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RESEARCH ARTICLE

A REVIEW ON RESPONSE OF RICE (*Oryza sativa* L.) UNDER SALINITY STRESS IN TERMS OF ITS GROWTH, DEVELOPMENT, CHARACTERISTICS, AND BIOCHEMICAL LEVEL

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Abstract

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Salinity is an important environmental factor that limits growth and yield of rice. It currently affects millions of hectares of soils otherwise suitable for rice cultivation in South and Southeast Asia. Attempts to understand the mechanisms of salt tolerance have revealed several key enzymes and altered biochemical pathways to infer crop resistance to salt stress. Over the past few decades, we have witnessed extensive research into the development of salt-tolerant varieties through traditional methods, improvisation with modern molecular tools and techniques. Rice (*Oryza sativa* L.) is the staple food crop in many countries around the world. Being a glycophyte by nature, its growth can be severely affected in the presence of excessive salt. Rice is particularly susceptible to salinity in the early vegetative and late reproductive stages, and the response of crops to excess salt toxicity at the biochemical and molecular levels as well as at the physiological level has been well studied and documented. This review aims to summarizes the different responses of rice, especially to salt toxicity, exhibited the detailed physiological, morphological, molecular and biochemical changes that occur in the rice plants**.**

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Introduction:-

Environmental stress is a major area of scientific concern because it limits crop including rice productivity. Most crops are sensitive to high salt concentrations in the soil; salinization is one of them, and worst environmental factors that may limit crop yields. This situation was further exacerbated by anthropogenic activities. Therefore, there is a lot of scientific room on researchers to improve crop productivity under environmental stress to cope with the increasing food needs (1). Abiotic stresses such as salinity, drought, cold and high temperature negatively affects the plant biomass production and yield of major food crops (2). Rice is considered as the main staple crop in major countries, and wheat is the second most important food crop in the world after rice, and rice occupies nearly 90% of the area in Asia alone. However, food crops are used as the staple food by for more than 3 billion people, accounting for about 50- 80% of daily calorie intake (3). It has been stated that 20% of the world's arable land and 33% of irrigated farmland are affected by high salinity, and the area of salt-alkaline land is increasing by 10% each year. In growth stages of rice during germination, rice shown high tolerance to salt better than other stages. It becomes delicate at the seedling.

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In the vegetative stage, tolerance is relatively regained and again very, likely reproductive phase (4). The effects of salinity on rice are multifaceted, resulting in inhibition of germination, difficulty in crop area establishment, leaf area development, reduced dry matter yield, delayed seed setting and even sterility (5). Generally, rice can tolerate small amounts of salt water without affecting growth and yield. However, this largely depends on the type and variety of rice and its growth stage (6). Salt-induced ionic and osmotic stress reduces the rate of photosynthesis, leading to oxidative stress, which is also responsible for reduced plant growth (7). Adverse effects of salt stress can eventually reduce yields in many crops, including rice. When rice plants are exposed to high salts concentration (> 5 mM NaCl), their stomata permeability and growth rate decrease rapidly and temporarily (1).

Salinity as an abiotic stress severely limits crop production. A saline soil is usually a reservoir of many soluble salts such as Ca^{+2}, Mg^{+2},Na^{+} and anions SO_4^{-2}, Cl^{-}, HCO_3^{-} exceptional amounts of K^{+}, CO_3^{-2} and NO_3^{-}. If the EC (electrical conductivity) of the soil is 4 dS/m or higher (equivalent to about 40 mM NaCl) and the osmotic pressure is about 0.2 MPa, the soil can be called saline. Asian cultivated rice (*Oryza sativa* L.) is the first fully sequenced crop genome and is a model crop. Salinity prone areas found in arid and semi-arid regions are generally responsible for the accumulation of salts of many ages. In addition, the weathering of parental rocks has greatly accelerated the process. Salinity is a natural phenomenon that occurs near the coast due to flooding of sea water (8).

Table 1:- Classes of salinity and EC (1 ds/m =1 m mhos/cm: adapted from NRCS Soil Handbook).

Sl No	EC (Electrical conductivity) (dS/m)	Salinity Class
1	0<2	Non-saline
2	2<4	Very slightly saline
3	4<8	Slightly saline
4	8<16	Moderately saline
5	≥16	Strongly saline

Table 2:- Response of crops affected by conductivity to salinity saturated soil extract.

Sl No	EC [dS/m at 25°C]	Crop Response
1	0-2	The effect of salinity is virtually zero
2	4	Decreased yield of highly sensitive crops
3	8	Decreased yield of most crops
4	16	Only tolerant crops give satisfactory yields
5	≥16	Satisfactory yield for very low tolerant crops

Salinity: an important abiotic limit for production:-

Soil salinity is one of the main abiotic stresses that destroy agricultural production globally. Figure 1 represents the whole plant responses under salt stress. The earliest response of plants exposed to elevated soil salinity level is the slow growth rate of leaves. Under low soil salinity level, root growth is almost less affected than the shoot growth, so that root and shoots ratio become increases, but root growth also decreases when they are exposed to higher salinity level in the soil.

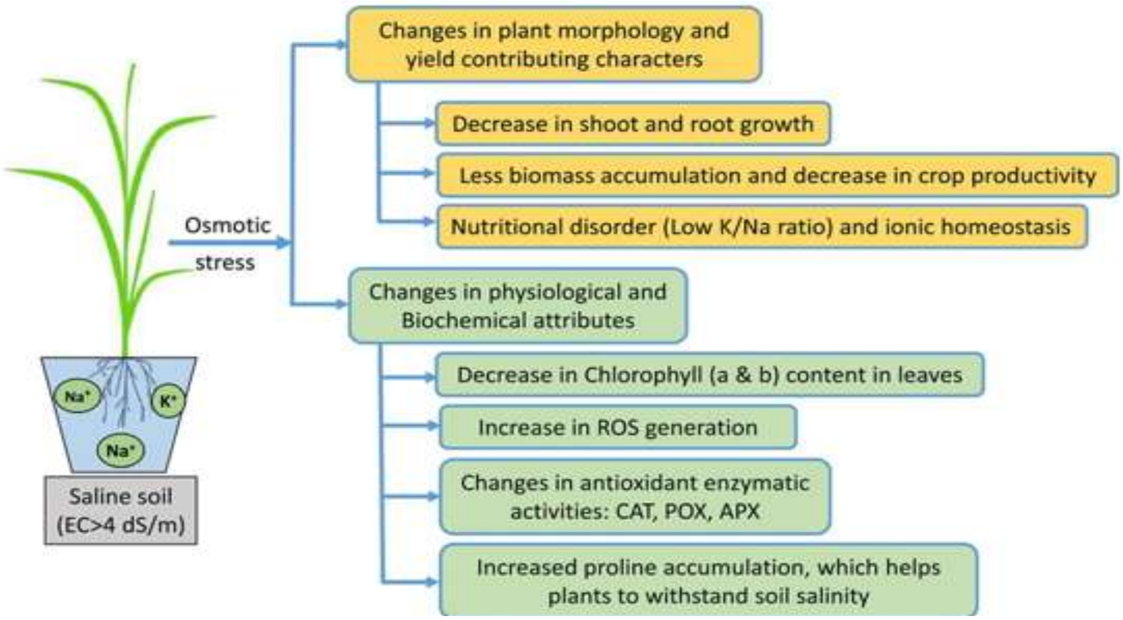

Figure 1:- Plant responses subjected to salt stress (29).

Effects of salinity stress on rice crops:-

Rice is an economically important staple crop, grown in 114 countries around the world. However, abiotic and biological stress can reduce its yield. This problem will be worse in attention to increase of the world population and food shortages. Rice is susceptible to salt, especially during the early vegetative propagation season and subsequent reproductive stages. The study of rice has been shown to be more resistant to reproduction and grain filling than at germination and vegetative stages, and low levels of salt can increase the resistance of rice to higher and deadly salt levels. Currently, salt is the second type of stress, the most dominant obstacle to rice production after a drought.

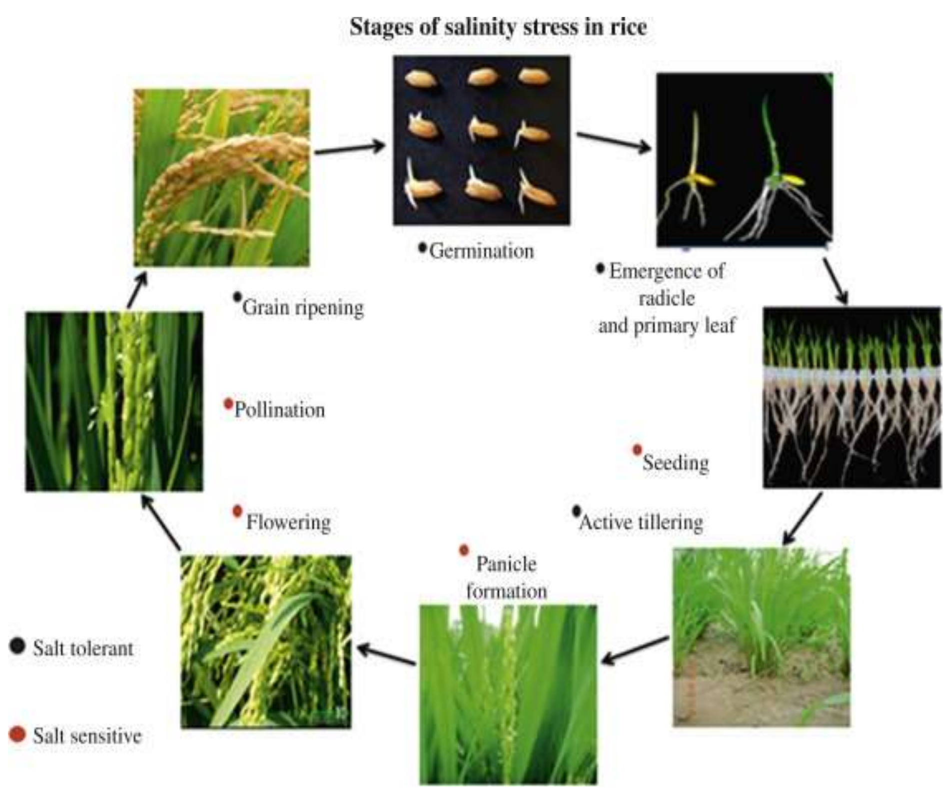

Figure 2:- Plant growth and morphological changes in rice under salt stress.

Response of rice under salt:-

In order to breed salt-tolerant rice varieties, some morphological and physiological studies have been completed till date. The main focus of this approach was to maximize the genetic diversity between parental genotypes. Response of plant to salt is a completely natural and random process. It has been reported that rice as a crop is sensitive in the reproductive and seedling stage (9) and has resulted in reduction of crop productivity (10). In the case of rice, salinity was found as the causal factor for biochemical and inhibition and yield loss (11). Several physiological parameters were investigated during the evaluation of true salt-tolerant lines to understand the dramatic effects of salt accumulation at physiological levels such as plant dry weight, plant height, leaf damage, and Na^{+}- K^{+} ratios (12). The effects of salinity on rice are multifaceted, resulting in inhibition of germination, difficulty in crop area establishment, leaf area development, delayed seed setting and even sterility (13).

Figure 3:- Increasing salinity of 0.3 to 12.0 dS/m clearly stunts rice growth and reduces yields (left to right) **(13).**

Morpho-Physiological Response:-

Salt stress is not dependent on a single trait and therefore, understanding of tolerance mechanisms should employ studies of rice responses under stress. The effect of salt on plants begins osmotic effect characterized by a decrease in osmotic potential than the later ionic effects lead to ionic toxicity. Earlier studies have explained that the response in rice at the physiological level exhibited chloroplasts and mitochondria are the most susceptible organs against salt stress (14). Therefore, chlorophyll content, fluorescence of $(\frac{F_v}{F_m})$ chlorophyll have changes and membrane permeability are useful and potential indicators to understand the inhibitory effect of salt stress on photosynthetic machinery (15).

The ultra-structural observations ensured that the inhibitory effect of salt on the leaves hindered the expansion of the photosynthetic efficiency, swelling of the thylakoids, followed by disruption of choloroplastids (14). The assessment of the response of the plant at later stage was to understand the toxic ionic effects of salt on plants. The toxic effects due to accumulation of sodium salt are mainly caused by plants through (i) salt exclusion (16,17), (ii) selective ion uptake (18,19) and (iii) modulation of K^{+}/Na^{+} ratios (20-23).

Response at Biochemical Level:-

The effect of high salt concentration on crop plants can be divided into two aspects including the process that initial osmosis, then ionic stress in the case of salt accumulation upto its toxic level (24). One of the most important defences in plants is the osmo-regulation by accumulating high concentrations of inorganic ions or low molecular weight organic solutes. These compatible osmolytes found in higher plants are actually low molecular weight sugars, polyols, organic acids, nitrogen-containing compounds such as imino acids, amides, amino acids, proteins, and quaternary ammonium compounds, etc. Soluble sugars and starches have been observed to perform as an osmoticum in many plants as a response to salinity (25-26). Increased sugar content in shoots, and starch content in roots of rice plants has been reported, which contributes to osmoregulation of salt-stress induced crops by maximizing adequate storage reserves to support primary metabolism (27).

The accumulation of glycine betaine in rice has been reported to mask the toxic effects of salt stress and these have positive effects in osmoregulation, cellular macromolecular strengthening, and nitrogen storage. Glycine betaine is also important for balancing cellular p^H, detoxifying cell tissues, and scavenging free oxy radicals.

Another way to deal with salinity is the alteration or accumulation of protein levels. Exposure to salt stress causes protein *de novo* synthesis or up-regulation of process to increase the concentration of certain proteins already present in plants (28). The soluble protein content of tolerant rice seedlings was significantly increased and positively correlated in compared with sensitive seedlings.

Conclusion:-

Rice is the main staple crop in many countries throughout the world. As the global population increasing, so that the demand for rice is also increasing. Salinity as an abiotic stress is the second most destructive phenomenon after drought and disrupts rice production over worldwide. Rice, a glycophyte, is inherently susceptible to salinity and exhibits a broad and vivid response to the adverse effects of increased salt accumulation. The defence system of rice involves preventing and mitigating the harmful effects of salt toxicity at the physiological, biochemical and molecular levels. Comprehensive study of multiple efforts to understand the effects of salinity and crop responses have been described here. Due to the polygenic nature of stress, it is very, nuanced to comment on the exact mechanisms that achieve stress relief in rice plant.

However, till date, numerous metabolic pathways, enzyme complexes, regulatory genes and QTLs (Quantitative trait locus) have been enumerated to elucidate various specific responses at different stages against this abiotic stress. With regard to the damaging effects of salt stress on this staple food crop, it is important to absorb knowledge about the crop's response to salinity. This will aid future efforts to improve salt tolerance and breeding process. Numerous, work is being done globally to understand the phenomenon of salinity stress and mechanisms by which rice alleviates its toxic effect. This review is a minor attempt to summarize the outstanding contributions and breakthroughs made in the field in course of understanding the response process, and thus the defence ability of plants against salinity as a stress. The future aspect should be on the study of intercellular and intracellular molecular interaction involved in salinity responses in different varities of rice (*Oryza sativa* L.) cultivars.

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