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Microbial Population in the Rhizosphere of Some Cultivation Region from Saudi Arabia

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ABSTRACT

The present study was conducted to investigate the current status of soil properties and microbial population density in different rhizosphere cropping regions from Saudi Arabia. Rhizospheric soil samples (0-20 cm depth) were collected from different cropping farms of two regions, namely Al-Kharj and Al-Ahsa for estimation of their physical, chemical, heavy metals and microbial current status. The average of total bacterial counts in Al-Kharj was about double than average of total bacterial counts in Al-Ahsa. Also, the average of total fungi counts was also higher in Al-Kharj soil samples than Al-Ahsa. The results also depict that Al-Kharj region occupies more organic matter than Al-Ahsa. Heavy metals in all samples were less than the acceptable limits in the agricultural soils comparative to the Saudi standards. Correlation analysis, among the studied physical and chemical properties, depicts that EC and pH are negatively correlated with each other. This study is helpful for exploring the different characteristics of soils at the agricultural regions in Saudi Arabia as a results of the different monument.

Introduction

The area of Saudi Arabia is vast, and therefore it's the provinces differ in their climatic conditions, soil quality, and the type of crops suitable for each agricultural region, which made some agricultural regions have a comparative advantage over other regions, therefore certain types of crops succeed in them over others. Soil microorganisms play an important role in providing some necessity nutrients for crops productions, especially in conditions of desert soils and lack of organic matter and moisture. Therefore, the numbers and activity of microbes may differ in Saudi soils, especially in the rhizosphere assoil is a highly complex and variable matrix comprising a wide range of habitats and supporting some of the most species-rich, biochemically diverse, microbial communities in nature. The activity and diversity of soil microbial communities fluctuate in response to alterations in the environmental conditions (Steele and Streit, 2006). Many microorganisms live in soil, but even more live close to the roots of plants (Amal and Nepal, 2003).

In Saudi Arabia's despite the unfavorable climate the government has started a number of initiatives to support agriculture. According to Fiaz *et al.,* (2018), 25% (52.7 × 10^6 hectares) of the country's total land is currently cultivable. Arid region's microbial populations are also likewise largely uncharacterized (Khan and Khan, 2020).

Since there is no flora in the huge desert, it is expected that neither macromolecules nor the microbial populations required in nutrient recycling will be there. Even in the Atacama Desert's hyperarid regions, where rain falls just once every ten years, active microbial communities have been found, however (Schulze-Makuch *et al.,* 2018). These studies are essential for increasing the viability of agriculture in these harsh ecosystems and for developing plans for modifying soil using microbial consortia to increase the viability of agriculture in arid soil (Batool *et al.,* 2021; Fierer, 2017; Fierer *et al.,* 2012).

Through maintaining the soil's nutrient cycle, carbon sequestration, and other geochemical activities, these microbes may affect soil fertility. In reaction to changes in the environment, the activity and diversity of soil microbial communities change (AL-Barakah *et al.,* 2020), considerably if there are many microorganisms in soil, considerably more are found near plant roots (Sohaib *et al.,* 2022). Due to poor organic matter, the rhizosphere is a significant site of microbial activity in soils.

Different chemicals, including carbohydrates (sugars and oligosaccharides), organic acids, vitamins, nucleotides, flavonoids, enzymes, hormones, and volatile molecules diffuse from the roots and promote microbial activity. Numerous microorganisms are present in the rhizosphere, or zone of influence, around plant roots and are impacted by both abiotic and biotic stressors (Abbas *et al.,* 2013; Rafique *et al.,* 2022). Therefore, the objective of this study was an environmental assessment of rhizophere based on chemical properties, heavy metal and microbial counts in cropping areas of Al-Kharj and Al-Ahsa region in which may shed light on the function that microbes play in various geochemical processes.

Materials and Methods

Soil Sampling and Locations

Two different regions of Saudi Arabia i.e. Al-Kharj and Al-Ahsaas shown in Fig. 1. Were chosen for this studyAl-Kharj region is one of the important agricultural governorates located in the southeast of the capital Riyadh and famous for cultivation palm trees, wheat and vegetables. Al-Ahsa region is in the eastern side of Saudi Arabia and famous for cultivating palm trees and fruit. Both, regions differ in the soil type, location calamite and in the soil management foe agricultural crops, soil care and the use of organic and mineral fertilizers for production.

Samples of rhizosphere soils of different cropping areas along with the bulk soil as control were collected in October and November 2022 and transfer immediately to the Soil Microbiology Laboratory, Department of Soil Science, College of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia, for further processing. A total of 14 and 22 composite soil samples (0-20 cm depth from the soil surface) were collected from Al-Kharj and Al-Ahsa, respectively.

Soil Physical, Chemical and Heavy metal

The particle size distribution of soil samples was estimated by particle size analyzer (Callesen *et al.,* 2018). Soil textural class was calculated by using the texture triangle (USDA, 2021). Electrical conductivity (EC) (mS/cm) and pH of soil paste extract were measured using the digital meter (WTW inoLab pH/Cond Level 1). Total Sodium (Na) and total Potassium (K) of soil paste extract were estimated using the Flame Photometer. The heavy metal (i.e., Ca, Mg, Fe, Mn, Cd, Co, Cr, Cu, Mo Ni, Pb, and Zn) of the digested soil samples were analyzed by ICP-AES (Rashid, 1986).

Enumeration of microbial population

Serial dilutions were prepared by distilled sterilized water by taking 10 g of soil sample up to 10^6 dilutions. After that, 1 ml of the desired dilution was spread to the agar plate. For total bacterial count (CFU/g) half strength of Nutrient Agar and for total fungi counts (CFU/g) Rose Bengal Agar, as adopted and by Sohaib *et al.,* (2022) were used for enumeration.

Cycloheximide (50 µg/ml) was added to the nutrient agar medium (<55^0 C) before plating to reduce fungal contamination, while Chloramphenicol (0.1g/L) was used as a selective agent to suppress the growth of bacteria in respective media. After incubation, the individual colonies were counted for each plate, and colony-forming units (CFU/g) were calculated using the following equation (Page, 1982; Sohaib *et al.,* 2022);

CFU/g = (Number of colonies/volume of sample plated) × Dilution Factor

Isolation and storage of bacterial isolates

After enumeration of bacterial colonies, the morphologically different colonies were isolated by repeated streaking on half strength nutrient agar to get pure isolates. Pure isolates were cultured in nutrient broth until turbidity (i.e. for 24-48 hours). The broth cultures were preserved in Cryovials (2.0 ml) after mixing (1:1) with 50% sterilized glycerol with a ratio of 1:1 and stored for a long time at -80°C to -70°C for further studies (Bibi *et al.,* 2017; Sohaib *et al.,* 2022).

Statistical analysis

Descriptive statistics were done through Statistics 8.1. Spearman correlations among studied soil were analyzed and visualized by R programming using the corrplot and RColorBrewer packages.

Results and Discussion

In the Al-Kharj soil samples the sand, silt and clay fractions ranged was between 20.39 to 90.12 %, 9.88 to 66.88%, and 0 to 13.43%, respectively. While in soil samples of Al-Ahsa region the sand, silt and clay fractions ranged between 61.7 to 92.12%, 7.88 to 34.53%, and 0 to 3.77%, respectively. The textures class of Al-Kharj soil samples ranged from silt loam or sandy loam, and sand to loamy sand. While the texture classes of Al-Ahsa soil samples were recorded as sand, loamy sand and sandy loam, regardless growing plant species. AL-Barakah *et al.,* (2020) also reported previously presence of loam or sandy loam, and loamy sand texture class of rhizosphere samples collected from Riyadh region. Figure 2A and Figure 2B visualized the texture classes of Al-Kharj and Al-Al-Ahsa regions according to USDA (2021) texture triangle.

The present study results is in line with these observed by Alotaibi *et al.,* (2020) and Al-Saeedi (2022).

Table 1 and 2 shows the descriptive statistical results of chemical properties and status of heavy metals for the Al-Kharj samples. pH of the Al-Kharj region was between 7.03 (K6) to 7.77 (K9) with average of 7.3929 (n=14), while EC was 0.509 (K12) to 7.05 mS/cm (K8) with average of 2.3516 (n=14). Correlation among studied soil properties of Al-Kharj samples (Figure 3) illustrate that EC is positively correlated with Mg, SO_4^{2-}, Ca, Cl^-, Na^+, K^+ and P and negatively correlated with Cu, pH, Pb, CO_3^{2+}, As, and Zn, while pH is positively correlated with Cu, Pb, Mo, Zn, Mn and Fe and negatively correlated with K, Ca, EC, SO_4^{2-}, Mg^{2+}, Na^+, CO_3^{2+}, and P. OM contents in bulk sample (KC) was higher (3.25%) than average OM contents (1.66%) and most of rhizospheric samples of Al-Kharj. Similar results were obtained by Modaihsh *et al.,* (2015), and in line with Al-Barakah and Mridha (2014) in Al-Kharj region.

Table 3 and Table 4 showed the descriptive statistical results of chemical properties and status of heavy metals for the Al-Ahsa samples. pH of the Al-Ahsa region was between 6.75 (H2) to 7.94 (H8) with average of 7.4718 (n=22), while EC was 0.401 (H9) to 19.53 mS/cm (H1) with average of 2.986 (n=22).Correlation among studied soil properties of Al-Ahsa samples (Figure 4) illustrate that EC is positively correlated with, Mg, Ca, Na^+,, K^+, Cl-, SO_4^{2-}, and As and in contrast negatively correlated with OM, CO_3^{2+}, P, Pb, Cr, and Ni, while pH is positively correlated with CO_3^{2-}, Zn, P, OM, Cr, Ni,Co, Fe and Clay and negatively correlated with Na, K, SO_4, Ca, Mg, Mo, and Sand.OM contents in bulk sample (HC) were (0.81%) than average OM contents (1.20%) and most of rhizospheric samples of Al-Ahsa. This results in consistent to the result reported by Modaihsh *et al.,* (2015) and, Figure 3 and Figure 4 showed that there is negative correlation between pH and EC in both studied regions (i.e. Al-Kharj and Al-Ahsa). This confirms the finding of Al-Saeedi (2022) for Al-Ahsa and Alotaibi *et al.,* (2020) for AlKharj. Sohaib *et al.,* (2023) also, Aizat *et al.,* (2014) reported the negative correlations among pH and EC of mangrove environment sample, in contrast mentioned that there is no direct effect of soil pH is not directly affect the soil electrical conductivity, but pH may affect the salts` solubility and moisture contents. It means more high soil pH (alkaline soil) will show low EC (less quantity of soluble salt) and low soil pH will show high EC (more quantity of soluble salts). The negative correlation between EC and pH might be due to accumulation of such soluble salts in sampled soil depth which are acidic in nature, which showed decreasing trend in pH when EC increased.

Average OM contents of both studied regions, Al-Kharj (1.66%) and Al-Ahsa (0.81%), where higher than the OM contents in some medows of Riyadh region (0.16%) as reported by AL-Barakah *et al.,* (2020). Comparatively, higher OM contents in bulk soil were higher might be due to the effect of zero tillage and in contrast the agronomic soil management practices and biological activities in rhizosphere might be in favor of OM degradation or consumption, comparatively (Herre *et al.,* 2022). The soil OM contents were varying either with the climatic conditions, the growing plant species, and/or agronomic practices.

The present study results in Table 4. Indicate that the heavy metals are less than the acceptable limits in the agricultural soil in Saudi Arabia (Ministry of Environment, 2020).The results of low level from the heavy metals suggest that no health risk of the agricultural soils in AlKharj and Alhsa regions. This may be due to low contamination as they are a way from the major industrial area and for the good soil management by the farmers. The figure 5 and figure 6 showed the average of total bacterial colony counts in per gram soil sample (CFU/g) along with their standard errors in samples of Al-Kharj and Al-Ahsa regions, respectively. In Al-Kharj (Figure 5), location K12 showed highest bacterial counts (1.67×10^6 CFU/g) while KC (bulk soil) showed lowest bacterial counts (2.7×10^5 CFU/g) among all studied locations (n=14). In Al-Ahsa (Figure 6), location H3 showed highest bacterial counts (1.81×10^6 CFU/g) while HC (bulk soil) showed lowest bacterial counts (3×10^4 CFU/g) among all studied locations (n=22). The relatively similar microbial in KC (bulk soil) may be due to the fact that the site was previously cultivated and the farmer left the soil uncultivated during the collection of soil samples for this study and this may explain why the results of chemical properties of this site are similar to other sites, and may explain the significant increase in organic matter, which encouraged the microbial population. The figure 7 and figure 8 showed the average of total fungi colony counts in per gram soil sample (CFU/g) along with their standard errors in samples of Al-Kharj and Al-Ahsa regions, respectively. In Al-Kharj (Figure 7), location K4 showed highest fungi counts (8 × 103 CFU/g) while KC (bulk soil) showed lowest fungi counts (5.56 × 102 CFU/g) among all studied locations (n=14). In Al-Ahsa (Figure 8), location H4 showed highest fungi counts (9.73 × 102 CFU/g) while HC (bulk soil) showed lowest fungi counts (30 CFU/g) among sll studied locations (n=22).

Table.1 Chemical properties of soil in Al-Kharj samples

Sample	Rhizosphere plant	pH	EC	OM	Ca	Mg	HCO^{3-}	CO^{3-}	Cl-	K	Na	$SO4^{2-}$
			mS/cm	%	meq/L							
K1	Palm trees	7.35	1.47	0.93	16.67	17.67	0.60	1.20	7.75	3.82	18.87	47.47
K2	Clover	7.46	2.11	0.97	19.67	30.67	0.80	0.40	7.50	2.01	19.56	63.20
K3	Palm, trees	7.53	1.69	1.21	18.67	17.33	1.00	0.20	6.00	1.03	15.46	45.29
K4	Radish	7.08	1.13	0.87	14.67	11.33	0.60	0.80	3.75	2.29	14.61	37.75
K5	Zucchin	7.35	4.23	0.19	24.33	46.33	0.60	0.00	34.25	1.77	29.74	67.33
K6	Brocoli,	7.03	4.07	0.20	22.33	47.33	1.40	0.40	29.75	2.24	30.31	70.67
K7	Palm, trees	7.57	2.29	1.74	15.00	34.67	2.00	0.40	4.00	0.19	11.89	55.35
K8	Citrus	7.34	7.05	1.14	11.67	112.00	1.40	0.00	82.00	3.13	51.78	95.17
K9	Palm, trees	7.77	0.67	0.37	4.00	13.67	0.80	0.40	1.75	0.12	9.29	24.13
K10	Corn	7.56	1.98	0.20	14.33	18.33	0.80	0.40	6.50	0.41	15.14	40.51
K11	Palm, trees	7.42	0.85	0.97	8.00	10.67	1.00	0.40	2.75	0.38	9.78	24.68
K12	Palm, trees	7.51	0.51	1.02	2.67	9.00	1.00	0.80	0.50	0.10	7.79	17.25
K13	Zucchin	7.20	2.40	0.46	25.00	20.33	0.00	0.80	0.25	0.84	7.87	52.99
KC	Bulk Soil	7.33	2.49	1.67	27.67	30.67	4.40	2.40	5.33	3.68	10.23	60.10
Descriptive Statistics (n=14)												
Mean		7.39	2.35	0.85	16.05	30.00	1.17	0.61	13.72	1.57	18.02	50.14
SD		0.20	1.75	0.51	7.63	26.73	1.04	0.61	22.21	1.33	12.11	21.00
SE Mean		0.05	0.47	0.14	2.04	7.14	0.28	0.16	5.94	0.35	3.24	5.61
C.V.		2.70	74.59	59.90	47.58	89.09	88.81	99.30	161.85	84.53	67.22	41.89
Minimum		7.03	0.51	0.19	2.67	9.00	0.00	0.00	0.25	0.10	7.79	17.25
Maximum		7.77	7.05	1.74	27.67	112.00	4.40	2.40	82.00	3.82	51.78	95.17
Skew		-0.18	1.45	0.18	-0.29	2.20	2.26	1.87	2.33	0.43	1.70	0.31

Fig.1 Study locations of the two different areas of Saudi Arabia (Al-Kharj and Al-Ahsa)

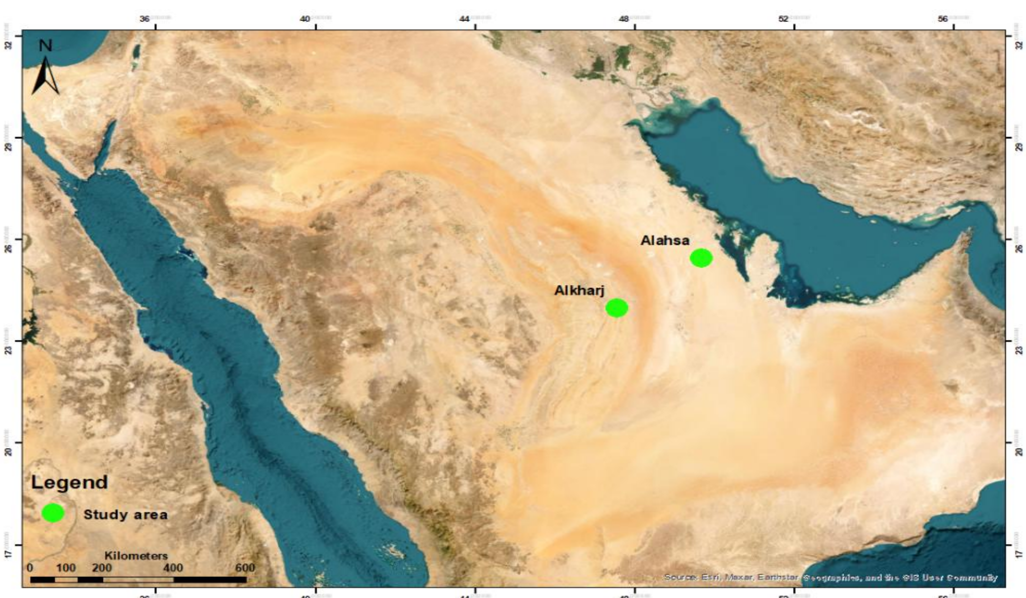


Table.2 Heavy metals status in soil samples of Al-Kharj, their descriptive statistics and Saudi Standards

Sample	Rhizosphere plant	As	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	P	Pb	Zn
		ppm											
K1	Palm trees	0.07	0	0.05	0.28	0.00	110.50	1.24	0.00	0.23	4.53	0.06	0.17
K2	Clover	0.05	0	0.07	0.45	0.00	145.20	2.08	0.00	0.35	42.07	0.05	0.13
K3	Palm, trees	0.06	0	0.06	0.35	0.00	155.20	1.68	0.00	0.28	4.81	0.05	0.37
K4	Radish	0.03	0	0.02	0.17	0.00	84.03	0.38	0.00	0.12	12.50	0.04	0.08
K5	Zucchin	0.02	0	0.00	0.12	0.00	53.15	0.00	0.00	0.07	6.97	0.03	0.00
K6	Brocoli,	0.01	0	0.01	0.13	0.00	62.12	0.01	0.00	0.08	8.08	0.03	0.03
K7	Palm, trees	0.00	0	0.01	0.20	0.00	86.93	0.29	0.00	0.13	48.67	0.04	0.12
K8	Citrus	0.00	0	0.02	0.21	0.00	87.58	0.22	0.00	0.17	40.94	0.05	0.00
K9	Palm, trees	0.07	0	0.02	0.20	0.09	96.50	0.53	0.00	0.12	5.03	0.07	0.12
K10	Corn	0.03	0	0.02	0.18	0.00	83.67	0.43	0.00	0.13	6.66	0.04	0.00
K11	Palm, trees	0.03	0	0.00	0.12	0.00	54.09	0.00	0.00	0.09	35.85	0.04	0.00
K12	Palm, trees	0.00	0	0.01	0.18	0.12	84.79	0.38	0.00	0.09	5.35	0.07	0.07
K13	Zucchin	0.03	0	0.02	0.18	0.00	76.77	0.19	0.00	0.15	43.71	0.03	0.00
KC	Bulk Soil	0.03	0	0.09	0.51	0.00	183.10	2.30	0.00	0.38	40.79	0.07	0.10
Descriptive Statistics (n=14)													
Mean		0.03	0	0.03	0.23	0.02	97.40	0.69	0.00	0.17	21.85	0.05	0.08
SD		0.02	0	0.03	0.12	0.04	38.61	0.79	0.00	0.10	18.40	0.01	0.10
SE Mean		0.01	0	0.01	0.03	0.01	10.32	0.21	0.00	0.03	4.92	0.00	0.03
C.V.		79.83	0	93.53	51.80	258.17	39.64	114.14	288.90	59.39	84.18	28.85	119.27
Minimum		0.00	0	0.00	0.12	0.00	53.15	0.00	0.00	0.07	4.53	0.03	0.00
Maximum		0.07	0	0.09	0.51	0.12	183.10	2.30	0.00	0.38	48.67	0.07	0.37
Skew		0.36	0	1.01	1.24	2.17	0.98	1.05	2.85	1.06	0.32	0.38	1.62
Maximum Acceptable Limit (ppm) according to Ministry of Environment Water & Agriculture, Kingdom of Saudi Arabia													
Agriculture Soil		17.00	1.40	20.00	64.00	63.00	-	-	4.00	45.00	-	70.00	200.00

Table.3 Chemical properties of soil in Al-Ahsa samples

Sample	Rhizosphere Plants	pH	EC	OM	Ca	Mg	HCO^{3-}	CO^{3-}	Cl^{-}	K	Na	$SO4^{2-}$
			mS/cm	%	meq/L							
H1	Palm trees	7.43	9.53	0.39	15.45	60.51	0.59	0.00	219.80	9.45	212.13	77.13
H2	Palm trees	6.75	3.88	0.56	16.67	34.33	0.00	1.20	37.25	3.62	83.00	99.16
H3	Palm trees	7.33	0.91	0.89	24.67	0.33	4.40	0.00	3.20	0.52	31.71	49.63
H4	Palm trees	7.61	0.64	0.89	4.00	4.67	0.60	0.80	4.40	0.52	17.52	20.91
H5	Palm trees	7.75	0.53	0.96	6.00	1.33	2.60	0.60	4.20	0.38	9.86	10.17
H6	Alfalfa,	7.91	0.98	1.06	1.33	4.67	0.60	1.40	7.40	1.07	14.97	12.65
H7	Citrus,	7.64	0.58	0.96	3.67	3.00	1.00	0.40	3.00	0.70	10.20	13.16
H8	Palm trees	7.94	0.57	0.70	4.00	3.00	0.60	0.80	5.20	1.07	19.72	21.20
H9	Alfalfa	7.34	0.40	0.61	2.67	0.33	1.40	0.40	1.67	1.02	18.26	18.81
H10	Citru	7.66	0.41	0.89	3.00	2.33	1.40	0.80	2.75	0.97	15.61	16.96
H11	Palm trees	7.67	0.44	0.61	4.00	0.00	0.40	1.60	4.25	1.02	17.90	16.67
H12	Clover,	7.64	0.41	0.53	4.00	0.00	0.60	0.80	1.75	0.81	17.62	19.28
H13	Palm trees	7.21	0.53	0.66	1.33	3.33	0.40	0.80	3.25	1.18	19.90	21.30
H14	Palm trees	7.61	0.78	0.34	3.00	4.00	0.60	0.80	6.25	1.24	23.28	23.87
H15	Citrus	6.83	0.57	0.71	0.67	7.00	1.40	0.80	6.00	1.02	21.09	21.58
H16	Palm trees	7.74	0.49	0.95	2.67	5.33	1.80	0.80	2.00	1.45	17.17	22.02
H17	Palm trees	7.71	7.88	0.26	7.33	60.33	0.00	2.00	121.00	5.98	158.83	109.47
H18	Palm trees	7.62	7.03	0.37	17.33	52.00	1.00	0.40	91.33	6.82	114.62	98.04
H19	Citrus	7.07	1.67	0.33	20.33	4.00	1.00	0.40	6.75	2.41	39.57	58.17
H20	Palm trees	7.15	0.86	0.40	12.33	8.33	0.80	0.00	1.25	1.57	30.13	50.31
H21	Palm trees	7.55	2.12	0.42	20.00	17.00	0.80	0.00	2.25	1.47	29.41	64.83
HC	Bulk Soil	7.22	14.50	0.07	23.33	132.00	1.80	0.40	289.75	34.87	333.30	231.56
Descriptive Statistics (n=22)												
Mean		7.47	2.53	0.62	8.99	18.54	1.08	0.69	37.49	3.60	57.08	48.95
SD		0.32	3.78	0.27	8.05	32.07	0.96	0.52	77.47	7.37	81.07	51.39
SE Mean		0.07	0.81	0.06	1.72	6.84	0.21	0.11	16.52	1.57	17.28	10.96
C.V.		4.32	149.29	44.40	89.54	172.98	89.12	75.66	206.66	204.75	142.02	104.98
Minimum		6.75	0.40	0.07	0.67	0.00	0.00	0.00	1.25	0.38	9.86	10.17
Maximum		7.94	14.50	1.06	24.67	132.00	4.40	2.00	289.75	34.87	333.30	231.56
Skew		-0.73	1.98	-0.06	0.73	2.35	2.02	0.70	2.33	3.72	2.30	2.22

Table.4 Heavy metals status in soil samples of Al-Ahsa, their descriptive statistics and Saudi Standards

Sample	Rhizosphere Plants	As	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	P	Pb	Zn
		ppm											
H1	Palm trees	0.01	0.00	0.01	0.25	0.00	59.74	0.01	0.00	0.10	6.12	0.05	0.00
H2	Palm trees	0.03	0.00	0.00	0.17	0.00	46.22	0.00	0.00	0.11	5.03	0.05	0.00
H3	Palm trees	0.03	0.00	0.00	0.07	0.00	22.54	0.00	0.03	0.02	5.70	0.02	0.00
H4	Palm trees	0.01	0.00	0.00	0.23	0.00	49.93	0.20	0.00	0.08	5.58	0.03	0.00
H5	Palm trees	0.00	0.00	0.01	0.29	0.00	48.54	0.25	0.00	0.09	18.34	0.04	0.26
H6	Alfalfa,	0.04	0.00	0.01	0.53	0.00	61.32	0.08	0.00	0.19	42.57	0.04	0.00
H7	Citrus,	0.01	0.00	0.01	0.40	0.00	52.20	0.00	0.00	0.16	45.85	0.05	0.00
H8	Palm trees	0.00	0.00	0.00	0.29	0.00	48.46	0.00	0.00	0.13	47.59	0.05	0.00
H9	Alfalfa	0.00	0.00	0.01	0.19	0.00	58.71	0.03	0.00	0.13	44.58	0.04	0.00
H10	Citru	0.03	0.00	0.00	0.11	0.00	38.76	0.00	0.00	0.05	4.39	0.03	0.00
H11	Palm trees	0.00	0.00	0.00	0.13	0.00	45.37	0.00	0.00	0.10	35.69	0.02	0.00
H12	Clover,	0.00	0.00	0.00	0.23	0.00	35.97	0.00	0.00	0.09	31.65	0.03	0.00
H13	Palm trees	0.02	0.00	0.00	0.36	0.00	48.76	0.00	0.00	0.09	2.21	0.05	0.00
H14	Palm trees	0.04	0.00	0.01	0.37	0.00	55.66	0.00	0.00	0.13	36.96	0.05	0.00
H15	Citrus	0.00	0.00	0.00	0.32	0.00	48.83	0.00	0.02	0.11	30.94	0.05	0.00
H16	Palm trees	0.00	0.00	0.01	0.41	0.00	57.31	0.00	0.00	0.11	2.92	0.06	0.00
H17	Palm trees	0.01	0.00	0.01	0.18	0.00	67.28	0.00	0.00	0.08	0.89	0.02	0.00
H18	Palm trees	0.02	0.00	0.00	0.18	0.00	56.17	0.00	0.00	0.08	1.02	0.03	0.00
H19	Citrus	0.00	0.00	0.00	0.10	0.00	31.30	0.00	0.00	0.03	1.41	0.02	0.00
H20	Palm trees	0.05	0.00	0.00	0.06	0.00	18.79	0.00	0.00	0.02	1.10	0.02	0.00
H21	Palm trees	0.01	0.00	0.00	0.07	0.00	21.32	0.00	0.00	0.05	28.29	0.02	0.00
HC	Bulk Soil	0.00	0.00	0.00	0.12	0.00	31.35	0.00	0.00	0.06	25.82	0.02	0.00
Descriptive Statistics (n=22)													
Mean		0.01	0.00	0.00	0.23	0.00	45.66	0.03	0.00	0.09	19.30	0.04	0.01
SD		0.02	0.00	0.00	0.13	0.00	13.67	0.07	0.01	0.04	17.64	0.01	0.06
SE Mean		0.00	0.00	0.00	0.03	0.00	2.92	0.01	0.00	0.01	3.76	0.00	0.01
C.V.		116.08	M	113.61	55.91	M	29.95	261.54	333.47	48.07	91.41	37.94	469.04
Minimum		0.00	0.00	0.00	0.06	0.00	18.79	0.00	0.00	0.02	0.89	0.02	0.00
Maximum		0.05	0.00	0.01	0.53	0.00	67.28	0.25	0.03	0.19	47.59	0.06	0.26
Skew		0.82	M	0.98	0.53	M	-0.57	2.61	3.14	0.19	0.33	0.19	4.36
Maximum Acceptable Limit (ppm) according to Ministry of Environment Water & Agriculture, Kingdom of Saudi Arabia													
Agriculture Soil		17.00	1.40	20.00	64.00	63.00	-	-	4.00	45.00	-	70.00	200.00

Fig.2 USDA soil texture triangles showing soil texture classes of Al-Kharj (A) and Al-Ahsa (B)

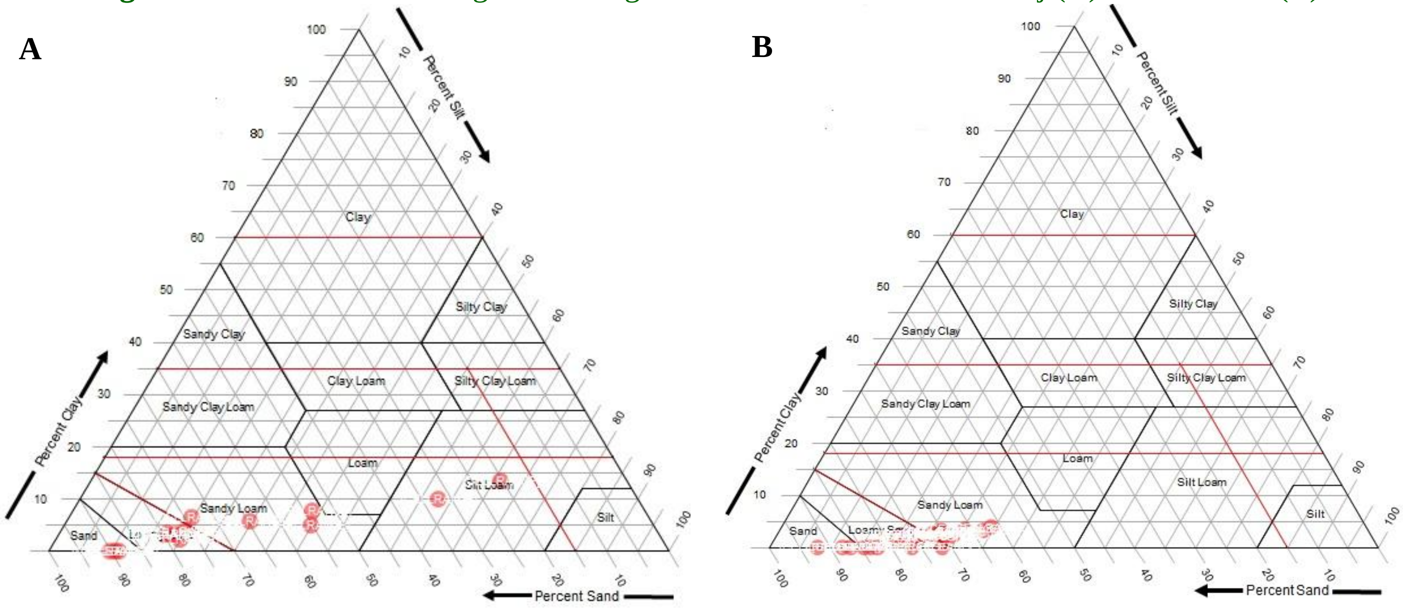


Fig.3 Spearman correlation among the soil properties of Al-Kharj samples

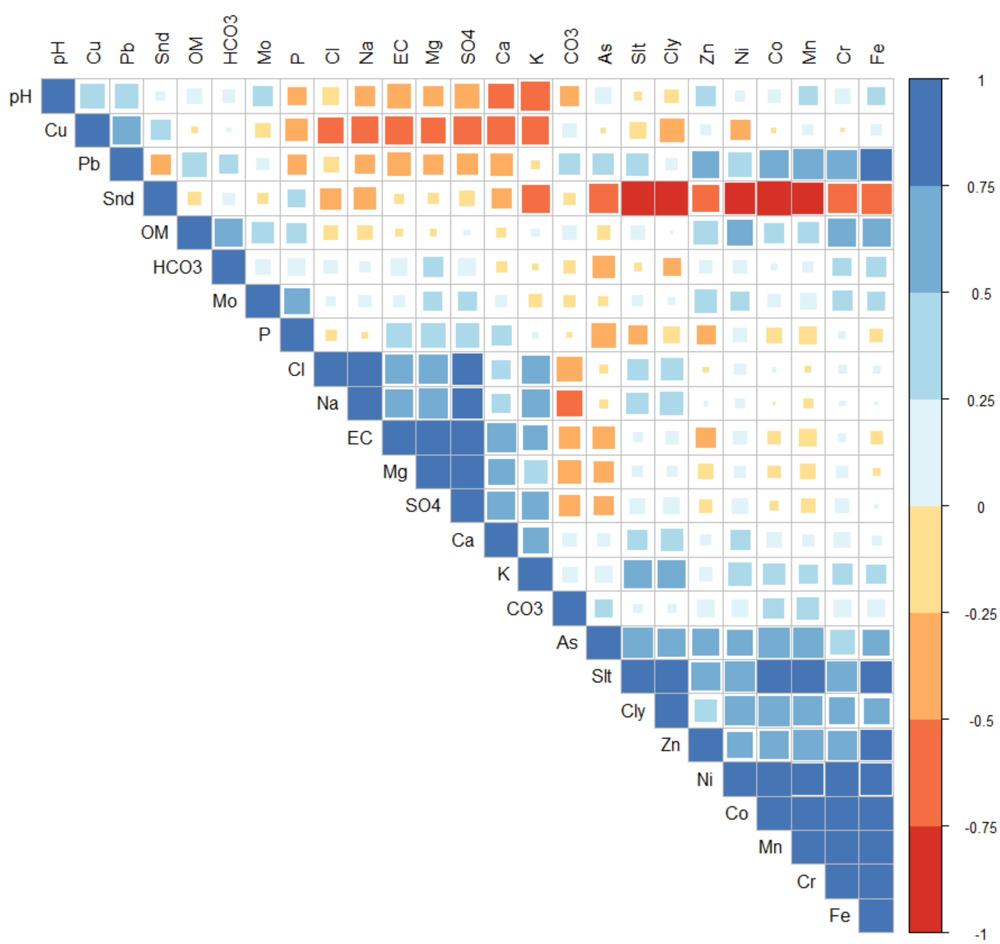


Fig.4 Spearman correlation among the soil properties of Al-Ahsa samples

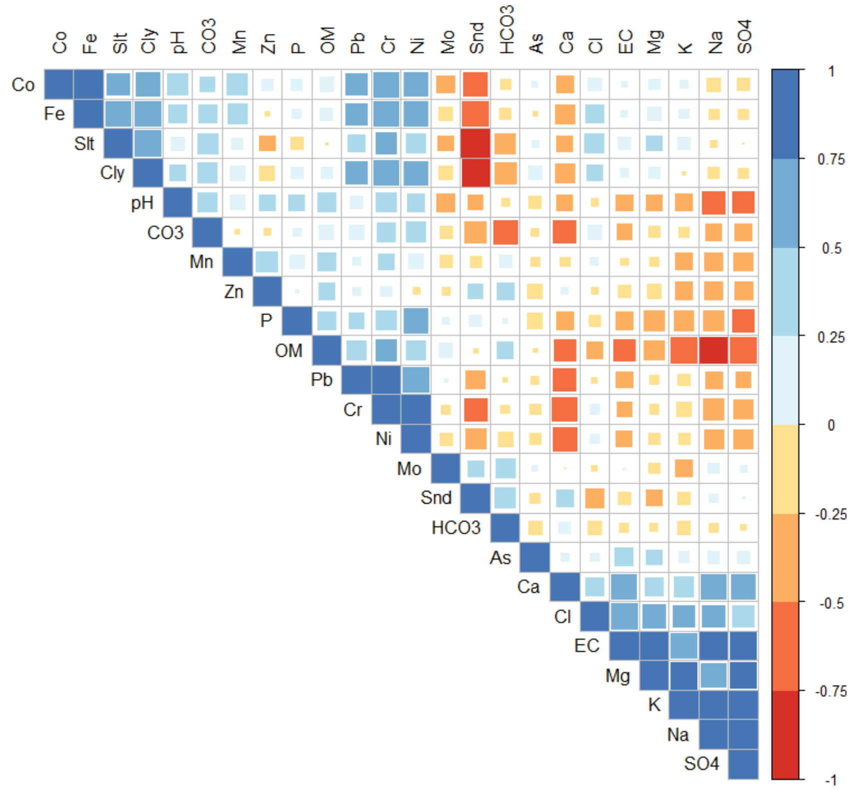


Fig.5 Enumeration of total bacteria in soil samples of Al-Kharj.

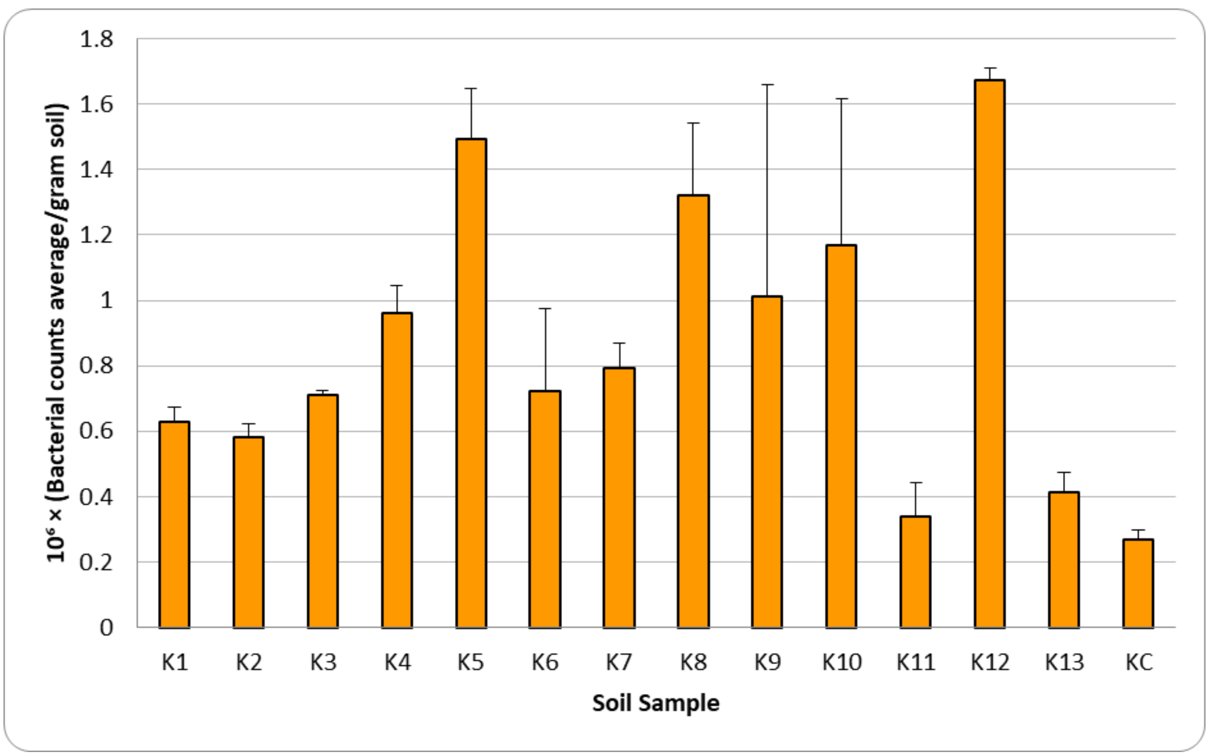


Fig.6 Enumeration of total bacteria in soil samples of Al-Ahsa

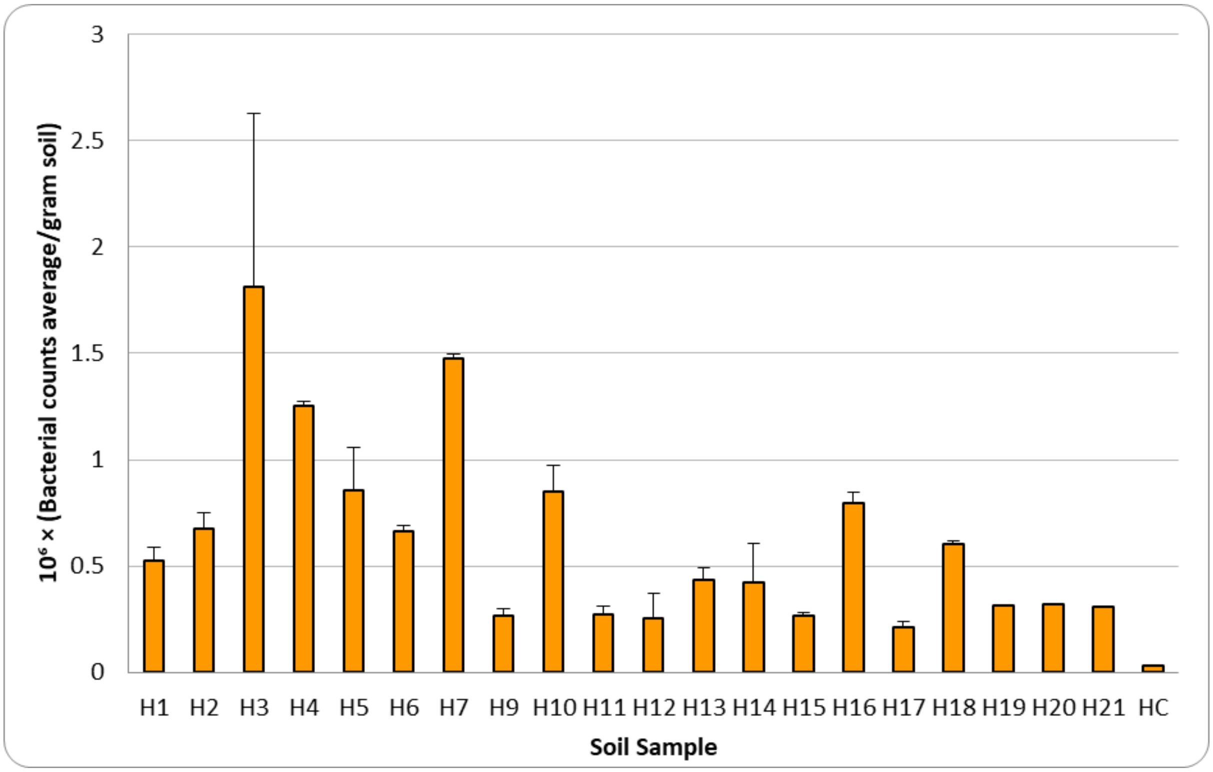


Fig.7 Enumeration of total fungi in soil samples of Al-Kharj.

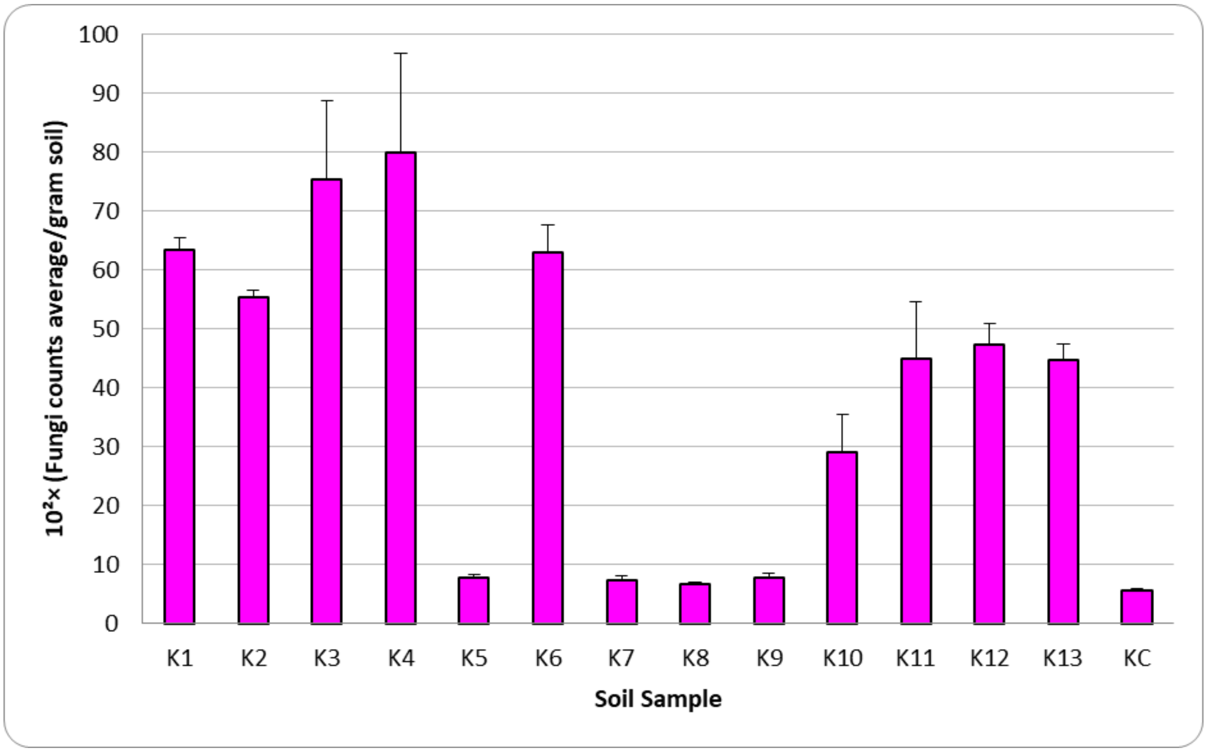
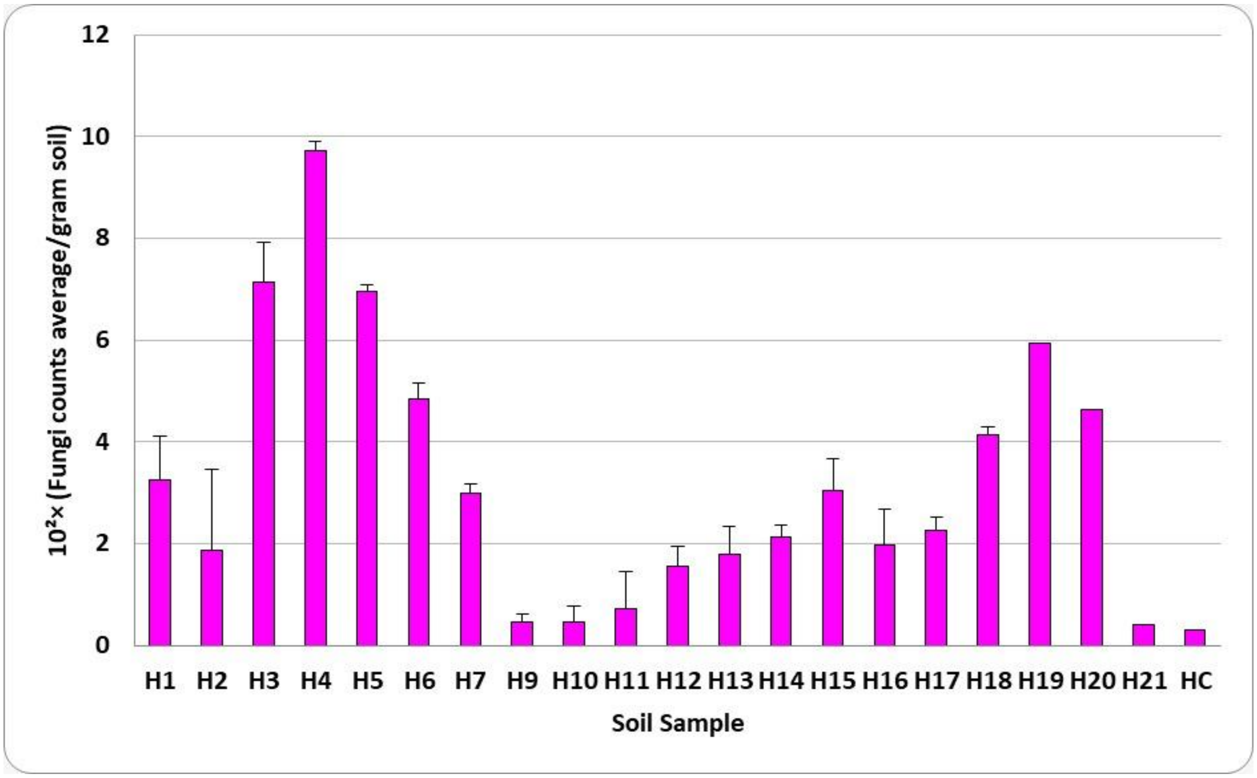


Fig.8 Enumeration of total fungi in soil samples of Al-Ahsa



Variation in microbial population among the samples may be due to the influence of agronomic practices and other chemical, physical, biological and environmental parameters. Praeg *et al.,* (2019) also reported the diversity between rhizosphere and bulk soil due to the effect of rhizo deposits and other environmental factors. This study also reported the highest number of total bacteria as compared with total fungi counts in both studied locations (i.e. Al-Kharj and Al-Ahsa), this trend was inline with the findings of (Sohaib *et al.,* 2022). The adaptation of cultural bacteria to the Al-Kharj and Al-Ahsa cropping zones indicates the studied zone could be a rich resource for discovering new microbial isolates of economic importance that could be important for human life, agriculture, industry, and bioremediation of environmental pollutants (Dias *et al.,* 2009; Dourado *et al.,* 2012; Sohaib *et al.,* 2022; Thompson *et al.,* 2013).

It is interesting to mention that some crops were not conducive to the growth of fungi, such as K5 and K8, on the contrary, fungal numbers were more in K10 and K13 at ALKharj region and at Al-Ahsa very low fungi population at H9 and H10. Most of the Palm trees gave high population. Perhaps this is due to the management of the farms and the use of fungicides to reduce fungal infection in the soil and obtain a good product.

There is no clear effect of plant type on the microbial numbers, whether bacteria or fungi, although the date palm was sometimes better than other crops such as K4, K5, K10 and H7. However, we need a more study to focus of such effect in the field.

Climatic conditions and agronomic practices of Al-Kharj regions are more in favorite of OM contents as compared to Al-Ahsa region, which also support microbial population. The average of total bacterial counts in Al-Kharj (8.6×10^5 cfu/g) is about double than average of total bacterial counts in Al-Ahsa (4.6×10^5 cfu/g). Average of total fungi counts is also more in Al-Kharj (3.8×10^3 cfu/g) than Al-Ahsa (2.2×10^2 cfu/g). Along with soil organic matter the comparative higher population in Al-Kharj regions indicates that Al-Kharj is more productive. To confirm this we might need more investigation especially to confirm the microbial community structure on molecular level.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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