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Desert Plant-Fungal Endophytic Association: The Beneficial Aspects to their Hosts

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ABSTRACT: Dry environments have plants with special adaptations enable them to live on nutrient poor soils, in high temperature and with a scarcity of water, one of the most important features of these plants are the ability to establish symbiosis relation with different microorganisms. It is very important to study and take advantage of the mechanisms of the phenomenon of plant-microbes interaction to make a worldwide mutation in the biotechnological potential of efficient partnerships for agriculture and a range of applications. Desert plants could survive in extreme conditions via microbial association. Fungal endophytes afford special adaptation for these plants and improve their performance and resistance against biotic and abiotic stresses through production of bioactive compounds which certainly increase the adaptability of both endophytic fungi and their host plants. Although little studies investigate desert plants-fungal endophyte association but there is a great number of endophytic fungi isolated from desert plants all over the world. In this review, we shed light on endophytic fungi as growth promoting (GPEF), a vital source of natural compounds and secondary metabolites, antimicrobial agents and stress tolerance mediator. Also we display a number of biotechnological applications of endophytic fungi association with desert plants in the field of agriculture and medicine.

Keywords: Desert Plant-Fungal Endophytic,

INTRODUCTION

Desert plants are defying the extreme environmental conditions as sporadic precipitation, high temperatures, nutrient deficiencies, and intense solar radiation. Human population increases the percentage of the Earth's surface covered by deserts; globally hot deserts are the most common type of climate, representing 14.2% of the Earth's land area. Actually there are many different kinds of deserts with varying patterns of temperature and precipitation, the African Sahara classified a hot desert (Peel, *et. al.* 2007). The abiotic stresses conditions have a wide range of effects on the plant morphology, physiology, biochemistry and even on gene regulation. Temperature, water deficiency, salinity and heavy metal pollutant are major stress factors in relation to climate change. The abiotic stress factors also influence the biotic stress and reduce crop productivity (Kumar, 2018). Due to the prevailing severer climate change conditions, most plant populations are adapted and build new stress tolerance strategies to withstand and complete their life cycle. Vascular plants are among these plants which do not function as autonomous individuals, but house diverse communities of associated microbes, and make their resistance strategy through its microbes (Choudhary, *et. al.* 2016). Many researchers have reported that environmental stresses resulted from climate change are the major threat to future of food security (Battisti, 2009). All plant taxa investigated have well-established symbioses relations with a large variety of microorganisms. These microorganisms are known to support plant growth and to increase plant tolerance to biotic and abiotic stresses (Bent, 2006). Endophytic fungi are one of the most important microbes in plant micro-ecosystems and have significant influences on the growth and development of their host plants, but still little is known about the relationships between them (Kumar, 2018). Hot desert plants could survive in extreme conditions, undergoing morphological and biochemical adaptations that could be attributed to microbial activity (Brundrett, 2009). Endophytic fungi produce bioactive compounds exclusive to their host plants, which certainly increase the adaptability of both endophytic fungi and their host plants to biotic and abiotic stresses and these compounds can contribute to production of biologically active secondary metabolites (Zhang, *et. al.,* 2006; Firáková, *et. al.,* 2007; and Rodriguez, *et. al.,* 2009).

Endophytic fungi that live in desert plants are considered a vital source for many natural products (Strobel, *el. al.* 2004).

A. What are endophytic fungi

Endophytic fungi include all fungal organisms that grow inside plant tissues without causing any immediate negative effects and are not mycorrhizae (Carroll, 1988, Strobel, 2003, and Strobel, *et. al.*, 2008). Endophytic fungi may also include a wide range of fungi characterized by the ability of living for a certain period of their life cycle internally and asymptomatically in plants, they are believed to have evolved from pathogenic fungi that either have extended later periods or have lost their virulence (Saikkonen, *et. al.* 1998, and Souza, *et. al*. 2008). Endophytic fungi are belonging to mitosporic and meiosporic ascomycetes that asymptomatically colonize the internal tissues of the host plants and stay beneath the epidermal layer (Bacon, 2000). Fungal endophytes can be devided into two groups: 1- the balansiaceous group which specifically colonize grasses and usually belong to ascomycetes genera Epichloe and Balansia (anamorphs Neotyphodium and Ephelis), 2- the non- balansiaceous group that almost occurring in all plant species and usually belong to Ascomycota (Wang, *et.al.* 2007). Endophytes are known from plants growing in tropical temperature and boreal forests, from herbaceous plants, from various habitats including extreme arctic, alpine (Fisher, *et. al.* 1995) and xeric environments (Muhsin and Botth, 1987). Endophytic fungi have been isolated from phanerogams in alpine, temperate and tropical regions, although plants of Conifera, Ericaceae and Gramineae have been most intensively sampled (Jian Qui, *et.al.* 2008). Endophytic fungi play a vital ecological functioning process in plant succession through the beneficial interaction between them which formed in the long-term ecosystem evolvement, this interaction could promote plant growth, increase disease-resistant ability, and heighten abiotic stress tolerance (JianQiu, *et. al.* 2008). Many studies investigated the distribution and the community composition of endophytic fungi in common plants and their results proved that, the distribution and colonization rates of endophytic fungi were different among the bark, twigs, and leaves while some fungi are specific to certain plant family (JianQiu, *et.al*. 2008). Endophytic fungi are classified as the potential sources of novel natural products which may be exploited biotechnologically in many sectors as in medicine, agriculture and industry. Gradually, these organisms will be isolated and cultivated widely for biotech extra-exploitation processes (Visalakchi, and Muthumary, 2010).

B. Fungal Endophytes as stress tolerance mediator

Several studies showed that endophytic fungi could enhance the resistance of their host plants to biotic and abiotic stresses by producing bioactive molecules (Nejad, and Johnson, 2000; Cavaglieri *et. al.*, 2004). Plants of extreme environments have a certain adaptations to these stresses, for example, drought tolerance can be attributed to associated endophytic microorganisms (Rodriguez, *et. al*., 2008). Redman *et al.* (2002) studied the association between *Dichanthelium lanuginosum* growing in the geothermal soils of Lassen Volcanic and Yellowstone National Parks and its endophytic fungus *Curvularia protuberata* where the later was able to confer heat tolerance to the host plant. In India Thar Desert is characterized by dry and hot weather for most part of the year, fifteen plant species colonizing this arid habitat were used for isolation of 507 endophytic fungi of which thermotolerant isolates was evaluated. Six endophytes were tolerant to high temperature, among them *Chaetomium* sp. confer high temperature tolerance to a variety of Indian rice (Sangamesh, *et.al*. 2017). *Thermomyces lanuginosus* a thermophilic fungal endophyte isolated from desert plant *Cullen plicata* induced heat tolerance to inoculated cucumber plants (*Ali et. al.* 2017). Different types of a biotic stress tolerance provided by endophytes to different plant species are shown in Table 1.

C. Isolation of endophytic fungi from desert plants

Semiarid and arid lands constitute one-third of the terrestrial ecosystems, but still limited number of studies investigated root-associated fungal communities in semiarid grasslands. Table.1. Show the endophytic fungi isolated from desert plants. At the Sevilleta National Wildlife Refuge in (SNWR) New Mexico, fungal community associated with the roots of a dominant grass, *Bouteloua gracilis* was isolated by Alfro *et. al*. (2008). The most important results obtained are that *B. gracilis* roots are highly colonized by Dark Septat Fungi (DSF), in addition to its function as drought tolerance and nutrient acquisition, DSF may be integral to the function of arid ecosystems. Endophytic fungi play crucial ecological roles in protecting plants from harsh abiotic and biotic stresses so it is valuable to investigate the endophytic fungi associated with desert plants.

Table 1: Endophytic Fungi conferring abiotic and biotic stress tolerance in desert plants isolated from desert areas.

Desert	**Host plant**	**Endophyte**	**Stress type**	**Isolation organ**	**Reference**
Chihuahuan desert (new mexico)	*Boutrloua eriopoda, Atriplexcanescens*	*Various isolates*	Aridity, high temperature and drought	Root, and Leaves	Barrow *et al.* (2004)
Deaert areas (Arizona) USA	*21 Cacti species*	*Various isolates*	Aridity, high temperature and drought	stem	Suryanarayanan *et al*. (2005)
Sonoran (North America)	*Platycladus orientalis*	*Phyllosticta spinarum*	Aridity, high temperature and drought	leaves	Wijeratne *et. al*. (2008)
Chihuahuan desert (new mexico)	*Boutrloua eriopoda, Atriplexcanescens*	*9 isolates*	Aridity	Root	Lucero *et. al* (2005)
SNWR (New Mexico)	*Bouteloua gracills*	*Various isolates*	Aridity, drought and high temperature.	Root	Alfaro *et.al.* (2008)
Mongolia (China)	*Cistanche deserticola*	*Penicillium chrysogenum*	Aridity, high temperature, and drought	Root	Lin *et.al.* (2008)
Sothern desert (Egypt)	*Hyoscyamus muticus L.*	*44 Isolates*	Aridity, high temperature and drought	Root, Leaves and stem	Abdel-Motaal *et.al* (2010)
Rajasthan desert (India)	*Various plants*	*Piriformospora Indica*	High temperature, Drought, Aridity	Root	Varma *et.al* (2012)
Tennger (China)	*Various plants*	*19 Isolates*	Aridity, Soil infertility	Stem and leaves	Sun *et. al.* (2012)
Sonoran (North America)	*Various plants*	*Various isolates*	Aridity, high temperature and drought	Root, Leaves and stem	Wellensiek *et. al.* 2013
Sonoran (North America)	*Various plants*	*Preussia sp.*	Aridity, high temperature	Stem and leaves	Massimo *et.al.* (2015)
Sinai desert (Egypt)	*Asclepias sinaica*	*3 isolates*	Aridity, drought and high temperature.	Root	Fouda *et.al* (2015)
Wadi Dawkah, Dhofar(Oman)	*Boswellia sacra*	*77 Isolates*	Aridity, high temperature, and drought	Park and leaves	Khan *et al.* (2016)
Thar desert (India)	*Various plants*	*507 Isolates*	Aridity, high temperature, and drought	Root, stem, and leaves.	Sangamesh *et. al* (2017)
Eastern desert (Egypt)	*Cullen pilicata*	*Thermomyces lanigunosus*	Aridity, high temperature, and drought	Root	Ali *et.al.* (2017)
Atacama desert (Chile)	*Chenopodium quinoa*	*22 isolates*	Drought, high temperature.	Root	Teuber *et.al* (2017)
Wadi El zwatin, Siani, (Egypt)	*Teucrium polium*	*5 isolates*	Drought and high temperature	Leaves	Hassan (2017)
Aswan (Egypt)	*Ziziphus spina-christi Lawsonia inerims*	*57 isolates*	Drought and high temperature	Leaves and stem	Zidan *et.al.* (2016)

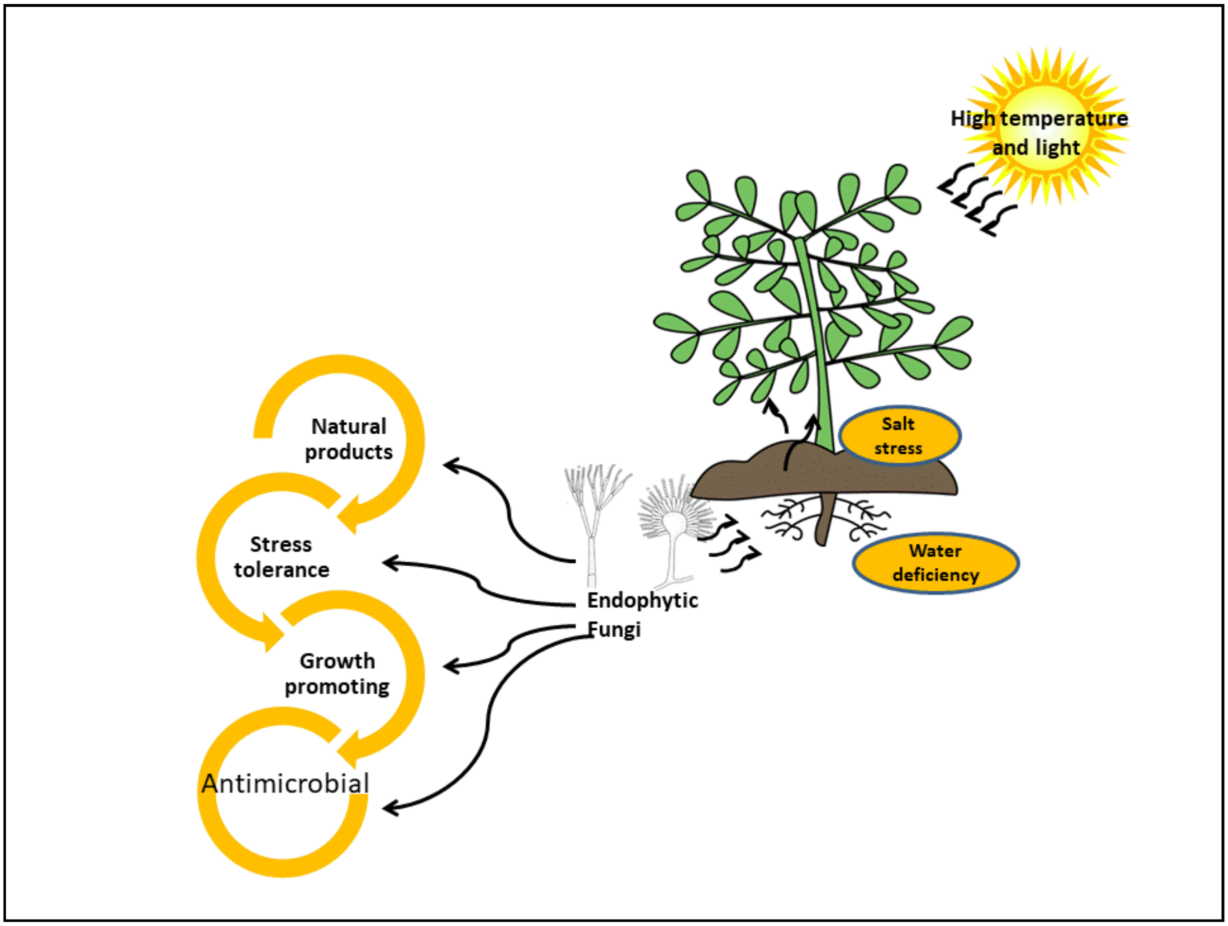

Fig .1. Biotic and a biotic stress affecting desert plant; and explaining the role of endopytic fungi association to the overall plant health improving via secreting natural metabolites enabling their host to skip harsh environmental stresses, intensified its growth and rebel pathogens and herbivores.

Sun *et.al*. (2012), investigated the fungal community of eight desert plant species from a desert in China where the most important finding were that the desert plants had low diversity of fungal communities but with a high colonization rate and there was tissue specificity of some endophytes as *Phoma pomorum* and *Phoma* sp. A study from Sonoran Desert, which classified as the hottest and most species-rich desert biome in North America examined the abundance, diversity, local distributions, and host affiliations of fungal endophytes in the leaves and stems of woody plants, and providing insights into the ecological factors affecting these endophytes and plant-fungal associations in arid and semiarid lands (Massi,mo *et .al*. (2015). *Bouteloua eriopoda* and *Atriplex canescens* are important species in arid rangelands of the northern Chihuahuan Desert, colonized by dark septated endophytic fungi that cannot be eliminated by seed disinfestation, Barrow et. al. 2004, detected that the same native fungal endophytes associated with callus and regenerated plants of *Bouteloua eriopoda* and *Atriplex canescens*. In some desert areas of Arizona Suryanarayanan, *et. al.* (2005), studied 21 cacti species and isolated 14 endophytic fungi, they found *Cylindropuntia fulgida* had the maximum fungal endophytes diversity, and *Cylindropunti ramosissima* associated with the maximum number of endophytic fungi, while *Alternaria* sp., *Aureobasidium pullulans,* and *Phoma spp*. were isolated from several cacti. Teuber *et.al.* 2017 at Atacama Desert isolated 100 endophytic fungi form *Chenopodium quinoa, Pencillium, Phoma* and *Fusarium* were the dominant genera. Zidan (2016) isolated 57 endophytic fungi from two medicinal plants, *Ziziphus spina-christi* and *Lawsonia inermis* inhabiting the Egyptian environment of which *Aspergillus, Penicillum* and *Paecilomyces* were the most dominant endophytic fungi.

D. Growth promoting endophytic fungi

Fungal endophytes live within plant tissues and have been shown to assist plant growth and health. Although desert plants are exposed to many environmental stresses that attributed to plant growth promoting endophytic fungi (PGPE) association but still have receive little attention, PGPE produce various bioactive compounds with several biological activities which can be directly or indirectly described as plant growth promoting (PGP) agents (Sun *et. al*. 2012). Fungal endophytes make genetically, physiologically, and ecological modification to its host plants. Fungal endophytes isolated by Lucero *et.al.* 2005 alter the morphology, biomass and reproductive potential of *Boutrloua eriopoda, Atriplex canescens.* Verma *et. al.* (2012), reported that *Piriformospora indica* isolated as a symptomless root endophyte from various plants, induced adaptation to abiotic and biotic stresses, growth promotion, early flowering, higher seed yield, changes of secondary metabolites of its host plants. Fouda, *et. al*. (2015), isolated three different fungal endophytes from the medicinal plant *Asclepias sinaica* of Sinai desert, which had a good impact on plant growth parameters including a considerable increment of roots, and may be mediated by these endophytic fungi effectiveness to produce ammonia and IAA. From the park and leaves of *Boswellia sacra* tree, 77 endophytic fungi were isolated, most of the isolated endophytic fungi showed the potential to produce IAA as growth promoting agent, *Preussia sp.* improved its host plant growth parameters and accumulation of photosynthetic pigments (Khan, *et. al*. 2016)). Egyptian desert characterized by harboring extreme hot arid adapted desert plants. An extreme hot endophyte, *Thermomyces lanigunosus,* isolated from *Cullen plicata* improved the root length of cucumber as a result to drought and heat tolerance mediate (Ali, *et. al*. 2017). Another recent fungal endophytic isolation from Egyptian desert is Hassan (2017), from *Teucrium polium* in Siant katherine protectorate. Five endophytic fungi were isolated and showed high growth pormoting and antimicrobial activity, and high rate of phosphate solubilization. Hundred twenty-two endophytic fungi were isolated from thirteen plant species grown in the coastal sand dunes of korea, that exhibited secondary metabolites production which helps in the increment of the height and shoot length of Waito-C rice (Khan, *et.al*, 2012).

E. Endophytes as source of natural compounds

Endophytic fungi associated with desert plants are one of the most important sources of several natural products (Strobel, *et. al*. 2004). *Penicillium chrysogenum* was isolated from the root of *Cistanche deserticola* collected from Inner Mongolia in northwest China. This study exploited the medicine characteristic of *C. deserticola* and its associated endophytic fungi to produce new medicinal components (Lin, *et. al.*, 2008). Wijeratne *et. al.* (2008), isolated five new metabolites from the fungal endophyte *Phyllosticta spinarum* associated with *Platycladus* orientalis in the Sonoran Desert, one of these compounds (Tauranin) showed potential anticancer promoter. In plant-microbe interactions, the higher accumulation of carbohydrates and flavonoids in plant tissue act as ROS-scavenger and signaling molecules promoting plant growth and increase tolerance to abiotic and biotic stress (Grover, *et. al*. 2011), and this in agreement with Ali, *et. al*. (2017) where the endophytic fungus *Thermomyces lanuginosus* increases total saponin, flavonoid, soluble and insoluble carbohydrate and soluble protein contents of the cucmber inoculated plants (Ali, *et.al.* 2017)

F. Endophytes as antimicrobial agents

According to Abdel-Motaal, *et. al*. (2010), the desert medicinal plant *Hyoscyamus muticus* L. harbored 44 strains of endophytic fungi secrete antifungal compounds. Fungal endophytes *associated with Asclepias sinaica* have antimicrobial inhibiting effect against bacterial and fungal strains (Fouda, *et. al*. 2015). Even with the most dangerous pathogens (Viruses) fungal endophytes have their effective function as antimicrobial, in this context Wellensiek, *et. al*. (2013), extracted four secondary metabolite compounds from endophytic fungi harbored some desert plants; these compounds inhabit HIV-1 (Virus) replication completely. Endopytic fungi isolated from Sinai desert plants have been screened and showed high antimicrobial activity against bacteria (Hassan, 2017).

Fungal Endophytes as biotechnology tools. Endophytes associated with arid plants have revealed a great phylogenetic diversity in association with their hosts and give chance to survey new taxa or new fungal habitats. These microorganisms have a great potential for; Use in plant resistance processes to face global climate changes especially for economic importance plants, Production of pharmacological metabolites, and Preservation of natural ecosystems (Bezerra, *et al*. 2017).The biotechnological interest of Endophytic fungi appeared strongly in 1993 when the anticancer drug Taxol isolated from endophytic fungus of a medicinal plant in the United States (Stierle, *et. al.* 1993).

Penicillium chrysogenum and *Penicillium crustosum* isolated by Hassan (2017) from medicinal desert plant *Teucrium polium* exhibited high rate of phosphate solubilization in maize as an economical important crop, and suggesting that phosphate solubilization by microbes is a promising tool for bio-fertilizer application. Bezerra, *et al.,* (2012) extended fungal endophytes isolated from the cactus Opuntia ficus-indica in the production of pectinase, cellulase, xylanase, and protease enzymes. Forty-four fungal endophytes isolated from *Cereus jamacaru subsp. Jamacaru*, among these endophytes *Aspergillus, Fusarium,* and *Penicillium* synthesize L-asparaginase profusely, and this reference have proved that cacti endophytes have a great potential for biotechnological production of antileukemic enzymes (Santos, *et. al.* 2015). The biotechnological applications of endophytic fungi are recent and scarce that need more studies in future.

CONCLUSION

Endophytic fungi isolated from desert plants play a key front role in the future biotechnological challenge. Our review tried to highlight desert plant-fungal endopytes interaction that conifer these plants to adapt to the extreme arid desert conditions. These factors can possibly affect the endophytic fungi population structure and distribution, as well as the benefits of these endophytes to their host desert plants, also the desert harsh conditions can encourage the production of bioactive compounds. In addition, the previous studies proved that there are many types of beneficial interactions between endophytic fungi and their desert host plants. For example: (1) growth enhancement of host desert plants, (2) resistance promotion of the desert host plants to biotic and abiotic stresses, (3) production of secondary metabolites, including bioactive compounds that could be used in many fields as medicine, industry and agriculture, and (4) antimicrobial agents that could be used as bio-controller. The mentioned above findings may have an important applied implications in agricultural sector. This review concluded that endophytic fungi isolated from desert plants are of great importance and need further assessment in the coming years.

AUTHORS' CONTRIBUTION

ME and AH suggested the topic and wrote the first draft. SE critically edited the manuscript and ME, UR, SE revised the final version. All authors read and approved the final manuscript.

REFERENCES

Abdel-motaal, FF., Mortada, SM., El-Zayat, SA., El-sayed, MA., Ito, SI. (2010). Antifungal activity of endophytic fungi isolated from Egyptian henbane (*Hyoscyamus muticus* L.) *Pak. J. Bot.* **42**(4): 2883-2894.

Ali, A., Abdelrahman, M., Radwan, U., El-Zayat, S., El-Sayed, A. (2018). Effect of Thermomyces fungal endophyte isolated from extreme hot desert adapted plant on heat stress tolerance of cucumber. *App. Soil Eco.,* **124**: 155-162

Bacon, C., White, J. Microbial Endophytes (2000). New York. NY: CRC.

Barrow, JR., Osuna-Avila, P., Reyes-Vera I. (2004). Fungal endophytes intrinsically associated with micropropagated plants regenerated from native *Bouteloua eriopoda* torr. and *Atriplex canescens* (pursh) nutt. In Vitro Cell. *Dev. Biol. Plant.* **40**: 608-612.

Battisti, D., Naylor, R., (2009). Historical warnings of future food insecurity with un precedent seasonal heat. Science. 323: 240-244.

Bezerra, JDP., de Azevedo, JL., Souza-Motta, CM. (2017). Why Study Endophytic Fungal Community Associated with Cacti Species? J.L. de Azevedo, M.C. Quecine (Eds), Diversity and Benefits of Microorganisms from the Tropics. Springer. 21-35.

Bezerra, JDP., Santos, MGS., Svedese, VM., Lima, DMM., Fernandes, MJS., Paiva, LM., Souza-Motta, CM. (2012). Richness of endophytic fungi isolated from *Opuntia ficus-indica* Mill. (Cactaceae) and preliminary screening for enzyme production. *World J Micro. Biotech*. **28**: 1989–1995.

Brundrett, MC. (2009). Mycorrhizal associations and other means of nutrition of vascular plants: understanding the global diversity of host plants by resolving conflicting information and developing reliable means of diagnosis. *Plant Soil.* **320**: 37-77.

Carroll, GC. (1988). Fungal endophytes in stems and leaves: from latent pathogen to mutualistic symbiont. Ecology. 69: 2–9.

Cavaglieri, L., Passone, A., Etcheverry, M. (2004). Correlation between screening procedures to select root endophytes for biological control of Fusarium verticillioides in *Zea mays* L. *Biol. Control. J.,* **31**: 259-267.

Choudhary, DK., Varma, A. (2016). Microbial-mediated Induced Systemic Resistance in Plants. ISBN. 978-981.

Firáková, S., Šturdíková, M., Múčková, M. (2007). Bioactive secondary metabolites produced by microorganisms associated with plants. *Biologia.* **62**: 251-257.

Fisher, PJ., Petrini, LE., Sutton, BC., Petrini, O. (1995). A study of fungal endophytes in leaves, stem and roots of Gynoxis oleifolia Muchler (Compositae) from Ecuador. *Nova Hedwigia*. **60**: 589-594.

Fouda, AH., Hassan, SED., Eid, AM., Ewais, EED. (2015). Biotechnological applications of fungal endophytes associated with medicinal plant *Asclepias sinaica* (Bioss.). *Ann. Agric. Sci*. **60**(1): 95-104.

González-Teuber, M., Vilo, C., Bascuñán-Godoy, L. (2017). Molecular characterization of endophytic fungi associated with the roots of *Chenopodium quinoa* inhabiting the Atacama Desert, Chile. *Genom. Data*. **11**: 109–112.

Grover, M., Ali, Sk., Sanhay, V., Abdul, Rasul., Venkateswarlu, B. (2011). Role of microorganisms in adaptations of agricultural crops to abiotic stress. *World J Microbiol Biotechnol.* **27**: 1231

Hassan, SED. (2017) Plant Growth promoting activities for bacterial and fungal endophytes isolated from medicinal plant of *Teucrium polium* L. *J Adv. Res.,* **8**: 678-695.

JianQiu, S., Liang Dong, G., Wei, Z., Wen Xiang, P., DeFu, C. (2008). Diversity and ecological distribution of endophytic fungi associated with medicinal plants. *Sci. China Ser. C-Life Sci*. **51**(8): 751-759.

Khan, AL., Al-Harrasi, A., Al-Rawahi A, AlFarsi Z, Al-Mamari A, Waqas M, *et. al*. (2016). Endophytic Fungi from Frankincense Tree Improves Host Growth and Produces Extracellular Enzymes and Indole Acetic Acid. *PLoS ONE*. **11**(6): 1-19.

Khan, S., Hamayun, M., Khan, A., Lee, I., Shinwari, Z., Kim, J. (2012). Isolation of plant growth promoting endophytic fungi from dicots inhabiting coastal sand dunes of Korea. *Pak. J. Bot.,* **44**(4): 1453-1460.

Kumar, A., Verma, JP. (2018). Does plant-Microbe interaction confer stress tolerance in plants? *Microbiol. Res.* **207**: 41–52.

Lin, Z., Wen, J., Zhu, T., Fang, Y., Gu Q, Zhu W. Chrysogenamide A from an endophytic fungus associated with *Cistanche deserticola* and its neuroprotective effect on SH-SY5Y cells. *J. Antibiotic.,* **61**: 81–85.

Lu, L., He, J., Yu, XP., Li, GZ., Zhang, X. (2006). Studies on isolation and identification of endophytic fungi strain SC13 from harmaceutical plant *Sabina vulgaris* Ant. and metabolites. *Acta. Agric. Boreali-Occident. Sin*.**15**: 85-89.

Luceroa, ME., Barrowa, JR., Osunab, P., Reyesb, I. (2005). Plant-fungal interactions in arid and semi-arid ecosystems: Large-scale impacts from microscale processes. *J Arid Environ.* **65**: 276-284.

Muhsin, TM., T. Booth, T. (1987) Fungi associated with halophytes of an inland salt marsh Manitoba Canada. *Canad. Jour. Bot.* **65**(6): 1137-1151.

Nejad, P., Johnson, PA. (2000). Endophytic bacteria induce growth promotion and wilt disease suppression in oilseed rape and tomato. *Biol. Control.* **18**: 208-215.

Nicholas, C,. Massimo, MM., Devan, N., Arendt, KR., Wilch, MH., Riddle, JM., *et.al.* (2015). Fungal Endophytes in Aboveground Tissues of Desert Plants: Infrequent in Culture, but Highly Diverse and Distinctive Symbionts. *Microb. Ecol.* **70**: 61-76.

Peel, MC., Finlayson, BL., Mcmahon, TA. (2007). Updated world map of the K¨oppen-Geiger climate classification. Hydrology and Earth System Sciences Discussions, *Europ. Geoscie. Union*. **4**(2): 439-473.

Porras-Alfaro, A., Herrera, J., Sinsabaugh, RL., Odenbach, KJ., Lowrey, T., Natvig, DO. (2008) Novel Root Fungal Consortium Associated with a Dominant Desert Grass. *Appl. Environ. Microbiol*. **9**(74): 2805-2813.

Redman, RS., Sheehan, KB., Stout, RG., Rodriguez, RJ., Henson, JM. (2002). Thermotolerance generated by plant/fungal symbiosis. *Science*. **298**(5598): 1581-1581.

Rodriguez, RJ., Henson, J., Van Volkenburgh, E., Hoy, M., Wright, L., Beckwith, F. (2008). Stress tolerance in plants via habitat-adapted. symbiosis. *ISME J.,* **2**: 404-416.

Rodriguez, RJ., White, JF., Arnold, AE., Redman, RS. (2009). Fungal endophytes: diversity and functional roles. *New Phytol.* **182**: 314-330.

Saikkonen, K., Faeth, SH., Helander, M., Sullivan, TJ. (1998). Fungal endophytes:a continuum of interactions with host plants. *Annu. Rev. Ecol. Syst.* **29**: 319-343.

Sangamesh, MB., Jambagi, S., Vasanthakumari, MM., Shetty, NJ., Kolte, H., Ravikanth, G., *et.al*. (2017). Thermotolerance of fungal endophytes isolated from plants adapted to the Thar Desert, India. *Symbio.,* **75**: 135–147.

Santos, MGS., Bezerra, JDP., Svedese, VM., Sousa, MA., Silva, DCV., Maciel, MHC. (2015). Screening of endophytic fungi from cactus of the Brazilian tropical dry forest according to their L-asparaginase activity. *Sydowia*. **67**:147-156.

Souza, ADL., Rodrigues-Filho, E., Souza, AQL., Pereira, JO., Calgarotto, AK., Maso, V. (2008). Koninginins, phospholipase A2 inhibitors from endophytic fungus Trichoderma Koningii. *Toxicon.,* **51**: 240-250.

Stierle, A., Strobel, GA., Stierle, D. (1993). Taxol and taxen production by Taxomyces andreanae an endophytic fungus of pacific yew. *Sci.* **260**: 214-216.

Strobel, G., Daisy, B., Castillo, U., Harper, J. (2004). Natural products from endophytic microorganisms. *J Nat. Prod.,* **67**: 257-68.

Strobel, G., Daisy, B. (2003). Bioprospecting for microbial endophytes and their natural products. *Microbiol. Mol. Biol. Rev.* **67**: 491-502.

Strobel, GA., Knighton, B., Kluck, K. (2008). The production of myco-diesel hydrocarbon and their derivatives by the endophytic fungus *Gliocladium roseum* (NRRL 50072). *Microbio.,* **154**(11): 3319-3328.

Sun, Y., Wang, Q., Lu, X., Okane, I., Kakishima, M. (2012). Endophytic fungal community in stems and leaves of plants from desert areas in China. *Mycol. Prog.,* **11**: 781-790.

Suryanarayanan, TS., Wittlinger, SK., Faeth, SH. (2005). Endophytic fungi associated with cacti in Arizona. *Mycol. Res.*, **109**: 635–639.

Varma, A., Bakshi, M., Lou, B., Hartmann, A., Oelmueller, R. (2012). *Piriformospora indica*: A Novel Plant Growth-Promoting Mycorrhizal Fungus. *Agric Res.* **1**(2): 117–131.

Visalakchi, S., Muthumary, J. (2010). Taxol (anticancer drug) producing endophytic fungi: an overview. *Int. J. Pharma BioSci.* **1**(3): 1-9.

Wang, FW., Jiao, RH., Cheng, AB., Tan, SH., Song, YC. (2007). Antimicrobial potentials of endophytic fungi residing in *Quercus variabilis* and brefeldin A obtained from *Cladosporium* sp. *World J. Micro. Biotech*. **23**: 79-83

Wellensiek, BP., Ramakrishnan, R., Bashyal, BP., Eason, Y., Gunatilaka, AAL. (2013). Inhibition of HIV-1 Replication by Secondary Metabolites from Endophytic Fungi of Desert Plants. *The Open Viro. J.* **7**: 72-80

Wijeratne, EM., Paranagama, PA., Marron, MT., Gunatilaka, MK., Arnold, AE., Gunatilaka, AA. (2008). Sesquiterpene Quinones and Related Metabolites from *Phyllosticta spinarum*, a Fungal Strain Endophytic in *Platycladus orientalis* of the Sonoran Desert. *J Nat. Prod.* **71**(2): 218-222.

Zidan, R. (2016). Endophytic fungi associated with some medicinal plants in Aswan, Egypt, MSc. Thesis, Bot. Dept. Sci. Faculty, Asw. Uni. Aswan, Egypt.