REVIEW OF LITERATURE

Plant resort to many adaptive strategies in response to different abiotic stresses such as high salt, dehydration, cold, heat and excessive osmotic pressure which ultimately affect the plant growth and productivity (Epstein et al., 1980; Yancey et al., 1982).

Salinity is one of the most devastating environmental stresses, which causes major reductions in cultivated land area, crop productivity and quality (Yamaguchi and Blumwald, 2005; Shahbaz and Ashraf, 2013). At present, out of 1.5 billion hectares of cultivated land around the world, about 77 million hectares (5 %) is affected by excess salt content (Sheng et al., 2008).

It has been estimated that an approximate area of 7 million hectares of land is covered by saline soil in India (Patel et al., 2011). Most of which occurs in indogangetic plane that cover the states of Punjab, Haryana, U.P. Bihar and some parts of Rajasthan, arid tracts of Gujarat and Rajasthan. Semi-arid tracts of Gujarat, Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh are also largely affected by saline lands. Furthermore, the salinized areas are increasing at a rate of 10% annually for various reasons, including low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices.

Soil is considered saline when its electrical conductivity is 4 dSm$^{-1}$, approximately 40mM NaCl (Munns and Tester, 2008) and generates osmotic pressure approximately 0.2 Mpa. The naturally occurring salinization is recognized as primary and the anthropogenic form as secondary (Williams, 1999). Inadequate irrigation
management also leads to secondary salinization that affects 20% of irrigated land worldwide (Glick et al., 2007).

Agricultural crops exhibit a spectrum of responses under salt stress. Salinity not only decreases the agricultural production of most crops but also reduces economic returns and results in soil erosions (Hu and Schmidhalter, 2002). Salinity stress, the most adverse factor of plant growth and productivity triggers a wide variety of plant responses, ranging from changes in growth rates and crop yields to altered gene expression and cellular metabolism (Amor et al., 2005; Baek et al., 2005; Raja et al., 2005).

Salinity effects are the results of complex interactions among morphological, physiological and biochemical processes including seed germination, plant growth, and water and nutrient uptake (Singh and Chatrath, 2001; Akbarimoghaddam et al., 2011).

Excessive accumulation of sodium in cell walls leads to osmotic stress and cell death (Munns, 2002). High salt levels in the soil can interfere in some nutrient uptake and result in nutrient imbalance in the plants (Blaylock et al., 1994). The reduction in leaf area, chlorophyll content, stomatal conductance and for some extent photo system II efficiency, affects photosynthesis (Netondo et al., 2004).

Sumitahnun et al., (2015) noticed decrease in growth characteristics and chlorophyll accumulation and increase in the activity of proline, hydrogen peroxide, and peroxidase (POX) under salinity stress in rice cultivars. Similarly, Munns (2002) also demonstrated the high salinity, sodium toxicity may cause range of disorders affecting germination, development, photosynthesis, protein synthesis, lipid metabolism, leaf chlorosis, and senescence.
Metwali Ehab et al., (2011) have shown that salt stress suppresses seedling growth and reduces leaf area as well as chlorophyll content. Abbas et al., (2010) recorded decrease in soluble sugar and protein content with increasing salinity in Cucumber plants.

Tajdoost et al., (2007) noticed that the amount of malanodialdehyde (MDA) increased because of salt induced lipid peroxidation. Soluble sugars and proline being osmoregulators increased in stress conditions. They also concluded that salt stress causes serious physiological damages apart from the biochemical damages in plants.

There are many reports which show that salinity induces water deficit in many crop species such as corn, sunflower (Katergi et al., 1996). Reduction in both water absorption and water potential are primary effects of salinity as roots are directly exposed to salt and they are the most vulnerable organs (Alarcon et al., 1993; Munns and Tester, 2008). Extensive reports are available on inhibition of root growth as primary response of plant towards salt stress, which can be in terms of fresh weight (Lin and Kao, 2002; Jebra et al., 2005; Khan and Panda, 2008), dry weight (Ashraf and Hamad, 2000; Lin and Kao, 2002; Chaparzadeh et al., 2004), relative growth rate (Jeschke et al., 1986; Sibole et al., 2003), and root length (Wahid et al., 1998; Kopyra and Gwóźdź, 2003). Changes in root morphology by inhibiting the initiation and the elongation of lateral roots also triggers by salinity stress (Rubbinigg et al., 2004).

Many studies have shown the role of salinity concentration, salt type, type of plant species on shoot length, fresh weight and dry weight (Bayuelo Jimenez et al., 2002; Jamil et al., 2005; Niaz et al., 2005; Turan et al., 2007; Saffan, 2008; Rui et al., 2009; Taffouo et al., 2010; Memon et al., 2010).
According to Volkmar et al., (1998), salt causes a slower rate or shorter duration of expansion of cells and this compromise the size of the leaves. The ultimate effect of salinity on plants is the shrinkage of leaf size leading to death of the leaf, and eventually the plant. Salinity may also cause reduction in ATP and growth regulators in the plants (Allen et al., 1994). Further, proportionate relation between the number of leaves and the concentration was reported by Raul et al., (2003), Jamil et al., (2005), Gama et al., (2007), Ha et al., (2008). Razzaque et al., (2009) reported significant decrease in plant height, total tillers, root, shoot and total dry matter on the application of salinity in rice (Oryza sativa) cultivars.

Recent reports also show that salinity adversely affects plant growth and development, hinder seed germination, seedling growth, enzyme activity (Seckin et al., 2009), DNA, RNA, protein synthesis and mitosis (Tabur and Demir, 2010; Javid et al., 2011). Photosynthetic rates are usually reduced in plants that are exposed to saline water, especially NaCl, but it is unclear whether these low rates are also responsible for the reduced growth observed in salt-treated plants. Salt also reported to result in impairments in photosystem II activity (Garg and Singla, 2004), chlorophyll (Chl) content (Sudhakar et al., 1997; Silva et al., 2010) and in the activities of key enzymes involved in the photosynthetic carbon reduction cycle (Guerrier, 1988).

Reactive oxygen species (ROS) occur naturally in most eukaryotic cells because energy metabolism depends on oxygen, though stresses enhance these
Role of *Rhizobacterium* on Cowpea plants (*Vigna-ungiculata*) growth grown under salinity stress

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molecules (Shigeoka *et al.*, 2002). Alleviation of oxidative damage by scavenging ROS is an important strategy of plants to tolerate stress (Zhu, 2002).

The reactive oxygen species (ROS), including superoxide anion (O$_2^•$-), hydrogen peroxide (H$_2$O$_2$) and hydroxyl radical (OH$^•$), are normal by products of the metabolic activities in mitochondria and peroxisomes (Foyer and Noctor, 2000). Malondialdehyde (MDA) content, a product of lipid peroxidation, has been considered an indicator of oxidative damage. Salt stress, like other abiotic stresses, can also lead to oxidative stress. The salt-induces ROS over production thereby triggering the so-called secondary oxidative stress due to oxidative damage of lipids, proteins and nucleic acids (Moller, 2007; Amor *et al.*, 2007).

Increase in lipid peroxidation rate with increase in salt stress, especially in sensitive cultivars was reported by Arora *et al.*, (2008). Shao *et al.*, (2015) indicated enhancement in the levels of superoxide dismutase (SOD), catalase (CAT), cytochrome oxidase (CYT), Peroxidase (POD) in leaves and roots with increasing salinity. Proline as a signaling/regulatory molecule able to activate multiple responses that are components of the adaptation process (Maggio *et al.*, 2002). Its accumulation in the cytosol accomplish osmotic adjustment (Ketchum *et al.*, 1991). In response to the stress conditions, plants increase the osmotic potential within their cells by synthesizing and accumulating compatible osmolytes (Hanson and Hitz, 1980). Proline has been shown to be increased in abiotically stressed plants in presence of beneficial bacteria (Barka *et al.*, 2006). Under stress conditions, proline has been attributed with various functions such as the synthesis of key proteins necessary for stress responses (Iyer and Caplan, 1998), cell osmotic adjustment, and membrane...
detoxification of injurious ions (Hare et al., 1999; Kavikishor et al., 2005; Ashraf and Foolad, 2007). Proline accumulation is important for osmotic adjustment under abiotic stress conditions; it is believed that high level of proline can be beneficial to stressed plants (Hyun et al., 2003). Supra optimal level of proline also known to be beneficial to salt-stressed plants through stabilization of proteins, prevention of heat denaturation of enzymes and as a hydroxyl radical scavenger (Hsu et al., 2003).

Carbohydrates are accumulated in plant tissues under saline stress and these substances are suspected of contributing to osmotic adjustment (Munns and Termaat, 1986; Delauney and Verma, 1993). Soluble sugars play key role not only in osmoregulation, including controlling water potential and osmotic potential in plant cells (Pattanagul and Thitisaksakul, 2008; Cha-um et al., 2009b; Siringam et al., 2012), but also in detoxification as a chelating agent to bound Na⁺ with starch granules (Kanai et al., 2007). Changes in carbohydrate levels are of particular importance because of their direct relationship with physiological processes such as photosynthesis, translocation and respiration. Among the soluble carbohydrates, sucrose and fructose have a potential role in adaptation to these stresses (Housley and Pollock, 1993; McKersie and Leshem, 1994). Sugars in plants generally serve mainly as source of carbon and energy, osmotica, stress protectants and signal molecules.

Role of sugars in adaptation of plants to salinity have been concluded to be universally associated with salt tolerance. However, this does not rule out a significant role of soluble sugars in salt tolerance or a potential role for soluble sugar accumulation as an indicator for salt tolerance in breeding programs for some species.
Proteins accumulation also plays a role in osmotic adjustment. Large number of cytoplasmic proteins causes alterations in cytoplasmic viscosity of the cell stimulated by salinity (Hasegawa et al., 2000). In response to salt stress, these proteins may be present constitutively at low concentration, increase when plants are exposed to salt stress (Parvaiz and Satyawati, 2008). Ashraf and Harris (2004) reported higher levels of soluble proteins in salt tolerant species of barley, sunflower, finger millet and rice. However, these soluble proteins content in leaves decreases in response to salinity (Alamgir and Ali, 1999; Agastian et al., 2000; Wang and Nil, 2000).

Qualitative analysis (SDS-PAGE analysis) of proteins in plants reported to increase and decrease in specific soluble proteins in response to salinity. Hassanein (1999) showed induction of 127 and 52 KDa proteins and suppression of 260 and 38 KDa proteins in peanut (Arachis hypogaea L.) plants grown under NaCl stress. In wheat, the content of 26 kDa proteins increased in NaCl treated plants, while, the contents of 13 and 20 KDa proteins decreased and the 24 KDa proteins disappeared with NaCl treatment (Elshintinawy and Elshourbagy, 2001).

Characters like yield, survival, vigor, leaf damage and plant height, have been the most commonly used criteria for identifying salinity tolerance (Shannon, 1984). Seedling stage is the most sensitive stage in the plant life to salinity. Significant decrease in various parameters in seedling growth such as germination percentage, root and shoot length, seedling fresh and dry weight, chlorophyll content was reported in various crop plants including Vigna, Cotton, Sorghum, chick pea, Faba bean, Fenugreek, dry bean and Cowpea (Egeh and Zamora 1992; Elsheikh, 1992; Cachorro et al., 1993; Forawi 1994; Nada Hassan et al., 2006; Valdineia, 2011; Abdel-Haleem et al., 2015). Ameliorate effect of Salinity in the presence of rhizobacteria was
reported in number of crops such as Tomato, Pepper, Canola, Bean and Lettuce (Barassi et al., 2009; Kang et al., 2009; Egamberdieva, 2009).

Marcar et al., (1991) stated that the soil salinity particularly disturb the symbiotic interaction between legumes and rhizobia. Many studies have been shown that the soil salinity decreases rhizobial colonization and nitrogen fixation and nodulation (Singleton and Bohlool, 1984; Zahran and Sprent, 1986; Elsheikh and Wood, 1995; Zahran, 1999).

Role of Rhizobacteria on salt tolerance has been worked out in various crops. Sheikh Hasna Habib et al., (2016) also showed that rhizobacteria enhances the salt tolerance in Okra. Bharti et al., (2014), Mayak et al., (2004), Yildirim et al., (2006), Dimkpa et al., (2009) and Bharti et al., (2014) reported that plant growth promoting rhizobacteria alleviate the negative effects of salinity on growth and physiological status in plants. Similarly, Glick et al., (1997) and Han and Lee (2005) had shown that the Rhizobacteria ameliorate the salinity deleterious effects on pepper, bean, canola and lettuce. Limited work has been reported on salinity tolerance studies in Cowpea and its tolerance in presence of Rhizobacteria. Win, (2011) also demonstrated the influence of genotype and salinity levels on salt stress inhibition of growth parameters at seedling stage in Vigna species.

Doleib et al., (2006) noticed that salinity significantly reduces, while the presence of symbiotic rhizobacteria – Bradyrhizobium significantly increases shoot and root length, fresh and dry weight, number of nodules and nitrogen content in Cowpea (Vigna unguiculata).

While the treatment of rhizobacteria mitigate the harmful effects of NaCl and improves salt tolerance by enhancing the accumulation of non toxic metabolites such as total soluble sugar, proline and glycine betaine in Cowpea under NaCl stress conditions.