Review Article

Salinity Stress in Legume Crops: A Comprehensive Review of Effects, Mechanisms, and Mitigation Strategies

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ABSTRACT

Salt stress is a constant threat to crop productivity, especially in countries with extensive irrigation systems. Enhancing agricultural plants' ability to withstand salt is crucial for long-term crop growth on marginal soils, which ensures a future supply of food. The high protein content and ability of grain legumes to fix nitrogen in the environment make them an interesting class of plants. But the use of salty groundwater and the buildup of excess salt in the soil are endangering the world's ability to grow legumes. Because salt stress interferes with photosynthesis, hormone regulation, and nutritional balance, it lowers bean yield and quality. Additionally, it intensifies a number of osmotic effects and ion toxicities. Understanding the tolerance structures associated with grain legumes, how they respond to salt stress, and available management choices may this help in the development strategies to improve grain legume performance under salinity stress. This review~~study~~ looks at treatment and tolerance mechanisms as well as how salt stress affects legumes. The main conclusions of the review are as follows: (1) owing to ion toxicity, salt stress decreases growth (is more than 70%), yield (by 12-100%), and mineral absorption. The creation of transgenics and crop improvement management techniques should boost grain legume output and salt tolerance on soils affected by salinity. One accurate indicator of resistance to salt stress is apoptotic acidification. (2~~iv~~) Grain legumes may compartmentalise or excrete toxic ions in order to develop a resistance to salt stress.

Key words:

Comment [u2]: Didn't write key words write it alphabetically. Legume crops, mitigations strategy, salinity stress

1. INTRODUCTION

Soil salinity inhibits the normal growth and development of most crop plants, and causes significant yields losses globally (Cao *et al.*, 2018).~~Salt-affected soil may have excess soluble salt and commutable sodium at the soil's level or in the rhizosphere.~~ Salinity stress, which impacts more than 800 million hectares of land worldwide, is one of the primary obstacles to the development of profitable crops (FAO, 2008). The FAO has reported that increasing soil salinity may take approximately 0.3 to 1.5 Mha of agricultural land out of production each year and reduce the yield potential of about 20 to 46 Mha (FAO and ITPS, 2015). Inaccurate agricultural trails have contributed to an increase in salt attentiveness in the rhizosphere, together with environmental variables such as parent rock pollution, sea salt, and salty beach water (Rengasamy, 2010). The productivity of arable land under cultivation is at risk due to the global increase in salinization of arable land. According to Deinlein et al. (2014), oxidative damage and nutritional imbalances fall under the same category as salt stress for glycophytes as do osmotic stress and ionic imbalances. While Cl, the main anion in salt-affected soils, may also be hazardous to certain plant species, Na is the most potentially harmful ion under these conditions. Plant hydration is restricted by a "physiological/secondary drought" resulting from a "osmotic balance imbalance" caused by elevated salinity levels (Farooq et al., 2015).

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Fabaceae include low-cost, high-nutrient foods, ~~such~~and such grain legumes. These consist of 17–40% of the proteins included in food, as well as significant amounts of fibre, complex carbohydrates, vitamins, minerals, and important amino acids. Legumes are an important part of crop rotation because they have the biological capacity to fix nitrogen (N), which increases crop yields and enhances soil fertility. Legumes are unique in that they provide various living things with a skeleton of nitrogen (N) due to their ability to fix nitrogen (N) from biologically limiting molecular dinitrogen (N2) to accessible forms (Qureshi et al., 2010). Legumes comprise 12–15% of all arable land worldwide and provide 27% of major agriculture and 33% of dietary protein (Mishra et al., 2014). Because they are abundant in protein, legumes constitute a staple diet for millions of people and animals.

The effects, mechanisms of tolerance, and management of salt stress in grain legumes have not been adequately addressed, despite the fact that the effects of salt stress on numerous crops have been researched (Flowers et al., 2010; Deinlein et al., 2014; Farooq et al., 2015; Parihar et al., 2015). This article reviews and synthesises the impacts of salt stress on grain legumes, including how it affects nutrient intake, hormone control, senescence, grain growth, leaf development, carbon fixation, and light harvesting. The processes behind the tolerance to salt are explained. Moreover, a variety of management techniques, in conjunction with recently created breeding and functional genomics technologies, are being researched to increase grain legumes' resistance to salt stress.

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With the objectives to focus on how to address treatment and tolerance mechanisms as well as how salt stress affects legumes.

Saline Soils

Saline soils contain excess soluble salts that are classified according to their electrical conductivity (EC) of the saturation soil extract in deciSiemen meter^{-1} (dS m^{-1}) into nonsaline (EC < 2 dS m^{-1}), slightly saline (EC = 2–4 dS m^{-1}), moderately saline (EC = 4–8 dS m^{-1}), and strongly saline (EC > 16 dS m^{-1}; (Nackley and Kim, 2015). The excessive amount of saltwater soluble in these soils is hazardous to most plant development. According to the Soil Science Society ~~of ,~~of, the general categorization limit is ECe > 4 dS m^{-1}, while the minimum values for pH and SAR are less than 8.5 and 13 (mmolcL^{-1}) 1/2, respectively. Although suspensions of greater soil to water ratios (1:1, 1:2, or 1:5) are also utilised, the electrical properties of the extract of saturated paste (ECe) is typically used to determine the salinity of the soil. However, there are significant differences between various plant and crop kinds, as well as under varying soil and climatic situations, and the critical limit of EC 4.0 dS m^{-1} is merely arbitrary. These soils' structure and other physical characteristics remain unaffected.

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Saline Sodic Soils

Saline-sodic soils possess properties of both sodic and saline characteristics including EC > 4 dS m^{-1}, sodium adsorption ratio > 13, and pH < 8.5 (Chi et al., 2012). The majority of plant growth is threatened by these soils' significant saltwater soluble component. ~~The overall classification limit is ECe > 4 dS m^{-1}, while the minimum values for pH and SAR are less than 8.5 and 13 (mmolcL^{-1}) 1/2, respectively, according to the Soil Science Society of.~~ The electrical characteristics of the extract of saturated paste (ECe) are often employed to calculate the salinity of the soil. But larger soil to water ratio (1:1, 1:2, or 1:5) suspensions are also helpful. However, the EC 4.0 dS m^{-1} critical limit is completely arbitrary, and there are large differences between different plant and crop species as well as under different soil and climatic circumstances. The physical properties and content of these soils don't change.

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Salinity Effect on Transpiration, Photosynthesis, Plant Growth and Crop Yields

These soils have pH values larger than 8.5 and ECe and SAR values greater than 4 dS m–1 and 13 (mmolcL–1) 1/2, respectively. Changes exist in the ratios of soluble salts (ECe) and exchangeable sodium (assessed by SAR or ESP). These soils are relatively porous at first, but when soluble salts from raindrops or irrigation water seep through, sodium becomes more abundant and the physical characteristics of the soil progressively take on characteristics of a sodic soil. As a result, these soils have characteristics with both sodic and saline soils.

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Legumes and Salinity/Sodicity

Salinity has an impact on plant development and productivity, depending on the kind of plant, salinity levels, and ionic composition of the salts. The majority of agricultural plants produce less when irrigated with salted water or in more salinized soils; this results in discernible alterations in plant growth patterns. Many different types of salinized ecosystems are home to plants. On the other hand, species that are more resistant to salt, like cotton, may only exhibit a 20% dry weight drop, while sensitive plant families, like soybean, may perish at the same concentration of NaCl.

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Grain legume germplasm resources for improving salinity stress tolerance:

The use and classification of genetic resources are essential to the genetic progress of any crop. The breeding of salt-resistant crops, particularly grains like wheat and rice, has advanced significantly ~~[for further information,~~(Ashraf and Wu, ~~(~~2011)~~]~~. The progress in improving resistance to salt has been hindered by the weak genetic basis of grain legume crop breeding activities (Sharma et al., 2017).

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2. EFFECT OF SALT STRESS ON GRAIN LEGUMES

Grain legumes are very susceptible to salt stress, which significantly lowers production, as Table 1 illustrates. Salinity is a critical risk factor for the formation of root nodules, plant germination and development, the symbiotic relationship with Rhizobium, and legumes' ability to fix nitrogen, according to van Hoorn et al. (2001). Reduced carbon fixation (Flexas et al., 2004), imbalanced hormone regulation, nutritional deficiencies, specific ion and osmotic effects (Yadav et al., 1989; El Sayed, 2011), delayed flowering, and decreased flower numbers and pod set (Khan et al., 2016a) are some of the factors linked to salinity-induced yield reduction. Here, the impacts of salt stress on legume grain production and quality are discussed, along with their effects on seed germination, seedling establishment, nutrient absorption, carbon fixation, and light harvesting.

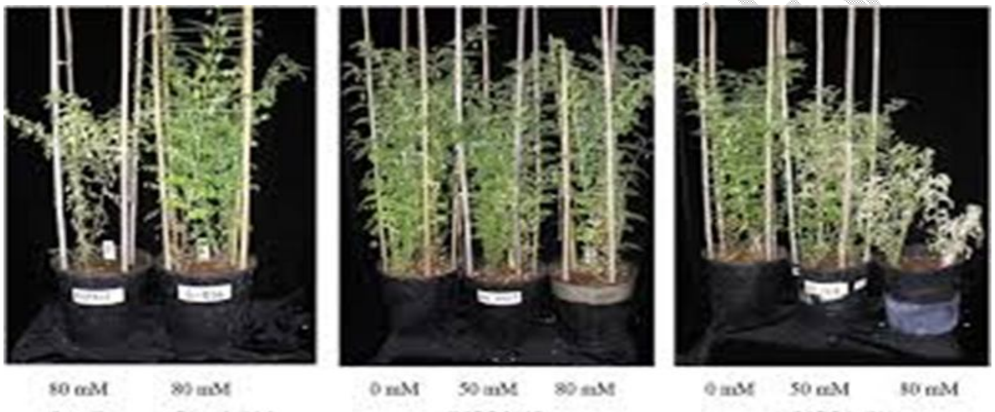

Fig .1 Effect of salt stress on grain legumes

Germination and plant growth

By reducing water intake and/or negatively affecting the embryo, salt exposure prevents germination (Okcu et al., 2005; Farooq et al., 2015). A reduction in the water potential gradient between the surrounding environment and the surface is the main barrier to dramatic growth (Munns and James, 2003). Salt stress limits water absorption, the first step in germination, but also accelerates the enzymes that break down food reserves and initiate the germination metabolism. Furthermore, salt inhibits the mobilisation of starch, delaying the development of the embryonic axis. For example, in cowpea (Vigna unguiculata L.), salt stress significantly reduced seed germination by decreasing the activity of the hydrolytic enzymes a- and b-amylase (Filho et al., 1995). Secondary seed dormancy may also be brought on by osmotic stress from salt. Higher intracellular concentrations of Na and Cl during the dividing and developing stage limit cell metabolism (Keshavarzi, 2011). Al-Mutata (2003) states that grain legumes are significantly more susceptible to salt stress during the establishment of seedlings and later stages of development than they are during germination. This is consistent with the biphasic paradigm put out by Munns (1993), according to which ion toxicity occurs in the second phase while osmotic stress inhibits development in the first. Since starch is mostly mobilised during the establishment phase, legume seeds are particularly vulnerable to salt stress. Chickpea (Cicer arietinum L.) development decreased significantly at extremely low salt concentrations (20 mM), but it decreased by 71% at 25 mM NaCl, as shown by Sadiki and Rabih (2001). Other grain legumes were also reduced by salt stress: faba bean (Vicia faba L.; Pitann et al., 2011); common bean (Phaseolus vulgaris L.; Ferri et al., 2000); mungbean (Vigna radiata (L.) Wilczek; Kabir et al., 2006); lentil (Lens culinaris L.; Bandeoglu et al., 2004); soybean (Glycine max L.; Luo et al., 2006); and lentil (Lens culinaris L.; Bandeoglu et al., 2004). Reduced tissue water potential, or less water accessible to cells,

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is often linked to these growth declines (Sehrawat et al., 2013a, b; Garg and Bhandari, 2016). Garg and Manchanda (2009) claim that this inhibits growth, decreases photosynthesis, and induces stomatal closure.

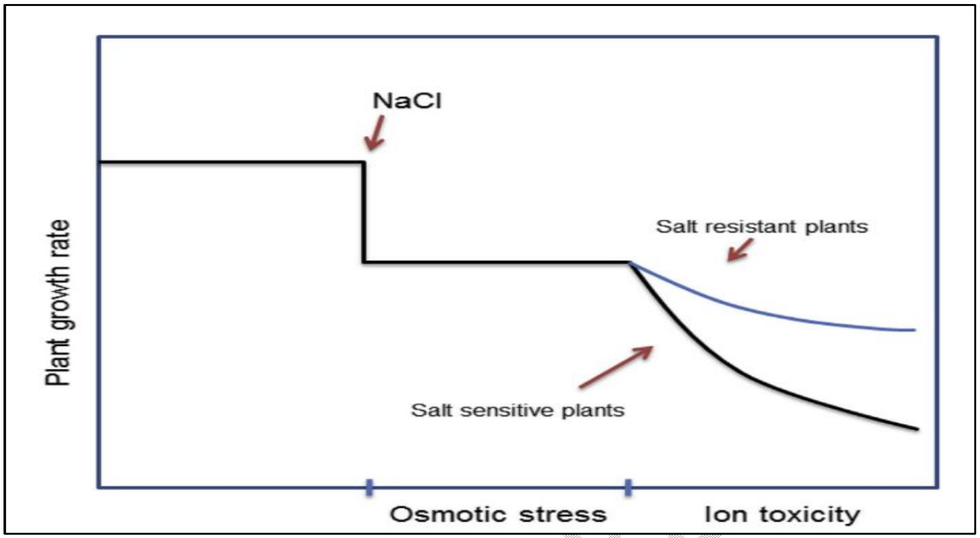

Fig.2 (A bi-phasic model of salinity-induced growth reduction (modified from Munns,1993).

Lower growth rates in grain legumes under salt stress have also been related to lack of cell wall acidification (Pitann et al., 2011). Apoplastic acidification, which is caused by plasmalemma H-ATPase activity and the activation of pH-dependent cellular-wall-loosening enzymes involved in cell growth and enlargement, facilitates growth stimulation (Rayle and Cleland, 1992). Thus, as the faba bean demonstrates, inhibiting the acidity of the cell wall slows down the growth of new cells. Another mechanism attributed to salinity-induced growth decreases in grain legumes is specific ion toxicity (Munns, 1993; Samani et al., 2011). One way to characterise this component would be as a function of tissue Na and/or Cl ion concentrations and time. Ion poisoning is the main cause of salt stress-induced leaf death, according to Samamineni et al. (2011). When chickpea plants were cultivated in 20 mM NaCl, their growth was reduced by as much as 17%; in this instance, it was Cl, not Na, that passed the threshold concentration and caused the harm. Shoot had more Cl than Na at a greater concentration of NaCl (60 mM) (Samineni et al., 2011). Grewal (2010) found no correlation between shoot Na and chickpea development under salt stress, in contrast to Vadez et al. (2007). In general~~conclusion~~, when grain legume seeds are subjected to salt stress, a number of processes, including as ion toxicity, osmotic stress, decreased water absorption, turgor loss, lack of apoplastic acidification, and/or specific ion toxicity, inhibit the seeds' ability to germinate. It also prevents them from developing.

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Table 1: Yield reduction under different salinity levels.

Legume Crops	Salt Concentration	Yield Loss (%)	References
Soybean (Galarsum)	14.4dSm−1	50%	Khan et al. (2016)
Soybean (Lee)	8.5dSm−1	53%	Essa et al. (2002)
Soybean (loam soil)	7dSm−1	46%	Van Hoorn et al. (2001)
Soybean (caly soil)	6.3dSm−1	46%	Katerji at el. (2000)
Mungbean (cv. Pusavishal)	50	41%	Shehrawat at el. (2015)
Mungbean (var. 245/7)	8dSm−1	60%	Ahmed et al. (2009)
Mungbean (var. NM-51)	12dSm−1	77%	Ahemd et al. (2009)
Mungbean (var. NM-92)	8dSm−1	61%	Ahmed et al. (2009)

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Mungbean (var. 6601)	12dSm−1	72%	Ahmed et al. (2009)
Chickpea (var. FLIP 87-59)	3.8dSm−1	69%	Katerji et al. (2000)
Chickpea (var. FLIP 87-59)	2.5dSm−1	43%	Van Hoorn et al. (2001)
Chickpea (var. ILC 3279)	3.8dSm−1	72%	Van Hoorn et al. (2001)
Fababean (loam soil)	6.6dSm−1	50%	Katerji et al. (2000)
Fababean (clay soil)	5.6dSm−1	52%	Katerji et al. (2000)
Fababean (loam soil)	4.9dSm−1	28%	Van Hoorn et al. (2001)
Fababean (clay soil)	4.3dSm−1	19%	Van Hoorn et al. (2001)
Lentil (cv. 6796)	3.1dSm−1	100%	Van Hoorn et al. (2001)
Lentil (cv. 6796)	2dSm−1	14%	Van Hoorn et al. (2001)
Lentil (cv. 5582)	2dSm−1	24%	Van Hoorn et al. (2001)
Lentil (cv. 5582)	3.1dSm−1	88%	Van Hoorn et al. (2001)

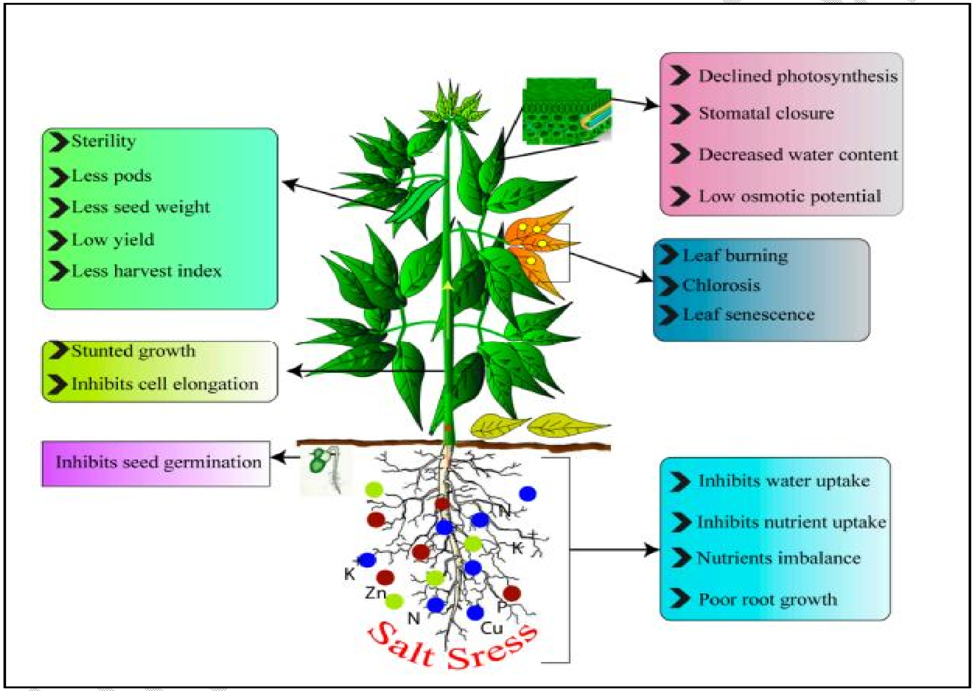

Figure 3. Schematic representation of plant response to salt stress (SS).

Grain development and yield formation: Salt stress suppresses physiological responses and morphological features, which hinders grain legume growth and decreases yields by 12–100%, according to Shahemi-Golezani et al. (2009), Flowers et al. (2010), Khan et al. (2016), and others (Table 1). The main factors that determine grain yield in grain legumes are the weight of each grain, the number of pods per plant, and the number of grains per pod. According to Dhingra and Varghese (1993) and Mamo et al. (1996), salt stress lowers pollen production and flower counts, which in turn lowers pod counts, grains per pod, and grain weight. Both within and across species, there is variation in this area (Dhingra and Varghese, 1993; Flowers et al., 2010; Turner et al., 2013). Reduced stigma receptivity, decreased pollen viability, and a lack of photoassimilates during grain filling are the three main factors causing salinity-induced decreases in grain production (Flowers et al., 2010; Khan et al., 2016a). For example, chickpea under salt stress had significantly lower grain yields because the

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pollen tube shortened, resulting in less grains and less fertilisation (Dhingra and Varghese, 1993). Turner et al. (2013) discovered that pollen viability was unrelated to salinity-induced increased pod abortion in sensitive chickpea genotypes, since salt stress had no effect on in vitro pollen germination or in vivo pollen development. According to several studies (Turner et al., 2013; Kotula et al., 2015; Pushpavalli et al., 2016), there was no appreciable increase in the concentration of Na~~+~~ in reproductive tissue that would have had an adverse effect on the mechanisms involved in reproduction. Since grain growth is primarily supported by assimilates from the current photosynthesis in leaves (photosynthates produced after anthesis provide up to 98% of the grain carbon in grain legumes), this salinity-induced pod abortion may be related to a significant reduction in assimilate supply under salt stress (Khan et al., 2016a). Even while the grain weight in chickpeas only drops by 20% or 10%, grains grown under salt stress may shrink and lose part of their grain protein, according to Vardez et al. (2007) and Dua (1992). However, other yield components are declining as well: the quantity of grains falls by 33.50%, and the number of pods decreases by 38% (Dua, 1992; Vadez et al., 2007). Lower grain weights and fewer grains per pod were the primary causes of salinity-induced decreases in mungbean grain production (Ahmed, 2009; Katerji et al., 1992~~; Ahmed, 2009~~). However, in soybeans, the yield loss caused by salt was equally attributable to every yield-related trait (Ghassemi-Golezani et al., 2009).

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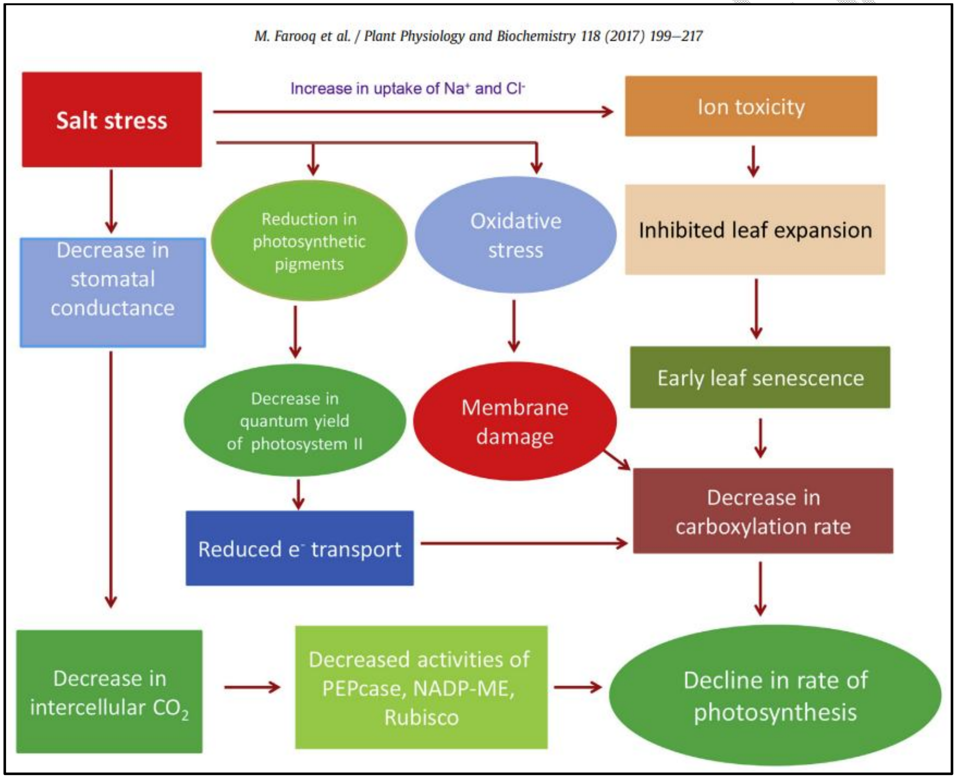

Fig. 4. Mechanism of salt stress-induced reduction in the rate of photosynthesis.

Salinity-induced osmotic stress causes oxidative stress, which disrupts the integrity of biological membranes and reduces the carboxylation rate. Increases in tissue Na and Cl cause ion toxicity, which decreases leaf growth, and triggers early leaf senescence, which reduces the carboxylation rate. Salt stress also reduces photosynthesis due to a reduction in the activities of ribulose-1, 5-bisphosphate carboxylase/oxygenase (Rubisco), phosphoenolpyruvate carboxylase (PEP Case), and NADP-malic enzyme (NADP-ME). Non-cyclic electron transport is also down-regulated to match the reduced requirements of lower nicotinamide adenine dinucleotide phosphate production, which reduces the synthesis of adenosine tri-phosphate (~~modified from~~ Farooq et al., 2015).

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Light harvesting and carbon fixation

Research by Flexas et al. (2004), Chaves et al. (2009), Khan et al. (2015), and others has shown the significant impacts of salt stress on grain legumes. Both stomatal and non-stomatal components may be responsible for this decrease (Fig. 4; Chaves et al., 2009; Khan et al., 2015). Legumes' capacity to fix carbon (C3 photosynthesis) is lowered in response to salt stress because of decreased stomata diffusion and resulting CO2 availability (Flexas et al., 2004). Non-stomatal reasons include oxidative damage to the photometric apparatus and mesophyll conductance to CO_2. For instance, in chickpea, the cause of the fall in photosynthesis under salt stress was damage to photosystem II (PS II) rather than stomatal restriction, or a drop in the concentration of CO2 between cells. Moreover, oxidative stress resulting from salinity and/or toxicity from Na and/or Cl could have played a part (Khan et al., 2015). Hernandez and colleagues (1995) confirmed a same discovery in pea. Eyidogan and Oz (2007) found a correlation between a decrease in photosynthesis in chickpea under salinity and non-stomatal factors, namely oxidative damage to the thylakoid.

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Salt stress causes an overabundance of reactive oxygen species, or ROS, which in turn causes oxidative stress. Reduced CO2 intake causes photorespiration in legumes, which stimulates cell membrane-bound NADPH oxidases and apoplastic diamine oxidases, resulting in excessive H2O2 synthesis in the peroxisome. In the Calvin cycle, reduced stomatal conductance minimises CO2 intake and minimises water loss. This leads to the release of oxidised NADP+, the last electron acceptor, and the start of electron leakage, which forms O (Abogadallah, 2010). These mechanisms lead to the generation of ROS. One area of cell biochemistry that is impacted by elevated ROS production is membrane permeability. Plants' vital physiological processes are hampered by the oxidative damage that salinity-induced ROS production does to lipids, proteins, and DNA, among other cellular components (Gupta and Huang, 2014). Although there is currently a dearth of study on legumes, it has been shown that certain species respond to salt stress by releasing both reactive oxygen species (ROS) and nitrogen reactive elements (NRS).

Many stomatal and non-stomatal factors, including as reduced photosynthetic pigments, ultrastructural degradation, and chlorophyll fluorescence, contribute to salinity-induced decreases in photosynthesis in grain legumes (Eyidogan and Oz, 2007; Khan et al., 2015).

Biological nitrogen fixation

By obstructing the biological fixation and absorption of N, salt stress lowers the amount of N accessible in grain legumes (Frechilla et al., 2001; Rabie and Almadini, 2005). In plant roots, specialised structures known as nodules emerge where biological N fixing occurs. However, since nodules involved in biological N production are susceptible to salt stress, the nodulation process is very vulnerable to it. For instance, salt stress dramatically decreased the quantity and activity of nodules in faba bean (Cordovilla et al., 1994; Rabie and Almadini, 2005) and pigeon pea (Cajanus cajan L.) (Garg and Manchanda, 2008) due to their premature senescence (Matamoros et al., 1999), which inhibited biological N fixation (Cordovilla et al., 1994; Delgado et al., 1994).

Rhizobia stimulate the formation of legume nodules in saline conditions, where they engage in molecular interactions with symbiotic partners. Moreover, proper rhizobia chemotaxis may get flavones or isoflavones, which are plant metabolites. When rhizobia approach the roots, they increase the expression of many genes associated with lipochito-oligosaccharide synthesis and secretion; these genes are called NOD factors (NFs) (Lerouge and al., 1990; Spaink et al., 1991). Alfalfa (Medicago sativa L.), peanuts (Arachis hypogaea L.), peanut butter (Arachis truncatula Gaertn.), peas, soybean, faba bean, and common beans (Phaseolus vulgaris L.) are among the legumes that are more susceptible to salt than others (Lauchli, 1984). Thus, host plants are more vulnerable to salt stress than Rhizobium, according to Manchanda and Garg (2008), whereas Mudgal et al. (2010) discovered that functional symbiosis is particularly vulnerable to salt stress. When faced with salt stress, Zahran (1999) said, "Better findings can be obtained for symbiotic N fixation if partners have mutual symbiosis and various other steps between their interaction (nodule formation/development, activity, etc.) oppose salt stress."

In grain legumes, salt stress often affects symbiotic relationships and plant growth (Tejera et al., 2004; Lopez et al., 2008). The suppression of particular nitrogenase activity is one technique to illustrate the

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deleterious consequences of salt stress on the legume-Rhizobium symbiotic relationship. According to Delgado et al. (1993), bacteroids and protein haemoglobin were found to be decreasing, which resulted in a reduction in nitrogenase activity. Reduced availability of vitamin C, mostly as malate, worsens the harm that salt does to bacteroids. This may be due to the fact that salt inhibits some enzymes, including phosphoenolpyruvate carboxylase and sucrose synthase. This implies that the oxygen supply to the nodules is one of the limiting variables. As salinity rose, a tolerant Rhizobium's increased oxygen nodule conductance stability was connected to higher salt tolerance (L'taief et al., 2007).

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Ion homeostasis

Ion homeostasis, which is controlled by ion flux regulation to maintain low concentrations of detrimental ions like Na+ and high concentrations of essential ions like K+, is a crucial property of live cells under salt stress (Hasegawa et al., 2000; Farooq et al., 2015). Maintaining intracellular (K+ and Na+) homeostasis is necessary for regulating cell volume, protecting membrane potential, and enabling the proper function of many cytosolic metabolic enzymes (Hasegawa et al., 2000). Plants maintain a balance between intracellular K+ and Na+ concentrations in salinity by removing excess salt from the cytosol via primary active transport as well as secondary transport pathways. (Hasegawa et al., 2000; Li et al.,~~and associates,~~ 2006).

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To maintain ion homeostasis in the face of salt stress, plant cells control these sodium transporters in the tonoplast and plasma membrane (Li et al., 2006). The transcript levels of many K+ transporter genes vary with salinity (Cordovilla et al., 1995). Extruding or compartmentalising excess Na+ in the vacuole is an effective strategy to counteract the detrimental effects of Na+ in the cytoplasm (Li et al., 2006; Farooq et al., 2015). Ion distribution patterns vary across grain legume species and cultivars, particularly with respect to the cytosolic Na+/K+ ratio (Cordovilla et al., 1995). For instance, the salt-tolerant mashbean cultivar (T-44) has special Na+/K+ transporters that help to maintain low intracellular Na+ concentrations (Mishra et al., 2014). Pigeon peas have a mechanism for salt tolerance that involves enhanced K+ absorption, maintaining high K+/Na+ ratios in shoots, and keeping Na+ and Cl out of shoots, according to Waheed et al. (2006). Munns and Tester (2008) suggest that ion toxicity in reproductive organs and younger leaves may be prevented by ion sequestration in older tissues and the exclusion of Na and Cl by roots. According to Turner et al. (2013), there is a significant correlation between chickpea salt sensitivity and higher Na+ concentrations in immature leaves and seeds, but not in later tissues. Salt tolerance requires limiting the build-up of excess Na+ in younger tissues; however, this may not be connected to ion storage in older tissues (Turner et al., 2013).

Table 2: Accumulation of osmolytes in different grain legumes under salt stress.

Crops	Osmolytes	Traits	References
Chickpea	Proline Total soluble sugars, proline, glycine betaine and choline	Energy-yielding substrates for Bacteroides Improved plant biomass and photosynthetic pigments	Soussi et al. (2001) Qurashi and Sabri (2013)
Faba bean	Free amino acids and free proline	Osmotic adjustment	El Sayed (2011)
Groundnut	Proline	Osmotic adjustments and protection of membrane integrity	Jain et al. (2001)
Kidney bean	Glycine betaine	Increased stomatal conductance and leaf RWC	Lopez et al. (2002)
Mungbean	Potassium accumulation in leaf, root, and stem	Increased survival tolerance, leaf RWC, membrane stability index, grain weight and grain yield	Shehrawat et al. (2014)
Pea	Reducing sugars, total free amino acids, and ascorbic acid Potassium and calcium	Osmotic adjustment Increased root and shoot dry weights	Olmos and Hellin (2016) Shahid et al. (2012)
Pigeon pea	Leaf proline	Tolerance to salinity	Prakash and Sarin (1993)

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Because Na+ and K+ are exchanged at the xylem/symplast boundary of the roots, Na+ may move from the transpiration stream into the xylem parenchyma cells under salt stress (Phang et al., 2008). This exchange depends on anion permeability, which is supported by high apo plastic Concentrations, the plasma membrane H+-ATPase, and the Na+/H+ and K+/H+ antiporters (Lacan and Durand, 1995, 1996). The vascular H+-ATPase and H+-Paes activity in tonoplast vesicles of a salt-tolerant soybean variety increased under salt stress compared to a less tolerant variety (Yu et al., 2005). In summary, one of the most important ways that plants resist salt is by getting rid of extra Na+ and Cl ions or separating them into vacuoles or older tissues. This might lessen the negative consequences of increased Naá content and osmotic potential, which could aid grain legumes in osmoregulation.

Acidification of polymeric materials

Cl ions accumulate in the root zone of faba beans under salt stress, leading to a transient alkalization that extends from the root to the shoot. This short alkalization may change the distribution of ABA when salt stress first manifests, resulting in stomatal closure (Geilfus et al., 2015). Any abiotic stressor may cause the apoplast to briefly become alkaline, ensuring the plant's survival (Geilfus and Mühling, 2012, 2014). (Felle et al., 2005). Sharp and Davies (2009) assert that an increase in the pH of apo plastic (Wilkinson and Davies, 1997) may set off stress signalling cascades that propagate from roots to shoots and initiate reactions linked to stress adaptation. The extensibility of the cell wall is impacted by apo plastic acidification because enzymes and expansions that loosen the cell membrane are active at low apo plastic pH levels (Rayle and Cleland, 1992; Cosgrove, 2000) (Hager, 2003). The process of apoplastic acidification is regulated by H+-ATPase activity in the plasma cell membrane (Rayle and Cleland, 1992; Pitann et al., 2011). Thus, the degree to which plant growth is impeded (sensitivity) or preserved (salt tolerance) in response to salt stress depends on the relative degree of acidic or alkalinization of the apoplast (Pitann et al., 2011; Morgan et al., 2014). Geilfus and Mühling (2013). Because systemic plastic acidification under salt is necessary for cell wall extensibility, it is thought to be a reliable indication of salinity tolerance. When salinity is present, apo plastic's pH rises due to ionic components of salt stress rather than osmotic ones.

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Hormone control

Plant hormones, often known as phytohormones, are substances that regulate plant development. Important plant hormones include auxins, cytokines, gibberellins (growth promoters), ethylene, and ABA (growth retardants). During salt stress, alterations in ethylene and ABA—sometimes known as stress hormones—are often seen. For instance, the white lupin (Lupinus albus L.) closed its stomata in response to ABA produced locally; subsequently, after salt stress, it changed its response to ABA produced by the roots and transferred to the leaves (Wolf et al., 1990). Elevated levels of ABA affect stomatal oscillations in leaves and other tissues, but they also help plants adapt to salt by adjusting osmotic pressure and producing certain stress proteins associated with salt tolerance (Singh et al., 1987). Kukreja et al. (2005) reported that ethylene and its precursor 1-aminocycloprane-1-carboxylic acid (ACC) were created by salt-stressed chickpea and faba bean roots and nodules. These compounds promoted leaf senescence but were not associated with appreciably quicker growth. Consequently, changes in stress hormone levels brought on by salt stress have an impact on photosynthesis, osmotic adjustment, and plant growth.

Management strategies

To increase grain legume output in salted environments, production technology must be used to modify genotypes of various grain legumes that are salt-tolerant. The next section discusses methods for enhancing grain legume yields under salt stress and enhancing salinity tolerance.

Selection and traditional methods of breeding

Salt tolerance is a complex trait from a genetic and physiological perspective. There aren't many accessible and useful methods for determining grain legumes' salt tolerance. The capacity of grain legumes to tolerate salt has not significantly improved using conventional breeding methods (Flowers, 2004). An integrated approach that utilises genetic variation already present (Smíkal et al., 2015), generates new variation through novel and diverse sources (Sharma et al., 2013), and uses a historical breeding approach with multiple traits instead of breeding for a single trait (Duc et al., 2015) may be helpful when creating genotypes of salt-resistant legumes. Fortunately, different species of legumes have different salt tolerances (Moreno et al., 2000). This variety may be used by breeders to create genotypes of legumes resistant to salt. To locate salt-tolerant germplasm for breeding, legume genotypes are often screened extensively, allowing for the production of better genotypes. In the first phases of seedling development, Sehrawat et al. (2014) evaluated 11 mungbean genotypes' capacity to withstand salt. Despite significant variations in their decreased germination and early seedling development, the genotypes under inquiry were classed as highly tolerant, tolerant, moderately tolerant, sensitive, moderately susceptible, and very vulnerable (Sehrawat et al., 2014). To screen for salt tolerance, a variety of characteristics have been examined, including plant biomass, nodulation, osmotic adjustment, leaf K/Na/Ca ratios, pod number per plant, grain weight, and grain yield (Table 3). Stress tolerance has been increased by traditional breeding methods including Na+ exclusion (Flowers, 2004). Tissue ion homeostasis is a critical characteristic that is used to evaluate genotypes for resistance to salt stress (Munns and Tester, 2008). But it hasn't been shown how tolerance and individual Cl- or Na+ "exclusion" relates to other grain legumes like chickpea. Due to the accumulation of potentially hazardous levels of Na+ and Cl+ during the reproductive phase, chickpeas are particularly vulnerable to salt stress (Samineni et al., 2011).

However, due to salt stress, no correlation was found between yield and the accumulation of Na+ (% dry mass) in shoots during the vegetative stage (Vadez et al., 2007). A number of mechanisms, including tissue tolerance of excess ions and ion exclusion, seem to contribute to the at least moderate tolerance of chickpeas and other grain legumes to salt. However, breeding operations incorporating parental lines with varied origins are necessary to develop genetically modified genotypes that are salt-tolerant in other grain legumes, such mungbean (Sehrawat et al., 2013c). Grain output in salinized conditions is the ultimate test of salt tolerance; thus, characteristics that measure salt tolerance must be linked to grain yield (Flowers et al., 2010). Thus, a mass screening for salt tolerance might be carried out based on plant biomass, homeostasis, osmotic adjustment, and grain production in a salinized environment.

Biotechnology and functional genomics

The genes responsible for salt tolerance are widely distributed in the genomes of legumes (Table 4). Finding pertinent trait QTLs and marker tagging are necessary for targeted introgression, which combines salt-tolerant features into unadopted traits (Table 4). The readily available databased sequences have made whole genome sequences (WGS) the basis for newly developed simple

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sequence repeats (SSRs), single-nucleotide polymorphism (SNP) markers, and next-generation sequencing techniques; as a result, the efficiency and cost-effectiveness of molecular markerebased crop improvement have increased recently. Soybean is one such grain legume where genotyping by sequencing has been made simpler to enhance salt tolerance. Additionally, studies have looked at the possibility of using genetic markers to identify important QTLs in order to produce cultivars with improved salt tolerance (Table 4). One research discovered that the sequence was differentiated by an amplified regions marker (QS08064), two SSR markers (Barcsoysr-3-1306 and Barcsoysr-3-1310), and an InDel marker (QS080465) when crossing two farmed soybeans, Tiffing 8 (tolerant) and 85-140 (sensitive). On chromosome 3, this area and the salt-tolerance gene co-segregated (Guan et al., 2014). Moreover, a significant QTL on chromosome 17 was linked to Na+ tolerance; a robust association between salinity tolerance and the SSR markers indicated that SSR markers might be useful in marker-assisted selection. QTLs between the markers sat 255 and sat-091 on chromosome 3 were examined in soybeans. Lee and colleagues, 2004).

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Table 3: Potential traits/characters for screening grain legumes for salinity resistance.

CROPS	TRAITS/CHARACTERS	REFERENCES
Faba bean	Leaf soluble proline	El Sayed (2011)
Chickpea	Surge in nodule growth Total nitrogenase activity and nodule dry weight	Soussi et al. (1999) Swaraj and Bishnoi (1999)
Cowpea	Plant biomass	Gogile et al. (2013)
Kidney bean	Stomatal conductance	Lopez et al. (2002)
Mungbean	Survival Photosynthetic pigments Pods per plant 100-grain weight Rate of photosynthesis	Sehrawat et al. (2014) Sehrawat et al. (2015)
Pea	Leaf reducing sugars Total free amino acids Seedling emergence Plant biomass Leaf K+/Na+ ratio Leaf Ca2+/Na+ ratio	Olmos and Hellin (1996) Shahid et al. (2012)
Pigeon pea	Leaf soluble proline	Bishnoi et al. (2006)
Soyabean	Leaf soluble proline Leaf K+ contents Leaf Na+ contents Nodulation Osmotic adjustment	El Sabagh et al. (2015) An et al. (2002)

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Table 4: QTLs for salt tolerance identified from various grain legumes with their respective traits

CROPS	CHARACTER	QTLs	LINKAGE GROUP	REFERENCES
Chickpea	Days to flowering Shoot dry weight Seed number 100- seed weight	TA114-TA78 TA127-TS57 TR20s-TA46 TR20s-TA46		Vadez et al. (2012)
Pea	Salt tolerance index Symptoms of salt tolerance Salt tolerance index	Salt index_QTL 1 Symptom score_QTL 1 Salt index_QTL 2	Ps III Ps III Ps VII	Leonforte et al. (2013)

Soyabean	Percentage plant survival	qppsB2.1 qppsD1bþW.1 qppsK.1 qppsN.1	B2 D1bþW K N	Chen et al. (2008)
	Plant survival days	qpsdB1.1 qpsdK.1 qpsdG.1	B1 K G	
	Salt tolerance ratings	qtrG.1 qtrM.1 qtrM.2	G M M	

By creating 38 distinct microsatellite markers (SSRs), Sehrawat et al. (2014) produced twelve genotypes of mungbeans—nine cultivated and three wild—that were diversified enough to withstand salt. Of the 124 possible alleles, 65 (52.42%) were detected in the cultivated genotypes, 52 in the wild genotypes (interspecific), and 100 in the heterogeneous (interspecific, 80-65%) category where the cultivated and wild genotypes were combined. The polymorphism ranged from 86.84 to 100%, and the number of polymorphic alleles varied from 1 to 4, with an average value of 2.63 per locus. Significant QTLs or genes that confer salt tolerance may be found using these SSRs. Additionally, in order to tailor salt-tolerant mungbean hybrids for locations affected by salt, breeding initiatives may take use of the genotypes of naturally occurring salt-resistant plants as a source of beneficial traits or genes. Breeding strategies that prioritise early genotype selection over phenotypic screening may find value in the SSRs associated with the phenotype or genes (Nirmala et al., 2016).

Covarrubias and Reyes (2010) report that evidence of mi-RNA accumulation in common beans during drought or in response to ABA supplementation has been found. Their role in salt stress, however, has not been studied. However, in mature soybean root nodules generated under and without salinity stress, it was shown that mi-RNAs were up-regulated, suggesting that they actively control salt stress (Dong et al., 2013).

To synthesise the required quantitative or qualitative traits, one or more genes from one species are substituted for another using a transgenic technique. This approach is more effective than traditional breeding and guarantees that just the required genes from donor species are induced.

CONCLUSION

Salt stress is the biggest barrier to the development of good crops, especially in areas where salty irrigation water is utilised. Legumes derived from grains are an excellent source of protein and have the potential to fulfil the needs of expanding populations in the future. On the other hand, the majority of grain legumes rely heavily on salt stress. Salinity causes osmotic stress, specific ion effects, poor hormone regulation, nutritional imbalances, and reduced carbon fixation in legumes due to stomatal and non-stomatal restrictions. These impacts all negatively affect grain production and quality. Strategies to improve grain legume performance in saline environments may be developed by recognising other management options and understanding the resistance mechanisms associated with the response of grain legumes to salt stress. Legume crops respond to salt stress by altering both their catalytic and non-enzymatic antioxidant defence systems, hormone control, osmoregulation and osmotic balance, and detrimental ion exclusion mechanisms, among other things. In salinity-prone areas of the world, it is necessary to develop salt-tolerant genotypes of different grain legumes using precise and location-specific production techniques in order to sustainably boost legume output. However, transgenic legume genotypes that are more adapted to salinity-affected areas may be introduced via the fusion of modern genomics and biotechnology research with conventional breeding techniques. This complex feature will be better understood and clarified with the identification of putative salinity-responsive genes in a variety of grain legumes, further research on upstream and downstream components, and a thorough examination of gene expression at various developmental stages using more advanced technologies.

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