



## Impact of Salinity on the Behavior of Fungi

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### ABSTRACT

Salinity of the soil and water is one of the principal environmental elements that might influence the soil properties, crop production, distribution plant pathogens and their associated diseases. In addition to preventing plant growth and development, salinity also has an impact on antagonistic and pathogenic of numerous fungi. In addition to its direct effects on crops, salinity has been a significant problem that causes additional damage by enhancing the predisposition of plants to biotic diseases. However, salinity may either a potential antifungal agent by reducing mycelia growth, sporulation and conidial germination or increases the virulence of diseases by promoting the production of enzymatic activities including cellulase, pectin lyase, and polygalacturonase by the microorganisms. The effect of this environmentally agent on the growth and reproductive parameters differs between species, either directly or indirectly. There are numerous fungal species that can grow in situations with high salt concentrations; the majority of them are halotolerant, but there are also some halophilic species that can only flourish in salty conditions. The aim of this review is to characterize behavior fungal regarding salinity, in order to develop an integrated pest management strategy that incorporates biological, chemical, and cultural control approaches for disease management, economical effective, and extremely appealing for better crop quality and environmental sustainability in these salinity-related conditions.

**Key words:** Antimicrobial, Disease management, Osmotic stress, Plant diseases, Salt stress, Yield

### INTRODUCTION

Saline and sodic soils are a global problem, occur in over 100 countries and under almost all climatic areas (Zewdu *et al.* 2017), but their distribution is relatively more extensive in the areas that are dry and semi-dry. In terms of agricultural production, food security, and sustainability, soil salinization and sodification are the two main processes that degrade soil globally. Approximately, 833 million acres of agricultural land worldwide have been impacted by soil salinity (Zaman *et al.*, 2018). 33 percent of irrigated lands and 20% of agricultural lands worldwide are affected by salt (Machado and Serralheiro, 2017). Parent soil constitution or poor agricultural methods can both contribute to soil salinity, which is referred when referring to primary and secondary

soil salinity, respectively (Zaman *et al.* 2018). Salt-affected the soil functions, including, physical, chemical, and biological properties.

Salinity, which is an inhibiting factor for the growth and development of plants, may cause, in certain horizons of the soil, due to the high concentration associated with the precipitation of soluble salts, a great change of fungal diversity. A variety of morphological, physiological, biochemical, and molecular changes brought on by poor irrigation water that produces very saline soil, have a negative impact on fungal growth and cause a change in their lifestyle. The major impacts of excessive salinity are ion disequilibrium, which result in secondary effects such hyperosmotic stress (Zhu, 2001). High salinity affects plants in several ways: stomatal closure, cell division and cell growth were all prevented, alteration of metabolic

processes, membrane disorganization, resulting in decreased plant growth, crop yields and low economic returns (Munns, 2005; Parida and Das, 2005).

Salinity of the soil and water not only prevents the development and growth of plants, but also has an impact on associative, competitive, mutualistic, or antagonistic and pathogenic of microbial. Numerous microorganisms harm plants in a variety of ways, which ultimately yields a small amount and, consequently, poor economic worth. Furthermore, a few environmental elements, including salinity, temperature, humidity, drought, and nutrients, which further to exacerbate diseases caused by fungi. Previous studies showed that salt in the soil and water affects plant growth and makes plants more susceptible to certain phytopathogens (Egamberdieva and Jabborova, 2013).

Although only a few numbers of fungi are thought to be obligate halophiles, some others may grow more effectively in the presence of salt, giving them an advantage over species that are less salt-tolerant (Biango-Daniels and Hodge 2018). For example, *Aspergillus*, *Talaromyces*, *Penicillium*, and *Trichoderma*, for instance, are terrestrial fungus that have adapted to marine settings (Damare *et al.*, 2006). The effect of salinity against microorganisms was reported earlier (Boumaaza *et al.*, 2015; Regragui and Lahlou, 2005; Swiecki and MacDonald, 1991).

#### Pathogens halophilesto salts

Halophiles are generally understood to be microorganisms that can only grow in salty conditions (Larsen, 1986). The classification of halophilic microbes includes slight (growth optimal at 3%), moderate (3-15 %), and extreme (25 %, but unable to thrive at less than 12% NaCl) (Kushiner, 1978). Studies of fungal population's halophiles habitats on different continents have shown the frequent and prolific prevalence of several fungi (Gunde-Cimerman *et al.*, 2000). There have been several reports of fungi from halophiles environments, including *Aspergillus*, *Alternaria*, *Aureobasidium*, *Cladosporium*, *Penicillium*, and *Hortaea* (Jaouani *et al.* 2014, Mokhtarnejad *et al.* 2016).

The so-called black yeasts are the most prevalent fungus species in the salterns' hypersaline habitats (Gunde-Cimerman *et al.*, 2004). The exceptional abilities of these shady fungus with melanized cell walls allow them to withstand stressful situations, and many of them are polyextremotolerant. *G. marismortui*, which is characterized as a novel species, as well as *P. westlingii* and *U. chlamyosporum* were isolated from samples of Dead Sea. (Deuteromycota). On medium with up to 50% Dead Sea water, *G. marismortui* and *U. chlamyosporum* thrived. It was discovered that obligatehalophile *G. marismortui* thrives best at 0.5-2 M NaCl. Isolated cultures grew on agar used with 50% Dead Sea water rather than on agar media without salt. This implies that they might have developed a tolerance for the highly harsh hypersaline Dead Sea environment (Buchalo *et al.*, 1998).

These fungi can maintain a stable osmotic pressure in their surroundings by retaining less intercellular salt and collecting compatible solutes like glycerol (Gostinčar *et al.* 2011). Stress is detected by halotolerant and halophilic

organisms via the pathway of high osmolarity glycerol signaling (Gostinčar *et al.* 2011), for the maintenance of cellular osmotic equilibrium (Hohmann 2009). Additionally, fungi may produce extracellular polysaccharides to coat their cells or thicken their cell walls as passive stress tolerance mechanisms (Kuncic *et al.* 2010). Less consideration has been given to fungus reactions to high levels of other chaotropic and kosmotropic salts. These salts can only decrease the amount of water that is biologically available, produce toxicity when particular cations enter cells, and change how cellular macromolecules interact. The kosmotropic salts react in the opposite direction to the chaotropic salts, which weaken electrostatic connections and destabilize macromolecules (Oren 2013). Therefore, the presence of kosmotropic ions can somewhat offset the chaotropic effects of magnesium and calcium (Williams and Hallsworth 2009). An illustration, only a few number of halophilic Archaea spp. can survive in conditions with high NaCl (Oren *et al.* 1995).

#### Pathogens tolerant to salts

Microorganisms that can tolerate salt can live in saline conditions but survive without sodium chloride. Microorganisms that can flourish in saline settings exceeding 15% NaCl are referred described as being extremely halotolerant (Kushiner, 1978).

Many pathogens are tolerant to salts in culture, including certain oomycetes that resemble fungi. Research on the impact of salinity on fungus have shown that varying levels of salinity tolerance exist among *P. ultimum* (Hassan and Fadl-Allah, 1993), *F. oxysporum* (Ragazzi and Vecchio 1992), *P. aphanidermatum* (Rasmussen and Stanghellini, 1988), *P. parasitica* (Blaker and MacDonald, 1985), *Penicillium* (Tresner and Hayes, 1971), *P. arrhenomanes* var. *canadensis* (Machacek, 1936). Boumaaza *et al.*, (2015), also reported that six isolates of *Botrytis cinerea* obtained from various tomato genotypes, and all of the isolates examined were stimulated in 50 to 150 ppm of NaCl. These reports are in agreement with findings of Laxmi *et al.* (2013) showed that five isolates of *Trichoderma harzianum* could proliferate and sporulate in media with upwards to 240mM NaCl were chosen to be salinity tolerant under laboratory conditions. Previous research revealed that *Phytophthora* isolates from salty soils were much more resistant to salt than isolates from non-salty soils (Duniway, 1979). Different tolerances to salt stress, as described for *Phytophthora* isolates, may be the cause of different responses to salinity (Blaker and MacDonald, 1985). According to Gour *et al.* (1990), *Fusarium* attack leads to plant wilting and yellowing under high salt levels, while *F. oxysporum*, the primary cause of chickpea wilt, tolerates high salt concentrations. It was also looked into if plants could grow in salty environments. Under saline conditions, *Fusarium* sp. F092 growth accelerated by about 20%. F092 was able to survive and develop because it responded to salt stress by expressing a number of different genes and biochemical pathways (Hidayat *et al.*, 2012). In salter brines, *Aspergillus* and *Penicillium* species are frequently seen. For example, the Cabo Rojo saltern's salt pond water was used to isolate nine halotolerant *Aspergillus* and five halotolerant *Penicillium*

species (Cantrell *et al.*, 2006). Additionally, *Cladosporium* sp. was identified in media containing 50% sugar or a salt-and-sugar mixture, which indicates low water activity conditions (Gunde-Cimerman *et al.*, 2000). Fungi must resist osmotic and salt stress in reaction to high salinity in order to live in salt stress (Gunde-Cimerman *et al.*, 2018).

In order to keep intracellular sodium ion under toxic levels when growing in saltwater medium, fungi accumulate compatible solutes in the cytosol. (Hohmann, 2002). According to Zajc *et al.* (2014), glycerol is the most significant compatible solute, and glycerol-3-phosphate dehydrogenase regulates glycerol production (Lenassi *et al.*, 2011).

Second, fungus tolerant to salts is ability to respond to salinity stress is correlated with cell wall structure and melanization. In hypersaline environments, melanization of cell walls reduces their glycerol permeability and aids in the intracellular retention of glycerol (Kogej *et al.*, 2007).

Thirdly, a salt adaptation strategy involves maintaining ion homeostasis utilizing a variety of metal cation transporters. *Debaryomyces hansenii* is the halotolerant fungal species that has been examined the most in terms of ion homeostasis. According to early studies on marine yeast,  $K^+/Na^+$  fluxes play a role in this process and *D. hansenii* is the species that is least affected by high sodium chloride levels (Norkrans and Kylin 1969). Later, numerous investigations revealed that *D. hansenii* is not poisonous to  $Na^+$  and that when NaCl is present, compared to *S. cerevisiae*, *D. hansenii* develops more positively and collects more  $Na^+$  (González-Hernández *et al.* 2004).

### NaCl's effect on mycelial development

The mycelial growth of the fungus was greatly accelerated by a number of salts, including potassium (such as  $CH_3CO_2K$ ,  $KCl$ ,  $KNO_3$  and  $K_2HPO_4$ ), NaCl,  $Na_2SO_4$ , and  $Na_3PO_4$  (Türkkan 2013). Moreover, many studies demonstrated that sodium chloride enhanced the mycelial growth of numerous funguses. In a related context, Boumaaza *et al.* (2015); Regragui and Lahlou (2005) and Sanogo (2004) illustrated that using sodium chloride, increase mycelium growth with various NaCl concentrations respectively on *V. albo-atrum*, *P. capsici* and *B. cinerea*. Notably, Boumaaza *et al.* (2015) found that this growth stimulation only occurred at values lower than 0.3 g/L. A negative connection between mycelium production and NaCl content was seen above this cutoff point. With increase in salinity level, *Phytophthora capsici*'s mycelial dry weight increased by 8 to 16%, and the radial growth of the mycelium was accelerated by 5 to 30 % (Sanogo, 2004). Matsuda *et al.* (2006) reported that *P. tinctorius* hyphal growth at 25 mM NaCl was noticeably greater than that at the other NaCl levels (50, 200, 500, and 1000mM) and EC50 values were confirmed at concentrations of 50 to 200 mM. Recently, Wang *et al.* (2020) found that media containing different concentrations of NaCl (0-80 g/L) increase mycelium growth of *A. ochraceus* and *P. nordicum*, and the colony's diameter was maximum at a salt level of 40 g/L. According to research by Tarroum *et al.*, (2021) the isolates, *C. globosum*, *A. tenuissima*, *C. foveolata*, *P. melinii*, *N. chinensis* and *B. spectabilis* can all grow in 1

M NaCl. Intriguingly, isolates *Byssoschlamys spectabilis* and *Nigrospora chinensis* were more tolerant to NaCl; in addition, under 100 mm and 200 mm NaCl, the two bacteria immediately covered the whole surface of the agar compared to the controls. Under *in vitro* conditions, *Trichoderma asperellum* was very salt tolerant and shown robust growth up to 1400mM NaCl concentration (Singh *et al.*, 2019). The mycelial development and sporulation of various *Fusarium* genuses, as well as *F. oxysporum*, are motivated under salinity conditions (El-Abyad *et al.* 1988).

Fungi exposed to salt stress would trigger a series of responses with essential roles in stress adaptation, such as production of energy, metabolism of cell walls, ion movement, the synthesis and degradation of lipids in cells, cytoskeleton behavior and signage (Nivedita and Ramchiary 2021). The majority of funguses require passive strategies to survive at high salt concentrations, including the development of extracellular polysaccharides to coat the cells or thicken the cell wall and the formation of cell clumps (Kralj *et al.*, 2010). On the other hand, several recent studies that discuss the impact of salt and heavy metal stress on the rising indole acetic acid synthesis by fungus *in vitro* (Mehmood *et al.*, 2019). For example, the glycerol is the most prevalent osmolyte in *H. werneckii* and *W. ichthyophaga*, however smaller concentrations of erythritol, arabitol, and mannitol can also be observed (Kogej *et al.*, 2007; Zajc *et al.*, 2014). It is a signature stress osmolyte, indicating that in *A. sydowii* glycerol was only accumulated at 2 M NaCl. In *A. sydowii*, the fungal cell wall structure is extensively altered under salinity conditions. When the fungus developed in 2 M NaCl, the transcript levels of the enzymes endochitinase (chi) and chitotriosidase (chit) increased, which may have caused a general decline in the amount of chitin and chitosan in the cell wall (Pérez-Llano *et al.*, 2020).

Significant differences existed in the expression of many genes related to stability and change of the cell wall, within a salt stress. A fungus's cell wall goes through substantial modification to avoiding salt stress-related cell damage, as evidenced by the turning on of genes linked to chitinase, beta-glucosidase, glucan endo-1,3-alpha-glucosidase and Rho-type GTPase (King *et al.*, 2017). A high salinity may cause an elevation in ROS and, as a result, the body's response to oxygen-related stress (Tanaka *et al.*, 2006).

It has been previously reported that the fungi exposure to high salinity led to significant decreases in mycelial development, sporulation and germination rate. Early studies indicated that salinity stress caused the depression in mycelia production of *M. xanthopus* between 35 and 40 gL<sup>-1</sup> NaCl (Castillo and Demoulin, 1997). Aksu and Balibek (2010) reported that *Rhizopus arrhizus*' growth rates only decreased by 20–25 percent after being exposed to 50 gL<sup>-1</sup> NaCl (conductivity of 98.9 mS/cm). Also, by lowering the radial daily growth and mycelium dry weight, Jacques *et al.* (2019) shown that NaCl has a detrimental impact on growth metrics and number of infectious spores while resulting in an increased in germination rate of *F. oxysporum* f. sp. *elaeidis*. Mycelia may directly respond to the negative consequences of the increased salinity by experiencing

osmotic stress or becoming toxic substances that interfere with membrane stability and/or enzyme activity (Adler, 2020).

Salinity causes cells to experience both ionic and osmotic stress, which increases intracellular Na<sup>+</sup> buildup and can harm membrane systems and cytosolic proteins. The fungus cells' exposure to saline stress includes exposure to both osmotic stress and specific cation toxicity (Na<sup>+</sup>). These ions can block particular metabolic pathways, which makes them poisonous to cells (Posas *et al.*, 2000). According to reports, ROS damage to proteins, lipids, and DNA (Farrugia *et al.*, 2012) results in apoptotic cell death (Carmona-Gutierrez *et al.*, 2010), or aging (Fröhlich and Madeo 2001).

### Effect of NaCl on sporulation

It's possible that spore generation was crucial for fungus survival. The spore develops in reaction to unfavorable conditions. The spore is a multicoccal structure that is dehydrated and includes a full copy of the chromosome, the smallest amounts of necessary proteins and ribosomes, and a significant amount of calcium that is bonded to dipicolinic acid. The spore structure protects genomic DNA to many extreme conditions including salinity, alkalinity, heat, desiccation, UV and  $\gamma$ -radiation, and a variety of products chemicals (Eichenberger and Driks, 2014).

Due to its strong salt-resistant characteristics, spore production may be a useful escape mechanism from unfavorable high salinity conditions. However, contrary to expectations, high salinity effectively stimulates sporulation. Sporulation that is continuously exposed to salt-rich environments is stimulated at the earliest possible stage. In fact, Boumaaza *et al.* (2015); Daami-Remadi *et al.* (2009) and Rezagui and Lahlou (2005), all noted that *B. cinerea*, *V. dahliae*, and *V. albo-atrum* sporulation rates were stimulated when the concentration of NaCl was increased. Under situations of salt stress, various *Fusarium* species, notably *F. oxysporum* f.sp. *ciceri* (foc), motivate their mycelial growth and sporulation under salt stress conditions (El-Abyad *et al.* 1988; Gour *et al.* 1990). The highest production of *A. niger* and *P. lilacinum* conidia, collected from the soil, was seen in both species in the nutritional medium including 1% sodium chloride. Conidia of *P. lilacinum* were not produced on nutrient medium containing 5% sodium chloride; however *Aspergillus niger* grown in the same conditions at 5% sodium chloride did produce conidia (Mert and Dizbay, 1977). *Torpedospora radiata*, *Lulworthia floridana*, and *Halosphaeriopsis mediosetigera* all sporulated in artificial media made composed of saltwater dilutions ranging from 0 to 100% (Jones *et al.* 1971). According to Branco *et al.* (2015), the salinity-adapted *Suillus brevipes* fungus has distinct genomic areas that contained the gene for a membrane Na<sup>+</sup>/H<sup>+</sup> antiporter, a gene linked to tolerance for salinity stress.

Although the effect of sporulation in the presence of salt was somewhat variable. Previous studies using increasing NaCl concentrations to assess the rate of sporulation. Building on previous observations, salinity has a major impact on sporulation of fungus such as *S. fomicola*, *C. globosum*, *G. retispora*, *N. crassa*, and *S. fomicola*; a salinity of 60% didn't result in any ascospore

production (Jones *et al.*, 1971). Under saline conditions, production of *Phytophthora capsici* sporangia and zoospore was decreased by approximately 3 to 85 and 1 to 93%, respectively (Sanogo, 2004). In *Pochonia chlamydosporia*, the colony area was less inhibited (6.55%) and sporulation was less inhibited (21.57%) at a concentration of 40 mmol.L<sup>-1</sup> of NaCl than at 160 mmol.L<sup>-1</sup>, where values of 51.3% and 85.1%, respectively, were recorded (Ceiro *et al.*, 2014).

Some microorganisms are unable to survive due to osmotic stress brought on by high salinity. High salinity environments also have a low water index, are more alkaline, and provide poor nutrition for the microorganisms that live there (Corral *et al.*, 2020). Microorganisms have a variety of adaptation mechanisms in order to survive in such hostile environments. One of the main methods used by microorganisms to attain osmotic balance is the accumulation of massive quantities of ions within the cell (Kanekar *et al.*, 2012). The increased salt level inside the cell is primarily the result of K<sup>+</sup> ions, as organisms exclude Na<sup>+</sup> ions because of their toxicity a number cellular constituents (Gunde-Cimerman *et al.*, 2018). This strategy requires intracellular proteins and substances with acidic residues, which are found on the protein's external. Water molecules are coordinated by them to produce a wall that protects the protein from dehydration and precipitation of ions (Ma *et al.*, 2010). Microorganisms require organic molecules to keep osmolality inside of cells. Polyols, sugars, glycérol, ectone, and diméthylsulfonylpropionate are among the compatible solutions that do not obstruct with the function of enzymes (Ma *et al.*, 2010). The three chemical groups of organic solutes: anionic solutes, zwitterionic solutes and uncharged solutes (Kanekar *et al.*, 2012). Salt stress affects the lipid content that includes the quantity of sterols, the fatty acyl chain type, and the makeup of head groups in polar phospholipids. Fungi can tolerate in extremely high salinities by cell wall melanization to prevent water loss, intracellular compatibility solute leaking and to maintain high membrane fluidity (Plemenitaš *et al.*, 2008).

However, in salinity-sensitive fungi, the extracellular and intracellular compartments' membrane potentials are different from one another, in that enhanced by the increased extracellular quantities of ions (such Na<sup>+</sup> and Cl<sup>-</sup>). As a result of the membranes being excited, the potassium (K<sup>+</sup>) channels open, which allows for the entry of Na<sup>+</sup> and Cl<sup>-</sup> ions as well as the passage of K<sup>+</sup> out of the cell. In this manner, too many Na<sup>+</sup> ions could compete with K<sup>+</sup> ions for the same receptors in a variety of biological processes. Additionally, Cl<sup>-</sup> ions have negative consequences that might manifest at lower concentrations than Na ions. The ability of Na to establish more durable connections with the cell membranes contain lipids while Cl<sup>-</sup> is free in solution and has the capacity to cause toxicity at a greater number of distinct places inside the cells may be the cause of this higher toxicity of Cl<sup>-</sup> (Knecht and Klasczyk, 2013).

### Effect of NaCl on spore germination

Different fungi species show reduction of germination under saline conditions. Boumaaza *et al.* (2015), Sanogo (2004) and Ragazzi and Vecchio

(1992), they found that the germination rates of *Botrytis cinerea*, *Phytophthora capsici* and *Fusarium oxysporum* f. sp. *vasinfectum* were all negatively impacted by NaCl. In the presence of additional NaCl, 32.6 % of the spores germinated of *Rhizopogon roseolus* at 50 mM, 7.4 % at 150 mM, and 0.5 % at 300 mM. As the NaCl concentration increased, the total germination rate considerably decreased (Nakanoa *et al.*, 2022). *R. undulata* isolates had an ascospore germination rate of 83.3 % overall at 50 and 100 mM NaCl concentrations (no germinations were seen at 300 mM) (Lee *et al.*, 2015). According to several studies, fungus spores regularly hydrate and the germlings can grow at a concentration of around 50 mM NaCl, but the germination process is finally inhibited above a concentration of 100 mM NaCl (Campagnac and Khasa, 2014). *A. wentii*, *P. janthinellum*, and *Z. moelleri* exhibited limited germination at low salinities; however, the conidia of *G. fimbriatum*, *P. puntonii*, and *T. lignorum* could only germinate in distilled water (Borut and Johnson, 1962). At doses of 150 mM and above, *R. solani* exhibits aerial hyphal development, less thick mycelia, and a decrease in spore germination percentage (Dylan, 2018). A positive effect on fungal growth and conidia germination under 50 mM of NaCl was suggested by Boumaaza *et al.* (2015), Turco *et al.* (2002) and Dikilitas (2003). Ragazzi and Vecchio (1992) found that substrates containing 10 ds/m sodium chloride enhanced the germ tube length and germination of *F. oxysporum* f. sp. *vasinfectum* chlamydospore.

In principle, the germination process may be inhibited by NaCl at a variety of stages, including binding to receptors in the spore's membrane, signal transduction, the spore core's ion efflux followed by its DPA (dipicolinic acid) efflux and cortex hydration (Cortezzo *et al.*, 2004). According to earlier reports, reduced mycelia, conidia germination, and sporulation are characteristics of heavily salinized fungi due to the low osmotic potential, toxicity and reduced ion availability (Egamberdieva, 2011). Low osmotic potential causes fungi to undergo morphological changes, hyphal growth, and a general decline in spore germination (Juniper and Abbott, 2006). The mechanism of spore germination is started by water entering the spore, which is followed by the hydration of the spore's organelles and macromolecules. After that, the enzyme activates to initiate the cellular metabolic cycle. This mechanism is disrupted under saline conditions.

### Salinity's effects on pathogenicity

Salinity of the soil and water is one of the principal environmental elements that might influence the existence, growth, and frequency of phytopathogenic fungus. The growth and development of fungus in salt not just makes them more virulent, but also has the potential to reduce their pathogenicity. It's crucial to remember that under saline or typical conditions, naturally resistant to disease cultivars may also become susceptible to them (Mou, 2011). If pathogens demonstrate more tolerant to the harmful effects of salinity than those of their hosts, then added stress on host plants is unavoidable.

### Salinity's positive effects on pathogenicity

Salinity undoubtedly has a negative impact on plant growth, but it can also have a good impact on fungal

growth, including an increase in pathogenic activity. According to several researches on the relationships between microorganisms and salinity showed that increased in disease are associated with higher salinities. As is the situation with, *Phytophthora capsici* (Sanogo, 2004), *P. aphanidermum* (Rasmussen and Stanghellini, 1988), *Fusarium crown rot* (Woltz *et al.*, 1992; Triky-Dotan *et al.*, 2005) and *P. parasitica* (Swieckil and MacDonald, 1991). MacDonald (1984) reported that *Chrysanthemum* root rot was shown to be more common with exposures to salinity stress. He speculated that this may have been caused by the roots' vulnerability to zoospore infection as a result of the deplasmolytic shock. Various soilborne infections, particularly pathogenic strains of *Fusarium*, have been linked to amplified disease incidence after irrigation at extremely salty water (Sivan *et al.*, 1993). Although anecdotal information from earlier investigations in Oman suggesting that farms with higher salinities experienced significantly greater rates of pythium damping-off disease (Al-Kiyumi, 2006). Beech (1949) attributed increased damping-off of tomato seedlings treated with fertilizer salts was caused by *Phytophthora* species growing more quickly than their hosts when both were subjected to osmotic stress. According to Goudarzi *et al.* (2011), increasing soil salt levels up to 1400 mg of NaC kg<sup>-1</sup> significantly increased *Macrophomina phaseolina* shoot and root colonization. As a result, increasing NaCl levels were associated with more diseased crown and root. Similar results were found for tomato and cucumber, where increased soil salinity enhanced *Fusarium solani* root disease (Egamberdieva *et al.*, 2011). When *Verticillium albo-atrum* is grown on an 80 mM NaCl-enriched carboxymethylcellulose (CMC) medium, its carboxymethylcellulase activity increases, increasing its pathogenicity (Regragui *et al.* 2003). In cucumber seedlings infected with *Pythium aphanidermatum*, mortality increased considerably with saline irrigation from 0.01 to 5 dS/m (Al-Sadia *et al.*, 2010).

High salinity may alter a plant's morphology, anatomy, metabolism, and biochemistry, affecting factors like water relations, stomata size and number, stem, leaf, and root structure, photosynthesis, protein synthesis, lipid metabolism, cuticle thickness, ion homeostasis and membrane function, synthesis of nucleic acids, enzymes, and osmolytes (Bernstein and Kafkafi, 2002; Parida and Das 2005). The above alterations caused by high salinity to the plant may be linked to increased susceptibility to the disease. According to Bernstein and Kafkafi (2002), salinity causes in osmotic stress on the plant, decreased water potential, all of which could worsen the wilt.

Salinity may result in a reduction in other nutritional ions, such as K<sup>+</sup>, which is usually linked to disease resistance. Because potassium ion is necessary for cellular function, Na<sup>+</sup> competes with K<sup>+</sup> for binding sites, which results in metabolic toxicity. Na<sup>+</sup> and Ca<sup>2+</sup> ions were discovered to compete with one another in the root media (Flowers, 2004). In these conditions, the cell wall membrane weakens and lyses, allowing assimilates (such as glucose and amino acids) to continuously exit the cell and perhaps promote fungal development.

The potential exists for fungi to produce more enzymes at low NaCl concentrations. For example,

*Sclerotium rolfsii* produced more enzymes, including xylanase and galactanase, at higher salt concentrations (El-Abyad *et al.*, 1992). Similar to this, Turco *et al.* (2002) found that conidial formation and the generation of cell wall enzymes were both facilitated less than 50 mM of NaCl, which in turn improved the pathogenicity of fungal infections. In addition, even if crop plants develop high levels of resistance, salt's long-lasting effects and high concentrations have the power to weaken resistance and promote pathogenic attack (Fu *et al.*, 2013).

### Salinity's negative effects on pathogenicity

Pathogens not only become more virulent in saline environments, but also have the potential to non-virulent. Increased salt levels reduce the growth of fungi's mycelia and sporulation due to negative osmotic potential, toxic and nutritional effects, as well as other factors (Egamberdieva, 2012). According to Amir *et al.* (1996), salt inhibited soil mycelial development and conidia germination, making it suppressive to *Fusarium oxysporum*, the fungus that causes vascular wilt disease. Similar conclusions were reached by Goudarzi and Pakniyat (2008) and El-Mougy and Abdel-Kader (2009) on the *Fusarium culmorum*, *Macrophomina phaseolina* and *Alternaria solani*. According to Elmer (1992), the application of NaCl allowed for the controlled spread and growth of *Fusarium* crown and root rot brought on by *F. oxysporum* and *F. proliferatum*. The anammox process can be severely inhibited by elevated salinity levels. High salinity causes an increase in osmotic pressure, which causes microbial cells to lose water. This dehydration and plasmolysis eventually cause the cells to die (He *et al.*, 2017). In addition to these problems, the growth of mycorrhiza and symbiotic microorganisms may be significantly impacted relating to colonization potential and effectiveness (Asghari *et al.*, 2008).

### Conclusion

Soil and water salinity constitutes one of the most crucial environmental factors and impairs the plant growth through ionic and osmotic stress, nutritional deficiencies, and water deficiency. In addition to preventing plant growth and development, salinity also has an impact on antagonistic and pathogenic of numerous fungi. Sodium chloride may either a possible antifungal agent by decreases mycelia growth, sporulation, and conidial germination or increases the virulence of diseases. It has been recommended that the concentration of sodium chloride applied as an antifungal measure not goes above a particular point because the disease may eventually adapt to the salinity of the environment.

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