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Soil Salinity is a Serious Environmental Threat to Plant Diseases- A review

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Abstract
The rise in sea level, which causes an increase in salinity in both surface and ground water systems, is among the resultant effects of global climate change. Soil salinity is one of the notable environmental factors contributing to infectious plant diseases. Stress due to soil salinity affects plant tolerance to biotic stress by attenuating their immunity to pathogens leading to prevention of defence genes expression, reduced antioxidant activity and weakening of defence signalling proteins. The pathogen virulence and pathogenicity as well as an enhancement of pathogen development and multiplication are all influenced by soil salinity. Restriction of water absorption, toxic ion build up in plant tissues, nutrient deficiency, hormonal and metabolic imbalance, oxidative stress as physiological effects of salt stress, significantly affect the degree and occurrence of plant diseases. Thus, level of soil salinity is directly proportional to the severity and incidence of plant diseases. Controlling the effect of salinity by improving salinity tolerance in plants and deployment of salinity control measures will provide a long lasting solution on its effect on plant diseases. This will also serve as an approach to plant economic disease control.

Keywords: Soil salinity, Plant pathogens, Plant immunity, Disease severity, Incidence.

INTRODUCTION
When chlorides and sodium sulphate are present in soil at toxic levels, it is referred to as salinity (Tuteja *et al*., 2012). Soil is generally accepted to be saline when the electrical conductivity is greater than $4dSm^{-1}$. However, stress induced by soil salinity is known as salt stress, and this influences plant diseases in several ways. Plant disease is a term usually referred to an abnormality in plant health that is caused by plant pathogens or environmental factors (Ravichandra, 2013).

One of the prominent restrictions in global agricultural system is soil salinity, impacting about 20-30% of cultivated land, with a 50% increase in total irrigated fields predicted by 2050

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(Tuteja *et al*., 2012; Bahmani *et al*., 2015). Soil salinity initiated a major challenge with over one billion hectares of agricultural soil affected in more than 100 countries (Tian *et al*., 2020; Hopmans *et al*., 2021; Singh, 2022). Because of improper irrigation practice, poor soil drainage, intrusion of water from sea in coastal areas, and salt accumulation in arid and semiarid areas, soil salinity is becoming more of a problem (Tuteja *et al*., 2012).

In regions with high rate of transpiration and evaporation and low rates of precipitation, effects of salinity pose a serious socioeconomic and environmental threat (Abuelgasim and Ammad, 2018). Salinity, however, is anticipated to result in an annual agricultural output loss of up to $27 billion globally (Wang *et al*., 2021). Salinity is a prominent issue among complicated environmental challenges such as droughts, strong winds, heat waves, and floods (Etikala *et al*., 2021). Salinity dehydrates soils and irrigated land, impairing agricultural development and resulting in low productivity and land degradation (Shrivastava and Kumar 2015).

Secondary salinization which is caused by humans and primary salinization which is caused by nature are the two major factors contributing to soil salinity (Singh, 2022). The main human-made activity causing soil salinization is the use of poor-quality water for the irrigation of crops as a result of prolonged dry spells combined with excessive chemical fertilizers (Pena *et al*., 2020). Poor drainage conditions exacerbate the salinization conditions that are derived from anthropogenic activities (Manasa *et al*., 2020). The primary natural cause of soil salinization is the presence of parent materials, physico-chemical weathering of minerals, and intrusion of seawater (Ramos *et al*., 2020). According to Metternicht and Zinck (2008), irrigated soils are highly prone to soil degradation, and over about 14 km^2 of fertile land is lost every day as a result of soil salinization.

Salinity hinders plant growth by reducing phosphorus, potassium, nitrate, and calcium absorption, as well as causing ion cytotoxicity and osmotic stress (Tuteja *et al*., 2012). The ionic forms of essential elements, like K^+, for instance, help plants resist disease and abiotic stressors. It has been widely accepted that K^+ deficiency plants appear to be very susceptible to insect attack and increased disease incidence, and that K^+-sufficient plants appears to be less susceptible to diseases than those with an inadequate supply of K^+ (Wang *et al*., 2013). However, toxicity due to toxic ions, osmotic stress, and nutrients deficiencies under salt stress cause an imbalance in metabolism and induce oxidative stress by penetrating the protein hydration shells thereby interfering with their functions (Tuteja *et al*., 2012). These have an impact on plants' general physiology and obstruct metabolism and biomolecule synthesis, which generally have an impact on how well plants perform overall in terms of disease resistance.

Throughout the stages of the organization of living organisms, different phenomena are involved either directly or indirectly for that living system to adapt and survive in a challenging environment. This is applicable to plants as well, which they develop a series of defense mechanisms in order to tolerate, adapt or escape the effect of environmental stress factors such as salinity. Cellular homeostasis (including ion homeostasis, osmotic adjustment, antioxidant defense, compatible solute and transcription factors), stress damage control (repair and detoxification), and growth regulation are three categories of plant salt tolerance mechanisms (Tuteja *et al*., 2012; Bahmani *et al*., 2015).

Three key factors, the host, the pathogen, and the environment, which can all be represented as a disease triangle, play a key role in the establishment of any disease in the plant community; therefore, the disease triangle depicts the three fundamental prerequisites for disease development in any plant host community (Kutama *et al*., 2022). The host's susceptibility and the virulent pathogen are the two earlier key factors that the environment has the tendency to influence (Kutama *et al*., 2022). Various abiotic causes of plant diseases may act singly or in combination, some of them may cause diseases directly while several of them may enhance the disease attack by biotic agents (Ravichandra, 2013). Environment influences the pathogens and the diseases they cause in plants, and in the control and management of plant diseases, modification of environmental factors to become inhabitable is one of the strategies to get rid of the plant pathogens or their inocula. The main objective of this paper was to review the effects of soil salinity as an environmental factor on plant diseases and how such factor influenced plant diseases which has been considered as critical, particularly in the long-term management and control of plant diseases.

Effects of Salinity on the Development of Plant Diseases

During their life cycle, crops are exposed to a variety of stressors, including abiotic stressors like salinity and biotic stressors like pathogens (Bai *et al*., 2018). Evidently, abiotic stress factors can reduce or increase a plant's resistance to pathogens (Bai *et al*., 2018). Climate change, global warming, and environmental pollution all worsen the effects of biotic (disease) and abiotic stress on growth and yield of plants (Nejat and Mantri, 2017). Globally, different researches successfully improve significant number of crops for disease resistance. Despite these success stories, environmental factors such as salinity could neutralize the efforts of controlling plant diseases due to its impact on plant immunity. Thus, a resistant plant to a particular disease could lose its resistivity as a result of salt stress.

Haller *et al*. (2020) used immunoblot analysis with an anti-phospho p44/42 kinase antibody to examine the effect of salt on the innate immune system of *Arabidopsis thaliana*. They discovered that the activation of the classical salt stress response influenced susceptibility to infection with the hemibiotrophic *Pseudomonas syringae* or the necrotrophic *Alternaria brassicicola* and *Botrytis cineraria*, Abscissic acid (ABA) hormone levels significantly increased, and as a result, it played a regulatory role in increasing *A. thaliana*'s susceptibility to *Botrytis* when exposed to salt stress. This is exacerbated by the fact that hormonal imbalance caused by salinity stress increased plant susceptibility to disease.

In the process of infection, pathogens attack plants through different mechanisms, likewise the hosts deploy different strategies to prevent themselves from being attacked. Structural shield such as cell wall is commonly used by the host to escape the pathogen attack. The plant cell wall serves as a crucial physical barrier to overcome pathogen invasion, and changes in the integrity of the plant cell wall may be the cause of salinity's effects on plants' immunity (Haller *et al*., 2020). Under salt stress, plants' cell walls soften and undergo remodeling owing to a modification of the cellulose-pectin cross linking (Feng *et al* 2016; Kensten *et al*., 2017; Feng *et al*., 2018; Van Zelm *et al*., 2020). Salt stress and the Fusarium wilt pathogen (*Fusarium oxysporum* f. sp. *Ciceris*) in chickpea (*Cicer arietinum*) suppress the expression of defense genes, antioxidant activities, and weaken the G-protein mediated defense signaling; this lowers the plant's resistance to Fusarium wilt because salinity-induced root tissue damage is in addition to suppression of a variety of defense signals (Maharshi *et al*., 2022).

Effects of salinity on plant pathogens

For a successful infection to occur, pathogens must fully develop and provide required inoculum which if in contact with the susceptible host, will result in an infection or disease condition. Environmental factors play a critical role in the establishment and development of plant pathogens, in which salinity as a factor affects the pathogen growth and development as summarized in Table 1 below.

Table 1: Effects of salinity on different plant pathogens.

S/No.	Pathogens	Hosts	Diseases	Effects Due to Salinity	Citations
1.	*V. dahliae.*	*L. esculentum.*	Verticillium wilt.	Increase pathogen virulence, mycelial growth, number of- Conidia, number of micro- Sclerotia.	(Besri, 1993).
2.	*P. parasitica, P.citrophthora.*	*Citrus.*	Rot of citrus fruits.	Increased the production of- sporangia.	(Besri, 1993).
3.	*F. solani*	*O. sativa*		slightly increase the- Pathogenicity.	(Eydoux and- Farrer, 2020).
4.	*V. albo-atrum*	*L. esculentum.*	Verticillium wilt.	Accelerate disease- Progression.	(Dikilitas, - 2003).
5.	*P. cryptogea*	*C. morifolium*	Root rot.	Increase in number of cyst- Zoospores attached to the- With increase in salinity stress.	(MacDonald,- 1984).
6.	*F. oxysporum*	*L. esculentum.*	Fusarium wilt.	Increase sporulation.	Daami-Remadi- *et al.* 2009).

Soil salinity and irrigation water influenced the pathogen virulence and plant susceptibility to the diseases (Besri, 1993). It was found that salinity from both soil and irrigation water increases the inoculum density of *Fusarium oxysporum* f.sp *lycopersici* in the soil; pathogen sporulation in the plant vessels, the chlamydospores formation and the overall fungal development in very hot condition were enhanced by salinity (Besri, 1993). This indicates that, salinity as it influences the process of spore production, the population of secondary inoculum in a field will significantly increase. Agarios (2005) reported that that the likelihood of an epidemic increased significantly with the quantity of pathogen propagules present in or close to fields of host plants.

Salinity contributed to the increased virulence of *Verticillium dahlia*e and disease susceptibility in Tomato plant, the mycelial growth, number of conidia as well as microsclerotia increased with an increasing level of salinity (Besri. 1993). This author further reported the production of sporangia by *Phytopthora parasitica* and *P. citrophthora* (an important citrus pathogen) increased in salt affected soils. According to Eydoux and Farrer (2020), increasing salinity slightly influenced the pathogenicity of *Fusarium solani* in rice (*Oryza sativa*). Dikilitas (2003) reported that, disease progress in tomato inoculated with *Verticillium albo-atrum* under salinity stress accelerated due to effect of salinity.

The effects of salinity were found to increase the number of cysts zoospopres attached to the roots of Paragon stem (*Chrysanthemum morifolium*) cuttings, with increased stress by salinity (MacDonald, 1982). In the studies of the effect of salinity on *Fusarium* wilt caused by *F. oxysporum* f.sp *lycopersici*, Daami-Remadi *et al* (2009) detected that the *in-vitro* application of different salt concentrations did not affect the mycelial growth; while an increase in sporulation was observed at the highest sodium chloride concentrations of 8 and 10 g/L respectively. Using radial growth techniques, the sporulation of *F. oxisporum f.sp lycopersici* was enhanced at high salinity, while no effect was observed on vegetative growth of the pathogen (Daami-Remadi *et al.,* 2009). Mycelial dry weight of *Phytophthora capsici* increased by 8 to 16% with an increase in salinity level, and mycelium radial growth was accelerated by 5 to 30%. However, sporangial production and zoospore formation decreased by roughly 3 to 85 and 1 to 93%, respectively (Sonogo, 2004).

Effects of Salinity on Plant Disease Severity

Kumar *et al* (2010) reported that, in different cultivars of groundnut, foliar fungal disease severity decrease with an increase in salinity levels. The authors reiterated that, the development of foliar fungal disease could be as a result groundnut being sensitive to salinity. The decrease in severity however, could be attributed to the triggering effects of sodium salt in defense mechanism (Kumar *et al*., 2010). Additionally, changes in the host and pathogen during salinity stress result in either repression or stimulation of the activity of hydrolytic enzymes involved in disease development; in this case, the repression of cellulase and galactase activity during salinity stress resulted in a reduction in the disease's severity (Kumar *et al*., 2010).

On the other hand, ventura tomato inoculated with *F. oxysporum* F.sp lycopersici demonstrated that increasing salinity stress from 2 to 10 g/L of NaCl accelerated the disease. Subsequently, the leaf damage index (LDI) due to disease was observed to be highest at 8 and 10 g/L of NaCl concentration (Daami-Remadi *et al*., 2009). According to these authors, the enhanced wilt severity was due to the osmotic stress, decreased water potential as well as water deficit imposed by salt stress, and its effects on the exudates of the root which is considered as an important factor in early stage of disease development.

Although virulence variability of the pathogen was observed, treatment with 40 mM NaCl increased disease severity and development four days after inoculation of common bean (*Phaseolus vulgaris*) with a pathogen (*Macrophomina phaseolina*). The inoculated plant under salt stress showed high level of Na^+ and Cl^- ions with a significant decrease of K^+ ion in plant tissues under salt and *M. phaseolina* (You *et al*., 2011). This indicates that salt stress prevent plants from absorption of essential macronutrients especially K^+. Ions of K^+ when absorbed in to the tissues by plants, promote plant resistance to diseases.

Disease incidence in tomato transplants infected with *F. oxysporum* F.Sp *radices-lycopersici* attained 75% when saline irrigation water of 3.2±0.1 dSm^{-1} was applied; while treatment with 0.4±0.1 dSm^{-1} caused 38% disease incidence (Triky-Dotam *et al*., 2005). Application of mineral fertilizer coupled with salinity stress promoted the severity of the disease as earlier disease manifestation was also uncovered in plants irrigated with saline water (Triky-Dotam *et al*., 2005). This implies that when plants are exposed to salt stress, their response to the effects of salinity commonly resulted in the increasing disease condition.

Under the influence of soil salinity, incidence of blackheart disease of lettuce due to *Botrytis cinerea* increased to about 90%; while the necrotic disease symptoms first appeared in lettuce treated with 40 mM of NaCl (Tzortzakis, 2009). When Chile Pepper (*Capsicum annuum* L) was exposed to different salinity levels, the disease severity of wilt and root rot caused by *P. capsici* increased roughly to 3-fold with increasing salt concentrations, while *P. capsici* resistant variety showed no effects (Sanogo, 2004). This suggest that salinity may make chilli pepper plants more vulnerable to *P. capsici* infection.

CONCLUSION

Owing to the information provided in this paper, it can be concluded that salinity is an environmental factor that can significantly influence the plant susceptibility to pathogens, which is becoming problematic in the control and management of plant diseases. Salinity contributes in the growth, sporulation and development of plant pathogens. However, it causes a serious havoc in the plant disease epidemiology. The severity and incidence of diseases caused by phytopathogens are however influenced by increasing salinity, thus plants exposed to higher salinity stress tend to be more susceptible to diseases. Further research will assist in the identification and improvement of plants for salt tolerance, and invention of modern sustainable approaches to curb the escalation of salinity in agricultural soils will assist in the suppression of the effect of salinity specifically on non-halophytic plants. Lastly, proper and effective management of soil salinity will indirectly provide an avenue for the control of plant diseases.

REFERENCES

Abuelgasim, A. and Ammad, R. (2018). Mapping soil salinity in arid and semi-arid regions using Landsat 8 OLI satellite data. *Remote Sensing Applications: Society and Environment*. https://doi.org/10.1016/j.rsase.2018.12.010.

Agrios, G. N. (2005). Plant Pathology (Fifth Edition ed.): *Elsevier Academic Press*.

Bahmani, K., Noori, S. A. S., Darbandi, A. I., and Akbari, A. (2015). Molecular mechanisms of plant salinity tolerance: a review. *Australian journal of Crop Science*, 9(4), 321-336.

Bai, Y., Kissoudis, C., Yan, Z., Visser, R. G., and van der Linden, G. (2018). Plant behaviour under combined stress: tomato responses to combined salinity and pathogen stress. *The Plant Journal*, 93(4), 781-793.

Besri, M. (1993). Effects of salinity on plant diseases development. In *Towards the rational use of high salinity tolerant plants* (pp. 67-74). Springer, Dordrecht.

Daami-Remadi, M., Souissi, A., Oun, H. B., Mansour, M., and Nasraoui, B. (2009). Salinity effects on Fusarium wilt severity and tomato growth. *Dynamic Soil, Dynamic Plant*, 3(1), 61-69.

Dikilitas, M. (2003). *Effect of salinity and its interactions with Verticillium albo-atrum on the disease development in tomato (Lycopersicon esculentum Mill) and lucerne (Medicago sativa L and M. media) plants*. Swansea University (United Kingdom).

Etikala, B., Adimalla, N., Madhav, S., Somagouni, S. G., and Keshava Kiran Kumar, P. L. (2021). Salinity Problems in Groundwater and Management Strategies in Arid and Semi-arid Regions. *Groundwater Geochemistry: Pollution and Remediation Methods*, 42-56.

Eydoux, L., and Farrer, E. C. (2020). Does salinity affect lifestyle switching in the plant pathogen Fusarium solani?. *Access Microbiology*, *2*(6).

Feng, W., Kita, D., Peaucelle, A., Cartwright, H. N., Doan, V. *et al* (2018). The FERONIA receptor kinase maintains cell-wall integrity during salt stress through Ca2+ signaling. *Current Biology*, 28(5), 666-675.

Feng, W., Lindner, H., Robbins, N. E. II, and Dinneny, J. R. (2016). Growing out of stress: the role of cell- and organ-scale growth control in plant water-stress responses. *Plant Cell* 28, 1769–1782.

Haller, E., Iven, T., Feussner, I., Stahl, M., Fröhlich, K., *et al* (2020). ABA-dependent salt stress tolerance attenuates Botrytis immunity in Arabidopsis. *Frontiers in plant science*, 1816.

Hopmans, J. W., Qureshi, A. S., Kisekka, I., Munns, R., Grattan, S. R., *et al* (2021). Critical knowledge gaps and research priorities in global soil salinity. *Advances in agronomy*, *169*, 1-191.

Kesten, C., Menna, A., and Sánchez-Rodríguez, C. (2017). Regulation of cellulose synthesis in response to stress. *Current Opinion in Plant Biology*, 40, 106-113.

Kumar, V., Ghewande, M. P., Girdhar, I. K., Padavi, R. D., and Bhalodia, P. K. (2010). Effect of salinity stress on foliar fungal diseases of groundnut. *Indian Phytopathology*, 63(3), 273.

Kutama, A., Adamu, M., Baita, H., Zafar, S., & Hadiza, M. (2022). Review on the contributions of some human cultural practices to plant disease epidemiology. *Dutse Journal of Pure and Applieed Science (DUJOPAS)*, 8(2b):12-20

MacDonald, J. D. (1984). Salinity effects on the susceptibility of chrysanthemum roots to Phytophthora cryptogea. *Phytopathology*, *74*(5), 621-624.

Maharshi, A., Rashid, M., Teli, B., Singh, D. P., Babbar, A., & Sarma, B. K. (2022). Suppression of Defence Signalling and Wound-Healing Responses in Chickpea by Fusarium oxysporum f. sp. ciceris in Salinity-Affected Soil Increases Vulnerability to Wilt Incidence. *Journal of Plant Growth Regulation*, 1-12.

Manasa, M., Katukuri, N. R., Darveekaran Nair, S. S., Haojie, Y., Yang, Z., and Guo, R. B. (2020). Role of biochar and organic substrates in enhancing the functional characteristics and microbial community in a saline soil. *Journal of Environmental Management*, 269,110737. https://doi.org/10.1016/j.jenvman.2020.110737

Metternicht, G., & Zinck, A. (2008). *Remote sensing of soil salinization: Impact on land management*. CRC Press.

Nejat, N., and Mantri, N. (2017). Plant immune system: crosstalk between responses to biotic and abiotic stresses the missing link in understanding plant defence. *Current Issues in Molecular Biology*, 23(1), 1-16.

Peña, A., Delgado- Moreno, L., and Rodríguez- Liébana, J. A. (2020). A review of the impact of wastewater on the fate of pesticides in soils: Effect of some soil and solution properties. *Science of the Total Environment*, 718, 134468– https://doi.org/10.1016/j.scitotenv.2019.134468

Ramos, T. B., Castanheira, N., Oliveira, A. R., Paz, A. M., Darouich, H., Simionesei, L., Farzamian, M., and Goncalves, M. C. (2020). Soil salinity assessment using vegetation indices derived from Sentinel- 2 multispectral data. Application to Leziria Grande, Portugal. *Agricultural Water Management*, 241, 106387. https://doi.org/10.1016/j.agwat.2020.106387

Ravichandra, N.G, (2013). Fundamentals of Plant Pathology. Delhi: *PHI Learning Private Limited*.

Sanogo, S. (2004). Response of chile pepper to Phytophthora capsici in relation to soil salinity. *Plant Disease*, *88*(2), 205-209.

Shrivastava, P. and Kumar, R. (2015). Soil salinity: a serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. *Saudi Journal of Biological Sciences*22 (2): 123–131. https://doi.org/10.1016/j.sjbs.2014.12.001

Singh, A. (2018a). Alternative management options for irrigationinduced salinization and waterlogging under different climatic conditions. *Ecological Indicators*, 90, 184– 192. https://doi.org/10.1016/j.ecoli nd.2018.03.014

Singh, A. (2022). Soil salinity: A global threat to sustainable development. *Soil Use and Management*, *38*(1), 39-67.

Stetina, T. (2013). The Effects of Salinity on Pythium Disease of Rice and Soybean. *University of Arkansas.*

Tian, F., Hou, M., Qiu, Y., Zhang, T., and Yuan, Y. (2020). Salinity stress effects on transpiration and plant growth under different salinity soil levels based on thermal infrared remote (TIR) technique. *Geoderma*, 357, 113961. https://doi.org/10.1016/j.geoderma.2019.113961

Triky-Dotan, S., Yermiyahu, U., Katan, J., and Gamliel, A. (2005). Development of crown and root rot disease of tomato under irrigation with saline water. *Phytopathology*, 95(12), 1438-1444.

Tuteja, N., Peter Singh, L., Gill, S. S., Gill, R., and Tuteja, R. (2012). Salinity stress: a major constraint in crop production. *Improving crop resistance to abiotic stress*, 71-96.

Tzortzakis, N. G. (2009). Alleviation of salinity-induced stress in lettuce growth by potassium sulphate using nutrient film technique. *International Journal of Vegetable Science*, 15(3), 226-239.

Van Zelm, E., Zhang, Y., and Testerink, C. (2020). Salt tolerance mechanisms of plants. *Annual Review of Plant Biology*, 71, 403-433.

Wang, F., Yang, S., Wei, Y., Shi, Q., and Ding, J. (2021). Characterizing soil salinity at multiple depth using electromagnetic induction and remote sensing data with random forests: A case study in Tarim River Basin of southern Xinjiang, China. *Science of the Total Environment*, *754*, 142030.

Wang, M., Zheng, Q., Shen, Q., & Guo, S. (2013). The critical role of potassium in plant stress response. *International journal of molecular sciences,* 14(4), 7370-7390.

You, M. P., Colmer, T. D., and Barbetti, M. J. (2011). Salinity drives host reaction in Phaseolus vulgaris (common bean) to Macrophomina phaseolina. *Functional Plant Biology*, 38(12), 984-992.