Research findings in three soils treated with organic waste materials with various time

TABLE IV Effect of organic matter application on Kuwait soils total contents of macronutrients (mg/kg)

Duration (years)	*Soil depth (cm)*	*Ca*	*Mg*	*K*	*P*	*S*
0	0–2	190.41a*	14.15a	13.13a	4.776a	51.26a
20	0–2	188.33a	91.46b	158.52b	49.11b	466.15b
40	0–2	104.32b	74.20c	252.10c	12.87c	1029.30c
0	0–5	188.42a	8.69a	14.82a	4.58a	5.64a
20	0–5	185.84a	22.73b	63.27b	9.16b	2533.60b
40	0–5	126.14b	390.55c	4257.8c	18.45c	1052.50c
0	5–10	186.83a	9.98a	15.71a	4.44	1.76a
20	5–10	177.25b	38.97b	80.28b	9.33	1000.4b
40	5–10	172.61b	65.52c	335.48c	70.47	135.88c
0	10–15	180.77a	10.03a	13.77a	4.32	1.19a
20	10–15	153.41b	41.18b	81.88b	9.00	749.98b
40	10–15	146.68b	53.41c	334.69c	66.90	138.77c

*Mean figures within a column, which are followed by the same letter, are not significantly different at the 5% level, Duncan's multiple range test.

TABLE V Effects of organic matter on macronutrient contents (mg/kg)

Duration (years)	*Macro-nutrients contents*				
	Ca	*Mg*	*K*	*P*	*S*
0	190.41a*	14.15a	13.13a	4.77a	51.26a
20	188.33a	91.46b	158.52b	49.11b	466.15b
40	104.32b	74.20c	223.27c	12.87c	180.21c

*Mean figures within a column, which are followed by the same letter, are not significantly different at the 5% level, Duncan's multiple range test.

durations indicate extreme changes in the soils physical and chemical properties. Soils bulk densities decrease and soil water-holding capacities increase. With limited irrigation water resources in Kuwait these two important factors will have a large impact in irrigation water saving. Macro and micronutrients contents increase within the soil solution except calcium in the topsoils. Organic materials will improve soil productivity and plant growth and development in Kuwait.

Research activities in Kuwait should concentrate mainly on nutrients interaction within the soil solution. High concentration of macro and micronutrients were also achieved from organic matter application to various soils. Interaction of these added nutrients with soil contents of calcareous materials should be studied more intensively to understand nutrient availability to plants. Nutrients interaction and stability within the soil solution should also be investigated more scientifically to improve nutrients availability.

Acknowledgements

I wish to thank Dr. Mahdi Abdal for his revision of the manuscript, whose comments and advice greatly enhanced this article.

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