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Survey of *Fusarium* Species in an Arid Environment of Bahrain III. Abundance and Seasonal Changes of *Fusarium* Species in the Terrestrial Habitats of Bahrain Island

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ABSTRACT. Twelve *Fusarium* species were recovered from seven different habitats, namely salt marsh, *playa* basin, *sabkha,* sand dunes, *rhoda,* water spring, and cultivated soil in Bahrain Island. A soil-dilution plate technique was used to recover *Fusarium* species on Nash and Snyder, Komada selective, and *Fusarium* selective medium. A total of 59 isolates were recovered in summer and a total of 323 isolates were recovered in winter. The species recovered were *F. oxysporum, F. solani, F. tricinctum, F. equiseti, F. sambucinum, F. pallidoroseum, F. chlamydosporum, F. compactum, F. reticulatum, F. nivale, F. lateritium,* and *F. moniliforme. F. solani* and *F. oxysporum* were found to be the most prevalent species in summer and in winter. The results indicate that species distribution and abundance over this small geographical scale could be affected by salinity.

Studies on the ecology of fungi, particulary the genus *Fusarium,* are very limited in the Saharo-Arabian phytogeographical region. The biota in this region is under extreme stress, mainly due to drought and high salinity. Under such conditions, fungal spores are dormant and they germinate only when conditions become favourable. Only 3.4% of the total area of the Arab countries are cultivated with field crops, vegetables and fruit trees (Batanouny 1992). Large areas of the non-cultivated soils are characterized by high salinity and alkalinity (Batanouny 1993). Natural vegetation cover and productivity under such conditions are generally low. However, many plant species are adapted to these extreme conditions and some are of potential economic use. Halophytic plants are used as range plants, for fuel wood, windbreaks, for tannin production and for cleaning clothes (Abbas *et al.* 1992, Batanouny 1993).

The use of such lands in conventional agriculture, locally, as well as worldwide, is very much limited by the scarcity of fresh water for the irrigation of salt-sensitive plants. This raises the possibility of using seawater or saline water to grow salt-tolerant plants (Glenn *et al.* 1982, Aronson *et al.* 1988, Ismail *et al.* 1993). Thus, saline soils are of potential use to solve many agricultural problems facing the world today.

Ecological studies of fungi, including *Fusarium,* in arid environments are well documented (Ranzoni 1968, Burgess 1981, Stoner 1981, Marasas *et al.* 1988). However, similar studies in the Saharo-Arabian phytogeographical region are very few (Salama *et al.* 1971, Abdulla and Gindy 1987, Khodair *et al.* 1991).

An ecological study of this genus, in different habitats, in an arid region, could contribute to a better understanding of the nature and agricultural potential of such environments. In this present work we make an initial study of *Fusarium* in a number of natural habitats of Bahrain Island.

Materials and Methods

Study Area

Bahrain is an archipelago of 33 islands located in the Arabian Gulf 25 km off the eastern Saudi Arabian coast. The largest of these islands is Bahrain Island with a total area of 612 km^{-1} (Fig. 1).

Habitats

Seven contrasting habitats were surveyed, namely salt marsh, *playa* basin, *sabkha,* sand dunes, *rhoda,* water spring, and cultivated soil.

Salt marsh. This habitat is located at the north-western coastal area. The habitat is dominated by *Phragmites australis* (Cav.) Trin. ex Steud. The soil belongs to the cultivated solonchak group and is usually wet due to the infilteration of high tide and the inundation of seawater.

Playa basin. This habitat is located in the central depression of the main island at a relatively low elevation compared to the nearby *jabal.* The soil is mainly of raw minerals. The dominant plant species is *Zygophyllum qatarense* Hadidi.

Sabkha. This habitat represents an inland saline environment with cultivated solonchak. It is dominated by the halophyte plant *Halocnemum strobilaceum* (Pall.) M. Bieb. In many parts of this site the top layer of the soil is in the form of salt crusts.

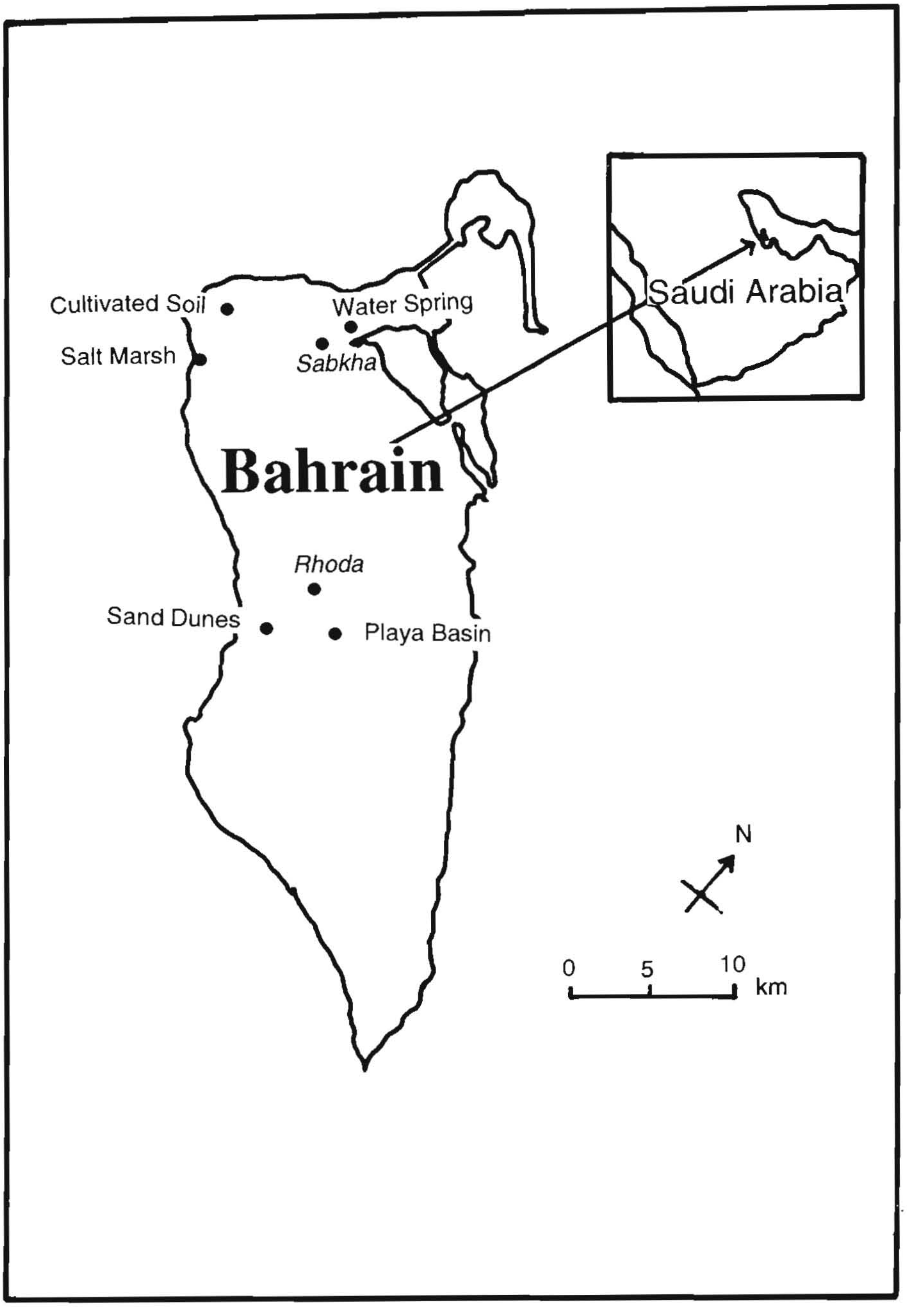

Fig. 1. Location map of Bahrain and the distribution of the habitats surveyed.

Sand dunes. The sand dunes are located mainly in the west of the island. They are in the form of phytogenic mounds consisting mainly of raw mineral soils. The dominant plants of these mounds are *Z. qatarense* and *Sporobolus arabicus* Boiss.

Rhoda. This is a low area, characterized by the presence of accumulated aeolian and alluvial deposits. The habitat has a good vegetation cover, mainly due to the growth of *Prosopis juliflora* (Sw.) DC. trees in addition to shrubs, and under-shrubs such as *Lycium shawii* Roem. et Schult. and *Panicum turgidum* Forssk.

Water Spring. This is an aquatic habitat located in the north-eastern part of the island. It has a water canal extending Northwards. The banks of this canal are inhabited by *Phragmites australis, Cynadon dactylon* (L.) Pers., and *Sesuvium verrucosum* Raf.

Cultivated Soils. These are found in the northern and eastern regions of Bahrain Island. The main cultivated plant is the date palm, in addition to some vegetables.

Soil

Doornkamp *et al.* (1980) divided the soils of Bahrain into five major groups: cultivated solonchak, natural solonchak, regosols, raw mineral soils, and rock dominated areas. Both types of solonchak soils are located mainly in the coastal areas, extending inside the island as far as the beginning of the backslopes. The regosols, raw mineral soils and rock dominated areas are mainly found in the central and southern parts of the island.

Climate

Bahrain, like mainland Arabia, falls in the North African-Euroasian dry climate province (McGinnies 1979). According to climatic norms obtained from the Civil Aviation Directorate (Bahrain), the climate is characterized by the prevalence of mild winters and very hot summers. The mean annual temperature is 17.3°C, with a June maximum of 47.5°C and a January minimum of 2.8°C. The climatic diagram of Bahrain shows that the dry period extends from May to October and the wet period extends from November to April. The mean monthly rainfall in summer is less than 1 mm and 15 mm in winter.

Collection of samples

Soil samples were collected from different habitats during the dry season (September, 1992) and the wet season (February, 1993). The collection sites were selected randomly. From each habitat, 5 samples (one from each site) were collected in clean polyethylene bags from the top 10-20 cm of the soil using a clean trowel. The 5 samples from each habitat were mixed together to give a composite sample weighing 2 kg. These composite samples were air-dried in a greenhouse for three days, sieved through 2 mm mesh and mixed thoroughly. Part of the sieved soil was used for chemical analyses and the other part was used for mycological analyses.

Chemical analyses

A soil: water extract (1:10) was prepared for the measurement of pH and electrical conductivity (EC). The measurement was taken using a JENWAY 1 Water Analyser. Twenty five ml of the soil extract was dried in an oven using a preweighed beaker. The difference in weight represented the total soluble salts (TSS). For the determination of organic matter percentage, 100 g of the soil sample was ashed in a furnace at 600 °C for one hour in a preweighed crucible. The organic matter percentage was calculated from the weight difference. Data were averaged from three replicates.

Mycological analyses

Based on a detailed comparative study of media used for the isolation of *Fusarium* species from the soils of Bahrain (Mandeel *et al.* 1994), a Nash and Synder medium (Nash *et al.* 1961), Komada selective medium (Komada 1975), and selective *Fusarium* medium (Papavizas 1967) were used in their original form in this study. Three replicates for each medium were taken for each habitat. The 10-fold soil dilution plate technique was adopted. A 10 g soil sample was diluted with 90 ml distilled water and shaken for five minutes. One ml was then taken, inoculated onto the media and incubated at 22 °C with 12 hour photoperiod under cool white fluorescent light for 10-20 days, or until the appearance of fungal colonies. For the purpose of identification, fungi with an appearance similar to *Fusarium* were transferred to a fresh potato dextrose agar medium using a monosporic technique and incubated for 10 days for further detailed examination. Identification of *Fusarium* species was carried out according to Nelson *et al.* (1983). Results reported here were the average for the three media used.

Data analyses

Statistical analyses of the data for communities similarity was based on the method of percentage similarity (Renkonen 1938). According to this method, relative abundance of each species in each community sample was calculated to give a total of 100% in each sample. The following formula was then applied:

$$P = \Sigma \text{ minimum } (P1i, P2i)$$

where P = Percentage similarity between samples 1 and 2
$P1i$ = Percentage of species i in community sample 1
$P2i$ = Percentage of species i in community sample 2

Results

A comparison of the soil analyses data revealed differences among the various habitats. In general, the electrical conductivity was higher in the summer than in winter (Table 1). However, *sabkha* attained the highest conductivity in summer (29800 uS/cm) and the lowest was recorded in the *playa* basin (174 uS/cm). In winter, the same pattern was observed with the highest conductivity in the sabkha (8338 uS/cm) and the lowest in the *playa* basin (106 uS/cm). The pH values ranged from 7.35 to 7.81 in summer and from 7.48 to 8 in winter. Variations in total soluble salts among the different habitats in summer and winter was pronounced (Table 1).

Table 1. Soil analyses for electrical conductivity (E.C., uS/cm), organic matter (O.M., %), Total soluble salts (T.S.S., %), and pH of various habitats during Summer and Winter. Winter values are shown in parenthesis

Habitat	E.C.	pH	T.S.S.	O.M.
Salt Marsh	8700 (1626)	7.67 (7.6)	6.26 (2.69)	13.92 (3.41)
Playa Basin	174 (106)	7.77 (8.0)	1.73 (0.75)	0.35 (0.51)
Sabkha	29800 (8338)	7.35 (7.57)	20.95 (7.88)	16.21 (9.22)
Sand Dunes	4063 (1863)	7.55 (7.77)	4.14 (1.19)	0.80 (1.43)
Rhoda	793 (145)	7.77 (7.95)	2.13 (2.46)	2.74 (1.21)
Water Spring	5130 (379)	7.43 (7.81)	3.71 (1.19)	3.70 (11.06)
Cultivated Soil	1032 (362)	7.81 (7.48)	1.02 (3.56)	2.27 (0.87)

The lowest value of total soluble salts was found in the *playa* basin in winter (0.75%) and the highest was found in the *sabkha* in summer (20.95%). Organic matter varied from 0.35% in the *playa* basin in summer to 16.21% in the *sabkha* in summer.

Table 2. Average number of isolates of *Fusarium* spp. recovered from Nash and Snyder medium, Komada selective medium, and Selective *Fusarium* medium in the various habitats during Summer and Winter. S.M.: salt marsh: P.B.: *playa* basin; S.: *sabkha;* S.D.: sand dunes; R.: *rhoda,* W.S.: water spring, C.S.: cultivated soil. Winter values are shown in parenthesis

***Fusarium* spp.**	**S.M.**	**P.B.**	**S.**	**S.D.**	**R.**	**W.S.**	**C.S.**
F. oxysporum	1(0)	0(17)	0(0)	3(1)	0(35)	0(0)	1(23)
F. solani	4(2)	1(12)	2(0)	0(0)	0(84)	0(16)	1(54)
F. tricinctum	0(1)	1(3)	1(0)	0(0)	1(7)	0(0)	1(0)
F. equiseti	0(0)	0(0)	0(0)	0(0)	2(0)	0(0)	1(0)
F. sambucinum	0(1)	1(0)	0(0)	0(2)	20(7)	0(2)	1(0)
F. pallidoroseum	0(0)	1(0)	0(0)	0(0)	0(0)	0(0)	3(0)
F. chlamydosporum	0(0)	0(10)	0(0)	0(0)	0(0)	0(0)	0(0)
F. compactum	0(0)	1(37)	0(0)	0(0)	0(0)	4(0)	0(0)
F. reticulatum	0(0)	0(0)	0(0)	0(0)	1(0)	0(0)	1(0)
F. nivale	0(0)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)
F. lateritium	0(0)	0(0)	0(0)	0(0)	4(0)	0(0)	1(0)
F. moniliforme	0(1)	0(5)	0(0)	0(1)	1(0)	0(1)	0(0)
Total Isolates	5 (5)	5 (85)	3 (0)	3 (4)	29 (133)	4 (19)	10 (77)
Species Richness	2 (4)	5 (7)	2 (0)	1 (3)	6 (4)	1 (3)	8 (2)

Twelve *Fusarium* species were recovered from the different habitats (Table 2). These were *F. oxysporum* Schlecht. emend. Synd. and Hans., *F. solani* (Mart.) Appel and Wollenw. emend. Snyd. and Hans., *F. tricinctum* Corda, *F. equiseti* (Corda) Sacc. sensu Gordon, *F. sambucinum* Fuckel, *F. pallidoroseum* (Cooke) Sacc., *F. chlamydosporum* Wollnw. and Reinking, *F. compactum* (Woolenw.) Gordon, *F. reticulatum* Mont., *F. nivale* Fr. emend. Synd. and Hans., *F. lateritium* Nees emend. Snyd. and Hans., and *F. moniliforme* Sheldon. The result of the average number of isolates recovered (Table 2) shows that the highest number was that for *F. solani* in winter (84) in the *rhoda*. The total number of isolates was highest in the *rhoda* during the winter (133) and was lowest in the *sabkha* during the winter, when no isolate could be recovered (Table 2). When species richness is considered, the highest value found as for the cultivated soils in summer (8) and the lowest value in the *sabkha* in winter (0).

Fusarium species with 40% or more relative density at any one habitat are shown in Fig. 2. In addition, the relative density of species which occurred in at least 40% of the different habitats are also shown in Fig. 2. In summer, *F. solani* attained more than 40% relative density in two habitats (salt marsh and *sabkha*); *F. oxysporum* attained more than 40% relative density in only one habitat (sand dunes). However, in winter *F. solani* was prevalent in 4 habitats (salt marsh, *rhoda*, water spring, and cultivated soil). Similarity between the various habitats (Table 3) is highest between *sabkha* and salt marsh (67%), and *playa* basin and cultivated soil (50%) in the summer. In the winter, the highest similarity was between *rhoda* and cultivated soil (89%), and between water spring and cultivated soil 70%).

Discussion

Some of the recovered species in this study, namely *F. oxysporum, F. solani, F. tricinctum, F. lateritium,* and *F. nivale* were also reported from soil samples taken from a plastic tunnel environment in Bahrain (Mandeel and Abbas 1994). The previous species, in addition to *F. compactum,* were also reported from the Sonoran Desert (Ranzoni 1968) and from Iraq, with the exception that *F. lateritium* was absent and *F. moniliforme* was present (Al-Doory *et al.* 1959). Joffe and Palti (1977) reported the occurrence of *F. moniliforme, F. oxysporum, F. compactum,* and *F. solani* in the desert of Israel.

Fusarium solani was the most prevalent species isolated in this study (Fig. 2). This species was also found to be prevalent in habitats of other dry regions (Lim and Chew 1970, Wearing and Burgess 1977, Marasas *et al.* 1988). *Fusarium oxysporum* and *F. compactum* were also prevalent in number of habitats of Bahrain (Fig. 2). These three species are considered as typical soil-based fungi (Burgess 1981). Both *F. lateritium* and *F. moniliforme* are air-borne fungi. In addition, the latter may also

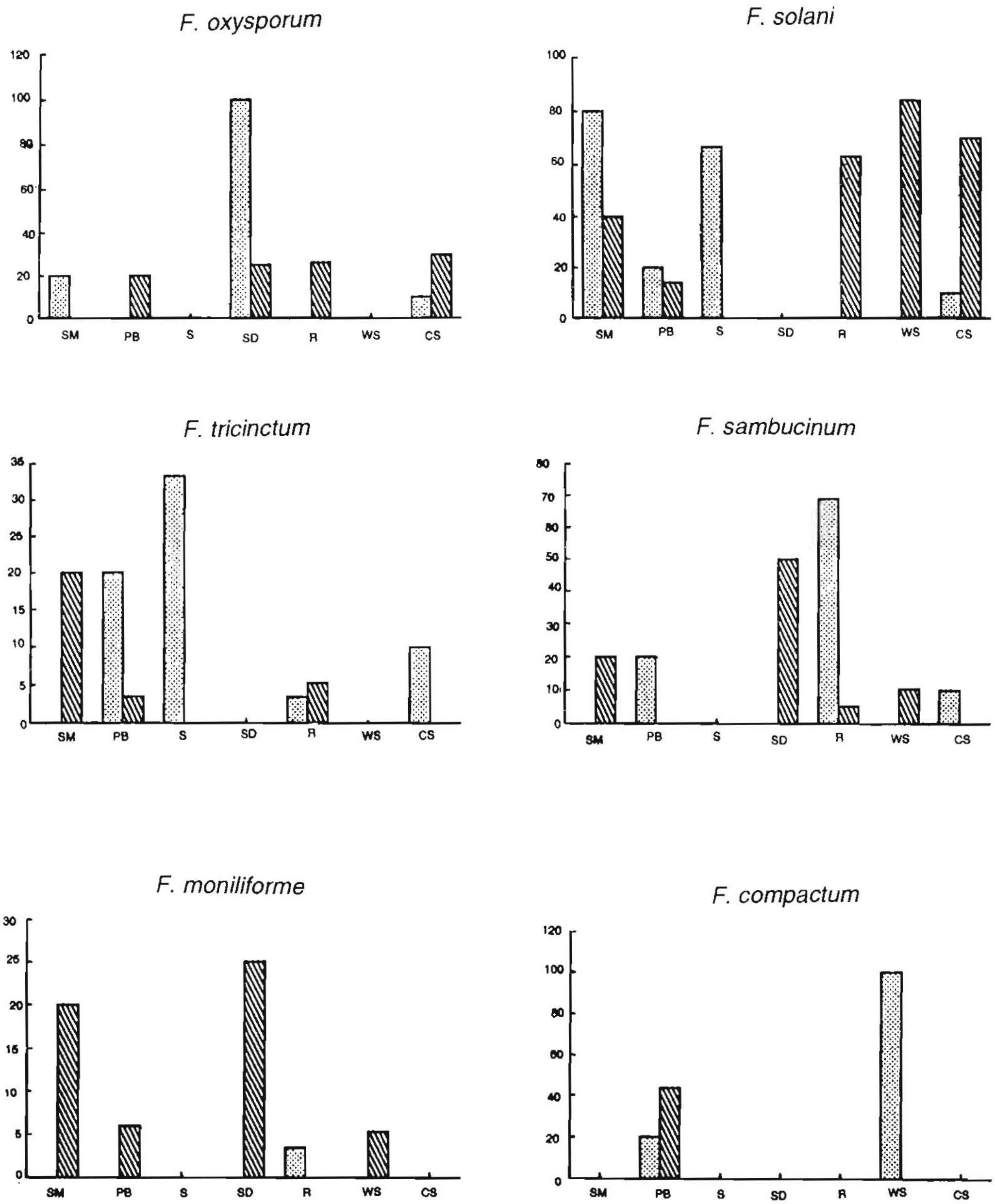

Fig. 2. Percentage relative density of selected *Fusarium* species in the habitats surveyed. SM: salt marsh; PB: *playa* basin; S: *sabkha;* SD: sand dunes; R: *rhoda;* WS: water spring; CS: cultivated soil. Summer: [dotted] Winter: [hatched]

be found in subterranean habitats (Burgess 1981). These two species occurred to a lesser extent than the previous three species. This could be attributed to their specific mode of existence. The occurrence and distribution of the remaining species varied from summer to winter and from one habitat to another. This is supported by the previous findings that some *Fusarium* species are very restricted in their distribution (Sangalang *et al.* 1994).

The large scale geographical distribution of *Fusarium* species shows that some, such as *F. oxysporum* and *F. solani,* are widely distributed and prevalent in many parts of the world, while others such as *F. tricinctum* and *F. moniliforme* are found mainly in specific geographical regions (Stoner 1981).

Studies on the distribution of *Fusarium* over a small geographical scale has also been reported (Kommedahl *et al.* 1988, Burgess and Summerell 1992, Onyike and Nelson, 1993). Stoner (1981) reviewed the effect of organic matter, pH, temperature, and moisture on the occurrence and distribution of *Fusarium* species within ecosystems. He concluded that, 'except in extreme situations, it is difficult to correlate the distribution of *Fusarium* species with individual soil factors such as pH, moisture, and organic matter'. In the present study, variation in the soil factors is pronounced for electrical conductivity (EC), TSS and for organic matter (Table 1). In summer, it seems that the combined effects of high temperature and high salinity has suppressed the growth of *Fusarium* species in the studied habitats (Tables 1 & 2). However, in winter, a noticeable increase in the average number of isolates of *F. solani* and *F. oxysporum* was observed in *rhoda,* cultivated soils, and *playa* basin (Table 2). These habitats were characterized at that time by low EC compared to the other habitats (Table 1).

The similarity of certain factors between habitats, such as high EC (*sabkh*a and salt marsh), or low EC (*playa* basin, *rhoda,* and cultivated soil) was reflected in the similarity percentage of *Fusarium* species between the various habitats in both summer and winter (Table 3).

The results of this study agree with the general pattern of distribution and abundance of *Fusarium* species found in arid regions. However, variations in the occurrence and prevalence of the different species seem to be affected by localized differences among the habitats studied, in particular EC and organic matter content. *F. solani* and *F. oxysporum* were the most prevalent species in these habitats.

Table 3. Similarity percentages of *Fusarium* spp. between the various habitats for Summer and Winter. S.M.: salt marsh: P.B.: *playa* basin; S.: *sabkha;* S.D.: sand dunes; R.: *rhoda,* W.S.: water spring, C.S.: cultivated soil. Winter values are shown in parenthesis.

Habitats	S.M.	P.B.	S.	S.D.	R.	W.S.	C.S.
S.M.	100 (100)	20 (24)	67 (0)	20 (40)	0 (51)	0 (56)	20 (40)
P.B.	20 (24)	100 (100)	40 (0)	0 (26)	23 (38)	20 (19)	50 (34)
S.	67 (0)	40 (0)	100 (100)	0 (0)	3 (0)	0 (0)	20 (0)
S.D.	20 (40)	0 (26)	0 (0)	100 (100)	0 (30)	0 (16)	10 (25)
R.	0 (51)	23 (38)	3 (0)	0 (30)	100 (100)	0 (68)	34 (89)
W.S.	0 (56)	20 (19)	0 (0)	0 (16)	0 (68)	100 (100)	0 (70)
C.S.	20 (40)	50 (34)	20 (0)	10 (25)	34 (89)	0 (70)	100 (100)

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مسح لأنواع فطر الفيوزاريوم *Fusarium* في بيئة البحرين الجافة
٣ : الوفرة والتغيرات الموسمية لأنواع الفيوزاريوم *Fusarium* في البيئات الأرضية لجزيرة البحرين

جميل عبد الله عباس و قاهر علي منديل

قسم علوم الحياة - كلية العلوم - جامعة البحرين

ص .ب (٣٢٠٣٨) - مدينة عيسى - البحرين

تم حصر إثني عشر نوعاً من فطر الفيوزاريوم *Fusarium* من سبع بيئات مختلفة في جزيرة البحرين وهي المستنقعات الملحية ، الأحواض ، السباخ ، الكثبان الرملية ، الرياض ، ينابيع المياه ، الترب الزراعية . وقد أستخدمت تقنية أطباق تخفيف التربة للكشف عن أنواع الفيوزاريوم بإستخدام وسط ناش وشنايدر ، وسط كومادا الإختياري ، ووسط الفيوزاريوم الإختياري . وقد تم الكشف عن ٥٩ عزلة في الصيف و٣٢٣ عزلة في الشتاء .

الأنواع التي تم حصرها هي فيوزاريوم أوكسي سبورم *F. oxysporum* ، فيوزاريوم سولاني *F. solani* ، فيوزاريوم تريسنكتم *F. tricinctum* ، فيوزاريوم ايكويزيتم *F. equiseti* ، فيوزاريوم سامبوسينم *F. sambucinam* ، فيوزاريوم باليدوروزيم *F. pallidoroseum* ، فيوزاريوم كلاميدوسبورم *F. chlamydosporum* ، فيوزاريوم كومباكتم *F. compactum* ، فيوزاريوم ريتكيولاتم *F. reticulatum* ، فيوزاريوم نيفالي *F. nivale* ، فيوزاريوم لاتريتم *F. lateritium* ،

وفيوزاريـوم مونيليـفورمي *F. moniliforme* . وقد وجد أن أكـثر الأنواع شيـوعاً في الصـيف والـشتاء هـي فيـوزاريوم سـولاني *F. solani* وفـيوزاريـوم أوكسـي سبـورم *F. oxysporum* . وتشير النتائج إن أن توزيع الأنواع ووفرتها على مدى جغرافي صغير قد يتأثر بالملوحة .