

Degraded Arid Soil Reclamation for Cotton Cultivation Using Organic Waste Amendments

Reginald Kogbara^{1,2}, Helmi Hamdi³, Ali Al-Sharshani⁴, Osman Abdalla⁵,
Udeogu Onwusogh⁴, and Sabah Solim⁴

¹ Texas A&M University at Qatar, P.O. Box 23874, Education City, Doha, Qatar

² Izmir Institute of Technology, Gulbahce, Urla 35430, Izmir, Turkey

³ Center for Sustainable Development, Qatar University, Doha, Qatar

⁴ Qatar Shell Research & Technology Center, QSTP LLC, Doha, Qatar

⁵ Department of Agricultural Research, Ministry of Municipality & Environment, Doha, Qatar

regkogbara@cantab.net

Abstract. Qatar is one of the most fertilizer-dependent countries due to challenging soil and climatic conditions. The country strives toward self-sufficiency in agricultural production in alignment with the Qatar National Vision 2030. Hence, this work investigates the potential of utilizing nutrient-rich resources that are currently wasted for the reclamation of degraded arid soils to support the cultivation of industrial crops such as cotton (*Gossypium spp.*). Two abundant organic wastes, industrial biosludge and cow dung compost were employed as soil amendments at a 3% application rate on a silty loam soil with relatively high salinity (EC = 5.60 dS/m) and compared with conventional chemical fertilization. Cotton (May 344 variety) was then grown on the biowaste-amended soils in lysimeters for ten months (March through January) spanning through the hot season in Qatar, with the average temperature ranging from 19 to 37°C. Soil properties and plant growth characteristics, including soil metal concentrations, days to germination and flowering, plant height, and cotton yield, were determined at set periods. The results indicated that different from the chemical fertilizer treatment, the organic amendments led to a significant release of potassium eight months after planting, roughly twice the concentration available at the initial sampling period. In all treatments, soil magnesium and iron concentrations generally increased, while phosphorus and zinc decreased over time. There was generally no significant difference in the concentrations of metals analyzed such as chromium, copper, nickel and zinc between soils amended with the organic wastes and chemical fertilizer. The concentrations of metals were below the regulatory limits for sewage sludge applied to soils. The days to germination were 2, 9, and 11, while the days to flowering were 61, 92, and 77 for the cow dung compost, biosludge, and fertilizer treatments, respectively. The average cumulative plant heights were 74, 65, and 63 cm, while the average cumulative cotton boll yield was 7.3, 5.4, and 2.6 tons/ha, respectively, in the cow dung compost, biosludge, and fertilizer treatments. The results demonstrate that the organic amendments, especially cow dung compost, can help reclamation of degraded/saline arid soils under the described pedo-climatic conditions.

Keywords: Cotton, Cow Dung Compost, Industrial Biosludge, Organic Waste Amendments, Plant Growth Parameters.

1 Introduction

Qatar is one of the most fertilizer-dependent countries [1] due to challenging soil and climatic conditions. Hence, as the country strives toward self-sufficiency in agricultural production in alignment with the Qatar National Vision 2030, using biosludge and other organic wastes as soil enhancers presents a unique opportunity to utilize a nutrient-rich wasted resource. Thus, this work investigates the potential of utilizing two abundant organic wastes rich in nutrients, industrial biosludge and cow dung compost for the reclamation of degraded arid soils to support the cultivation of industrial crops such as cotton (*Gossypium spp.*). Cotton was chosen among other industrial crops as it thrives in warm and humid climates so could survive in Qatar's climate.

Organic wastes benefit crops by efficiently using organic nitrogen and phosphorus, which are released slowly throughout the growing season, allowing for better nutrient absorption [2-4]. However, using these biowastes may accumulate toxic metals and other contaminants in soils depending on their origins [4]. There is a paucity of literature on similar studies as cotton is not usually grown in Qatar, which has a hyper-arid desert climate. Several studies have shown that the ideal temperature for cotton growth and development ranges from 20 to 32°C [5]. Hence, this study aimed to investigate the use of organic waste amendments to reclaim degraded arid soil for cotton production under Qatar's prolonged hot climatic conditions and to evaluate changes in soil properties and the effect on cotton performance.

2 Materials and Methods

Lysimeters and soil: The experiments were conducted in 9 field lysimeters (3 replicates per treatment), each with 9 m² surface area (3 m by 3 m) and a depth of 1 m. The lysimeters were filled with soil of silty loam texture (9% gravel, 27% sand, 54% silt, and 10% clay). Table 1 shows key properties of the degraded saline soil. The soil had an *in situ* electrical conductivity of 5.60 mS/cm determined using an EC 1210 soil EC meter (Nieuwkoop BV, Netherlands), and 0.68% NaCl content.

Table 1. Key physico-chemical properties of the soil used for cotton cultivation.

C/N ratio	pH	NaCl (%)	mg/kg							
			Cl ⁻	Al	Cr	Cu	Fe	Mn	Ni	K
113:1	7.56	0.68	4,100	69,643	51.6	12.6	32,225	298	61.9	8,666
			Ca	Mg	Na	Zn	Cd	S	B	Pb
			212,083	566.8	6,735	40.0	< 0.5	1598	58.5	2.8

Soil amendments: Three nutrient sources were compared for fertilization of the soil, namely, industrial biosludge, cow dung compost and an inorganic fertilizer. The properties of the biosludge and cow dung compost used can be found elsewhere [3, 6]. The biosludge and cow dung compost was applied at 3% dosage of the soil mass in a given lysimeter (i.e., 115 ton/ha). The inorganic fertilizer was applied using chemical fertilizers to supply the required levels of N, P and K for cotton. Specifically, urea and K₂SO₄

78 were applied at 200 kg/ha divided into three equal doses to supply 92 and 86 kg/ha of
 79 N and K, respectively, while 150 kg/ha of triple super phosphate supplied 30 kg/ha P.

80 *Sowing, irrigation and analytical methods:* About 45 cotton seeds (May 344 variety)
 81 were sown in the nutrient-amended soils. These were grown for 10 months (March
 82 through January) spanning through the long hot and dry season in Qatar. The lysimeters
 83 were irrigated at set periods, on average 9 days per month for about 6 minutes with a
 84 bubbler flow rate of 4.75 L/min. Soil properties and plant growth characteristics were
 85 determined using methods documented in previous related publications [7-9].

86 *Data analysis:* This involved simple statistics such as mean and standard deviation.
 87 Analysis of variance (ANOVA) was used to test significant differences at the 5% level.

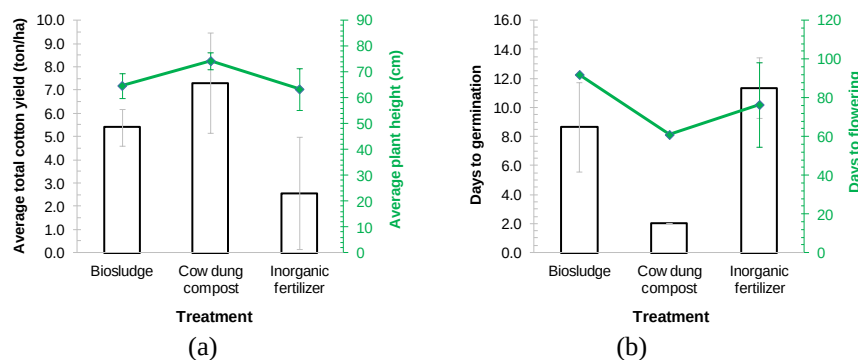
88 3 Results and Discussion

89 The soil and plant performance in the three treatments are shown in Table 2 and Fig. 1.
 90 Table 2 compares the elemental concentration of the soils at the initial stage (before
 91 seed sowing) and at the final growth stage (8 months after planting). Fig 1 shows plant
 92 yield and height over the 10-months period, and days to germination and flowering.

93 **Table 2.** Average key soil elemental concentrations over an 8-month period

Treatment	Elemental concentration* (mg/kg)									
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
	Total Nitrogen		Total Phosphorus		Potassium		Magnesium		Iron	
BS	300	500	2,793	1,164	4,292	11,355	39,807	96,371	35,419	75,179
CDC	335	503	830	681	3,578	7,427	34,147	58,886	24,081	111,314
Fertilizer	310	155	739	708	6,643	7,121	47,028	59,761	32,052	76,937
	Calcium ($\times 10^3$)		Chromium		Copper		Nickel		Zinc	
BS	231	368	48	121	61	0.2	77	81	224	102
CDC	183	232	93	137	43	34	100	78	136	62
Fertilizer	191	212	117	137	34	0.2	79	78	111	57

94 BS: Biosludge, CDC: Cow dung compost, Fertilizer: Inorganic fertilizer. *Concentrations were determined for 0 - 30 cm soil depth.



95 **Fig. 1.** Plant performance in the treatments in terms of, (a) average cotton yield and plant height,
 96 and (b) number of days to germination and flowering, over the 10-month growth period. *Note:*
 97 The columns represent the average total cotton yield on the primary y-axis, the dots represent the average
 98 plant height on the secondary y-axis, while the error bars represent the standard deviation of three replicates.
 100

The results show that different from the inorganic fertilizer treatment, the organic amendments led to a significant release of K eight months after planting, roughly twice the concentration available at the initial stage, and K is critical for cotton growth. This corroborates the findings of a previous study in which the application of organic manure significantly increased K release in the soil in contrast to inorganic fertilizer. This was attributed to the dissolution of some K-containing soil minerals through organic acids resulting from decomposition of the organic amendments [10]. The total nitrogen concentration in the soil increased between the initial and final stages for the treatments with organic amendments but decreased for the inorganic fertilizer treatment. This confirms observations made in previous studies on the quick loss of nitrogen from inorganic fertilizers (possibly through leaching and denitrification) from the soil compared to its slow release by organic amendments such as biosludge and compost [3, 4, 11].

In all treatments, soil Ca, Mg and Fe concentrations generally increased, while P and Zn decreased over time. Similar increases in Ca, Mg and Fe concentrations have been recorded in soils amended with organic and inorganic fertilizers [12]. The decreases in P and Zn however differ from the work of Amjadian et al. [12] as different types of fertilizers and soils were considered in both studies. There was generally no significant difference in the concentrations of metals analyzed such as Cr, Cu, Ni and Zn between soils amended with the organic wastes and inorganic fertilizer at the 5% probability level. This differs from observations in a previous study in which farmyard manure showed significantly higher concentrations of Cr, Cu and Zn than NPK fertilizer [13]. The concentrations of the metals were below the regulatory limits (< 300 for Cr, Ni and Zn, and < 100 mg/kg for Cu) for sewage sludge applied to soils [14].

The average cumulative cotton yield was 7.3, 5.4, and 2.6 tons/ha, while the average cumulative plant heights were 74, 65, and 63 cm, respectively, in the cow dung compost, biosludge, and fertilizer treatments. The days to germination were 2, 9, and 11, while the days to flowering were 61, 92, and 77 for the cow dung compost, biosludge, and fertilizer treatments, respectively. These results differ from a recent study in which mineral fertilizer gave superior cotton growth and yield compared to cow-dung based compost on loamy sand soils [15]. Thus, the observations here show that the organic amendments thrive better for the specific (saline silt-loam) soil type considered.

4 Conclusions

The performance of the treatments in reclaiming the degraded soil for cotton production in Qatar's hot climate was in the order, cow dung compost > biosludge > inorganic fertilizer. The results show that the organic amendments, especially cow dung compost, can better supply needed nutrients than inorganic fertilizer and help reclamation of degraded/saline arid soils under the described pedo-climatic conditions.

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