Review Article

Response of Pulses to Salt Stress – a Review

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Abstract

Legumes are important not only as a nutritious food and fodder but also for their contribution in increasing soil fertility by fixing atmospheric nitrogen. The salinity is worldwide problem that limits the growth and productivity of all vegetation's and it is going to increasing day by day. Similarly, production of legume crop species is also limited by salt stress. In plants the adverse effects of salinity are mediated through detrimental effects on nitrogen fixation, which in turn limits further growth and metabolism of plants. The present review underlines the effect of salinity on morphological and their physiological responses of pulse crops.

Keywords: Legumes, Salt stress, Morphological, Physiological responses, metabolism

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Introduction

Pulses are the basic ingredient in Indian diets and excellent feed and fodder for livestock. Endowed with the unique ability of, carbon sequestration, soil amelioration, low water requirement and capacity to withstand harsh climate, pulses have remained an integral component of sustainable crop production system since time immemorial, especially in the dry areas. They also offer good scope for the crop diversification and intensification.

Leguminous crops play a major role in fixing the nitrogen from the atmosphere through nodulation effect. *Rhizobium* species penetrate into the root through root hairs and colonize forming nodules. Thus, these species provides nitrogen required for the plant through biological nitrogen fixation and in turn absorbs carbohydrate for their growth and development. Legumes, the richest sources of protein and amino acids constitute a balanced diet. Besides, being a rich source of protein, they maintain soil fertility through biological nitrogen fixation in soil and thus play a vital role in furthering sustainable agriculture [1]. In India, legumes are cultivated in about 2.2 million hectares with a production of 1.09 million tonnes per year and productivity of 496 kg/ha [2]. In Tamil Nadu, it is cultivated in 5.12 lakh hectares with a production of 2.12 lakh tonnes.

Salinity is the most important abiotic stress that inhibits growth and productivity of pulses crop and it had adverse effects on the functioning and metabolism of plants considerably hinders the productivity. Salinity is of immense importance particularly for those countries that lies in arid to semi-arid zones of the World where rainfall is limited, evapotranspiration is high with high temperature, poor water quality and poor soil management practices, which exacerbate salinity effect [3]. It has reached a level of 19.5 per cent of all irrigated-land (of the 230 million ha of irrigated land, 45 million ha are salt-affected) and 20.1 per cent of dry-land (1500 million ha of dry land agriculture, 32 million ha are salt-affected soils) agriculture Worldwide [4] (**Table 1**). Increased salinisation of arable land is expected to have devastating global effects, resulting in 30% land loss within the next 25 years and up to 50 per cent by the year 2050 [5].

Soils which contain sufficient salt in the root zone to retard the growth of crop plants are known as saline soils [6]. However, since salt injury depends on species, variety, growth stage, environmental factors, and nature of the salts, it is difficult to define saline soils precisely. Hence, too many definitions have been developed to define saline soils, in order to overcome the problems [7] have developed a common definition and is widely accepted definition of a saline soil as one that has an ECc of 4 dS m^{-1} or more and soils with ECc's exceeding 15 dS m^{-1} are considered strongly saline. ECc is the electrical conductivity of the 'saturated paste extract', that is, of the solution extracted from a soil sample after being mixed with sufficient water to produce a saturated paste. Salinity occurs through natural or human induced processes that result in the accumulation of dissolved salts in the soil water to an extent that inhibits plant growth. Soil salinity is a major constraint to food production because it limits crop yields and restricts use of land previously cultivated. Hence, the existing salinity is a great challenge to food security.

Table 1 Magnitude of salinity in the world [4]

Regions	Total area (Million ha)	Saline soils		Sodic soils	
		Million ha	%	Million ha	%
Africa	1899	39	2.0	34	1.8
Asia, the Pacific and Australia	3107	195	6.3	249	8.0
Europe	2011	07	0.3	73	3.6
Latin America	2039	61	3.0	51	2.5
Near East	1802	92	5.1	14	0.8
North America	1924	05	0.2	15	0.8
Total	12781	397	3.1	434	3.4

Response of pulses to salinity at different growth stages

Salinity affects physiological functions such as seed germination, vegetative growth and gaseous exchange, in addition to changes in plant morphology and anatomy.

Germination and seedling establishment

Seed germination is a major factor limiting the establishment of plants under saline conditions [8]. Salt tolerance during germination is crucial for the establishment of plants [9], consequently for its further development and high yield performance, where soil salinity is mostly dominated at surface layer. Salinity may cause significant reductions in the rate and percentage of germination, which in turn may lead to uneven stand establishment and reduced crop yields. Salt concentrations of NaCl adversely affected the seedling growth. In general all the germinable characters decreased with increasing salt concentration [10]. Salinity has been shown to affect the time and rate of germination in chick pea [11]. The germination percentage was gradually decreased with regarding to increasing concentrations compared to control under salinity induced by NaCl in *Vigna* species. It was reported that increase in salinity not only decreased the germination of pulses also delayed the germination initiation [12].

Salinity can affect germination of seeds either by creating osmotic potential, which prevents water uptake, or by toxic effects of ions on embryo viability. Marked reduction in germination of bean (*Phaseolus vulgaris* L.) exposed to salt stress was reported [13]. According to [14], salt stress decreased seedling growth in chickpea. The NaCl salt stress induced changes in growth and enzyme activities in black gram seeds during germination [15]. A decrease in germination percentage, root length, shoot length and fresh mass was noticed with an increase in NaCl concentration and at 3 per cent NaCl concentration no emergence of root was reported.

Morphological characters

Morphologically the most common symptom of saline problems for plants is reduction of their growth, which is due to result of many physiological responses including modification of balance of ions, water quality, mineral nutrition, photosynthetic efficiency carbon accumulation and utilization [16]. Based on the pot culture experiment [17] reported that shoot length of blackgram was inhibited when the salt concentrations were increased and also the growth was detrimental. Salinity reduces shoot growth by suppressing leaf initiation and expansion, as well as internodes growth, and by accelerating leaf abscission salt stress causes a rapid and potentially lasting reduction in the rate of leaf growth [18]. A pot experiment carried out by [19] in mungbean genotypes grown under different levels of salinity (control, 3.87 dSm^{-1} and 7.82 dSm^{-1}) shared that plant height decreased with increasing soil salinity. Application of NaCl strongly decreased plant growth (plant height, fresh and dry biomass of the shoot) of soybean [20]. The percentage decrease in plant height at 0.7 MPa NaCl ranged between 21 and 46. A remarkable decrease in root shoot ratio of soybean was observed with increase in salinity indicating that salinity had more pronounced effect on shoot growth than that of root growth of soybean [21].

Reduction in internodal distance and number of leaves per plant is a common phenomenon under salinity stress in various plant species [22]. Number of leaves of mungbean genotypes at varying levels of salinity was reduced with increasing salinity as compared to control plants [23]. They [24] studied was about to observe the response of mungbean genotypes under different levels of salt stress (0, 3.87 dSm^{-1} and 7.82 dSm^{-1}) and revealed that increasing salinity levels deceased the number of leaves per plant. The harmful influence of salinity on leaf number also increases with the increase in concentration [25].

The NaCl concentration of 60mM decreased root growth and dry matter production of soybean [26]. Salinity significantly decreased shoot and root dry weight, nodule weight and mean nodule weight of faba bean. Roots were more sensitive to salinity than was plant growth [27]. Concentration dependent decrease in nodule size, the number, fresh weight, dry weight and leghaemoglobin content and nitrate reductase activity by induction of salinity to black gram plants at various stages of growth and development [28].

Nodule fresh mass is related with nodule size and nodule size is increased with the increasing levels of salinity level but nodule per plant decreased at the higher salinity level. The total nodule number, weight and nitrogen content per plant decreased in salt treatment [29]. The pea plants were also subjected to different salinity levels i.e., 0 to10 and 15 dSm^{-1}. High number of nodules was formed at 0 and 1 dSm^{-1} whereas at 2 and 3 dS m^{-1} the nodule number was reduced and yet at higher salinity levels no nodules were formed. Pea plants nodulated best at 12 hours photoperiod and $1/6^{th}$ concentration of Hoagland's nutrient solutions. The mature nodules developed at different temperatures and salinity levels [30].

Growth attributes

Leaf area is one of the best parameters to represent the effect of salt stress on plants as suggested [31]. Seeds could grow at different salt levels, but they could not continue their development [32]. A salt stress causes a significant decrease in leaf area with the increase of stress treatments. Report indicated that NaCl concentration decreased the leaf area in mungbean under salt stress [33].

Research showed the affection of leaf area negatively by using different concentrations of NaCl [34]. It was reported by [35], that the reduction in leaf area in plants under salinity stress indicated arrest of leaf expansion, which eventually might limit the area available for photosynthesis in groundnut. There is a general view that the crop maturity is shortened by environmental stresses due to the reduction. Salt stress reduced the dry mass of cowpea [36]. Both shoot and root mass of horse gram were decreased with increasing levels of salinity [37].

Physiological and biochemical parameters

Chlorophyll pigment is responsible for photosynthesis. Destruction of chlorophyll under salt stress is deleterious to plant productivity. The decreasing chlorophyll content with increasing salinity in rooting medium has been explained by increasing activity of enzyme responsible for the degradation of chlorophyll (chlorophyllase) [38]. Chlorophyll content was decreased as the salt concentration is increased in blackgram [18]. The chlorophyll content decreased beyond 0.6 per cent NaCl in sunflower and 0.4 per cent in mungbean [39]. Different concentrations of salt solutions to investigate the response of mungbean and found that leaf chlorophyll content was significantly reduced under salt stress [40]. Study revealed the effect of salinity on total chlorophyll content and photosynthesis of *Vigna radiata*. They found that salinity reduced photosynthesis and chlorophyll levels than that of the control [41].

From the research it was observed a drastic reduction in the level of soluble protein content due to salinity in mung bean plants [42]. Total soluble proteins in the leaves decreased in response to salinity [43]. Sodium chloride treatment decreased the protein content significantly in all parts of the seedlings except in the cotyledons, where it showed higher protein content in groundnut seedlings [44]. Salt stress was found to significantly decrease soluble protein content after exposure to 50,100 and 150 mM NaCl and the effect was aggravated with time from 42 to 72 hr in *Phaseolus vulgaris* [45]. Soybean plants exposed to 100 and 200 mM NaCl showed significant decrease in their protein content by 20.3 and 41.7 per cent [46].

SPAD reading is a parameter closely associated with chlorophyll content of the leaf. A strong positive correlation between SPAD reading and extracted chlorophyll content was also established [47]. A strong positive correlation was also found between SPAD readings and nitrogen content of the leaves of sunflower [48]. Growth regulators treated plants might be attributed to the increase in SPAD values, as there is a positive correlation between SPAD values and chlorophyll fluorescence [49].

Nitrate reductase the first enzyme in the nitrate assimilation pathway, is a limiting factor of plant growth and development and also it is influenced by a variety of environmental factors [50]. Nitrate reductase activity increased significantly in plants subjected to 100mM NaCl, while it decreased gradually under 150 and 200 mM treatments compared to control. The activity of nitrate reductase decreased significantly with increasing levels of soil sodicity at almost all stages of plant growth and the maximum reduction in nitrate reductase activity occurred at 30 DAS in lentil [51].

Rhizobia-legume symbiosis

Salinity stress is a major environmental constraint on rhizobia-legume associations, affecting their capacity for nodulation and N_2 fixation. At high solute concentrations water is withdrawn osmotically from nodules [52]. *Rhizobium* strains are more salt-tolerant than strains of *Bradyrhizobium* and differential responses of *Bradyrhizobium* sp. strains were reported to increasing concentrations of NaCI (50-400 mM) [53]. Symbiotic nitrogen fixation by legumes is sensitive to environmental stresses particularly salinity [54], which can limit plant growth due to both specific ion and osmotic stress, and reduced symbiosis with bacteria [55].The growth and development of root and nodule dry weights of faba bean were decreased by 100 mM NaCl [29]. Inhibition of root hair curling, shrinkage of root hairs, and reductions in nodule numbers were observed for NaCl treatments. Nodulation was completely eliminated at 1.2 per cent (205.6 mM) NaCl [56]. The impact of salinity on the growth and survival of free living rhizobial cells has also been investigated. Generally, rhizobia are less affected by salt stress than their plant hosts [57]. A 50 per cent reduction in soybean nodule number and weight was associated with extreme sensitivity of nodule initiation to salt treatment and this was attributed to limited root growth and decreases in the proportion of infected root hairs.

Crop productivity

Research revealed that morroccan chickpea lines under 25 mM NaCl in greenhouse and found that under salt stress, the yield was 32 per cent lower than the average performance in non stressed crop. Increasing salinity led to significant reduction in number of pods per plant over control and blackgram had higher number of pods per plant than that of mungbean [58]. Experiment on lentil genotypes under different levels of salinity (control, 4 dS m^{-1} and 6 dS m^{-1}) reported that number of pods per plant gradually reduced with increasing level of salinity as compared to control [59]. An experiment conducted with four genotypes of green gram at various level of salinity (4, 8 and 12 dS m^{-1}) and observed a remarkable reduction in number of pods per plant [60]. Study revealed the effect of varying salinity levels on weight of seeds of cowpea and found that seed yield/plant gradually decreased with increasing salinity [61]. Research disclosed that soil salinity affected seed yield of chickpea and soybean [62]. Study revealed that increase in salinity resulted in significant decrease in grain yield of wheat.

Conclusion

Upcoming years in future may incorporate the integrated strategies to enhance the yield considering sustainable agriculture incorporating resistant varieties within the reach of farmers. Attempts have to be made to look for future food security at physiological, biochemical and molecular levels of pulse crops.

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