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Effect of Agricultural and Pharmaceutical Residues on Overcoming Salinity Stress in Crop Plants

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Abstract

Natural and anthropogenic salinity stress is detrimental to all type of crops and vegetation's, except few which turned to be halophytes that deals with salt through excluding salt entry into the roots, or by separating and storing salt into their cell, example succulent halophytes, many halophytes referred as recretohalophytes contain salt gland that secrete salt out of the plants. Plants have various natural ways to overcome salinity stress and improve their productivity and performances. Most of the scientific research focus on the effect of salts on plants, but the present research emphasis to screen potential agricultural and pharmaceutical residue or wastes in overcoming salt stress on plants as they are rich source of nitrogen and improve the plants performances. Agricultural residue always affects the subsequent vegetation if not treated or neutralized properly and frequently move to water bodies by runoff. Active pharmaceutical ingredients (APIs) after expiration are directly released into sewers due to which a very important mineral nitrogen is wasted, which could act as a salt stress buster in plants.
Keywords- Halophytes, Glycophytes, Influx, ROS- Reactive Oxygen Species.

1. Introduction

India being an agriculture-based country is affected by increasing salinity of soil. Plants come under salinity stress and their performances decline. Plants suffer under high salinity growth condition and responses in terms of leaf senescence (Zhang et al 2011), inhibition of photosynthesis (Pearcy, 1984), protein synthesis and enzyme activity, together with water uptake, cell elongation and leaf development (Horie, 2012 Figure-1).

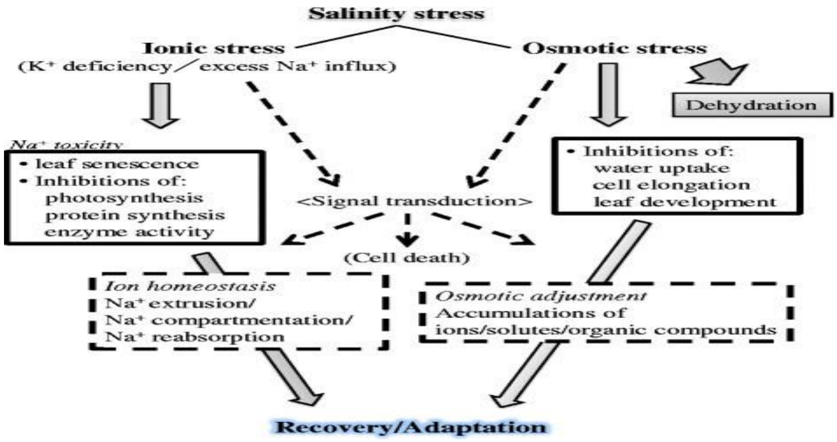

Figure-1 A schematic summary of the stresses that plants suffer under high salinity growth conditions and the corresponding responses that plants use in order to survive these detrimental effects (Adopted from Horie, 2012).

Both seed germination and dry mass production were negatively affected by increased salinity. (Ungar et al, 1996). With the increase in salt concentration, the germination of tomato seed was reduced and the time needed to complete germination lengthened, and the root/shoot dry weight ratio was also affected (Singh et al., 2011). There is decrease in the percentage seed germination, seedlings growth and respiration rate (M. Kaymakanova et al, 2009). On the contrary, with increase in salinity total phenols, flavonoids, condensed tannins and carotenoid contents increased (Salem et al., 2013).

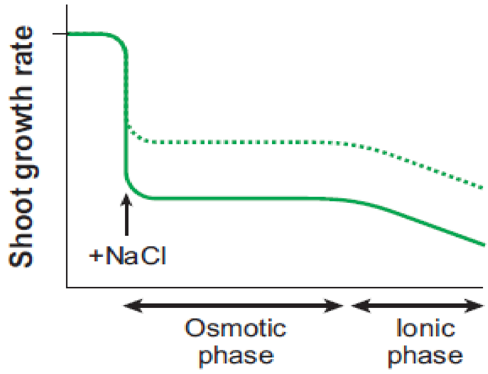

Figure-2 Growth responses to salt stress.

The shoot growth rate appears to decrease as the NaCl concentration increases (Figure 2). This suggests that salt stress inhibits the growth of the plant shoot. At 0 mM NaCl (no salt stress), the shoot growth rate is the highest. As the NaCl concentration increases, the shoot growth rate progressively decreases. At 100 mM NaCl (highest salt concentration), the shoot growth rate is the lowest.

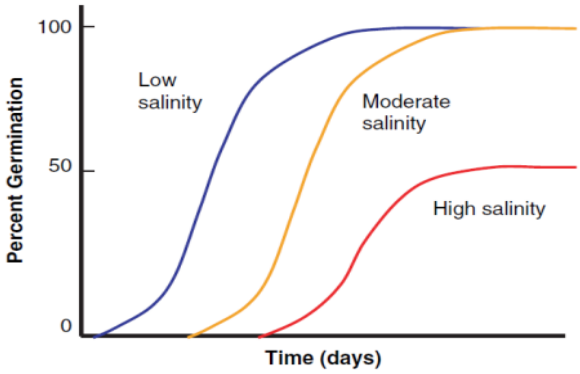

Figure-3-Salinity effects on the relationship between percent germination and time after water addition.

The percentages of germination over time (in days) at three different salinity levels: low, moderate, and high were investigated. At low salinity the germination rate was the highest. It increases rapidly up to 100% within a short period. Whereas, at moderate salinity, it increased steadily over time and reached around 75% by the end of the observation period. The lowest germination rate was observed at high salinity. It increased slowly over time and only reached around 25% by the end of the observation period (Figure 3).
Thus, it can be concluded that seed germination is negatively affected by high salinity. Salinity levels can affect germination in a number of ways, including interfering with the plant's ability to take up water and disrupting enzymatic processes (Oliveira et al 2013).

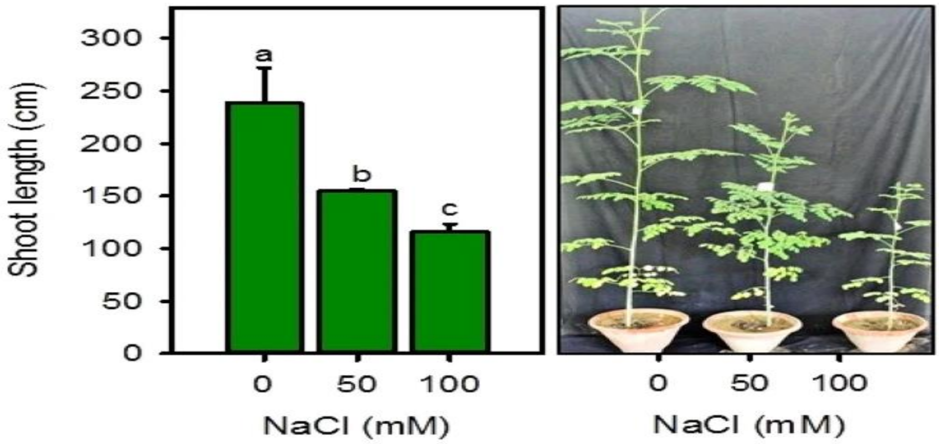

Figure-4 Effect of salinity on shoot length of Moringa oleifera at $P < 0.05$.

Salt stress inhibits the growth of the *Moringa oleifera* shoots. At 0 mM NaCl (no salt stress), the shoot length is the highest, at around 300 cm. At 50 mM NaCl, the shoot length is around 200 cm. There is a statistically significant difference in shoot length between the control group (0 mM NaCl) and the 50 mM NaCl treatment group (represented by the letter b). At 100 mM NaCl (highest salt concentration), the shoot length is the lowest, at around 100 cm. There is a statistically significant difference in shoot length between the 50 mM NaCl treatment group and the 100 mM NaCl treatment group (represented by the letter c). Thus, the data suggest that increasing NaCl concentration has a negative effect on the shoot length of *Moringa oleifera*, and this effect is statistically significant. NaCl concentrations as low as 50 mM can reduce shoot length by 33% compared to the control group (Figure 4).

2. Natural Mechanism to Overcome Salt Stress in Plants

There are various natural ways adopted by plants to overcome salinity stress. Plants develop abilities to sense hyper osmotic conditions (Monk, 2001), Calcium influx, ABA production and altering cuticle property (Deinlein et al, 2014 Fig-5). Probable routes of salt stress toxicity and its various tolerance strategies are adapted by plants (Parihar et al, 2014.) ROS, (Reactive Oxygen Species) production can help plant overcome stress (Ahanger et al. 2017).

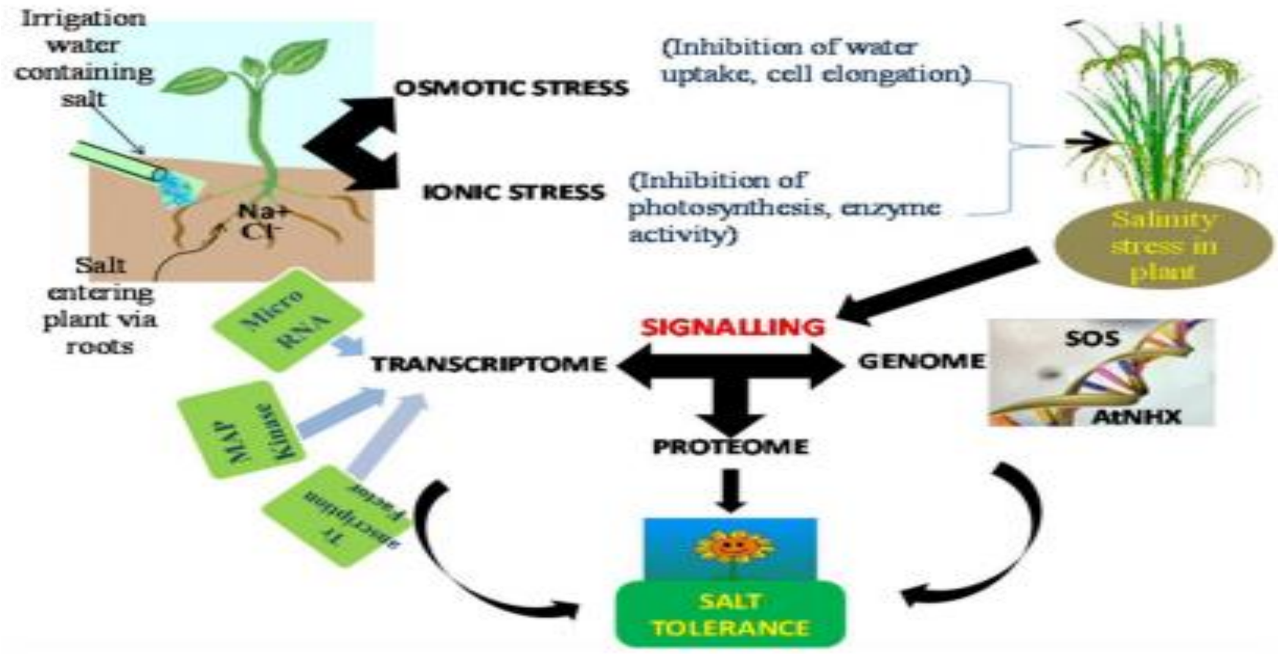

Figure-5 Natural mechanism to overcome salt stress in plants (Deinlein et al, 2014).

Once the plant "senses" the high salinity through pressure changes, it can trigger various defense mechanisms. These defenses might include: Building thicker cell walls to prevent further water loss. Producing special molecules that help the plant tolerate the salt. Sending signals to friendly bacteria in the soil for help so as to manage the salt. By having these sensing mechanisms, plants can react quickly to changes in their environment and fight back against the stress caused by salt.

Plasma membrane of a cell is made up of phospho-lipids and protein. Outside the plasma membrane is the cell wall made up of cellulose which is the polysaccharide containing beta D-glucose. The plant cells are attached with each other through a cement like structure called middle lamella made up of calcium and magnesium pectate. The calcium ions play a very important role in a stabilizing the membrane and permeability of a cell. The role of calcium is not only to stabilize and strengthen the cell wall and the middle lamella but also to act as signaling biomolecule and as a messenger inside the cells to help in overcoming different types of stresses by communicating cells with each other.

The phytohormone product in plants that helps in overcoming stress is abscisic acid-ABA. This plant hormone is working similarly as the adrenaline or the alert hormone in the case of humans and animals. This ABA instructs the plant guard cells to lose potassium ions due to which the water potential of the guard cells increases and hence they lose water to undergo flaccid condition. This closes stomata and conserves water during salt stress conditions.

ABA acts as a gene activator and transcribes gene responsible to produce the protein that strengthens plant cell wall against salt stress by not allowing water to escape (Deinlein et al, 2014). During stress conditions, plants produce more ROS- Reactive oxygen Species; they act as a signaling molecule alerting the plant to be cautious of salt stress (Ahanger et al. 2017).

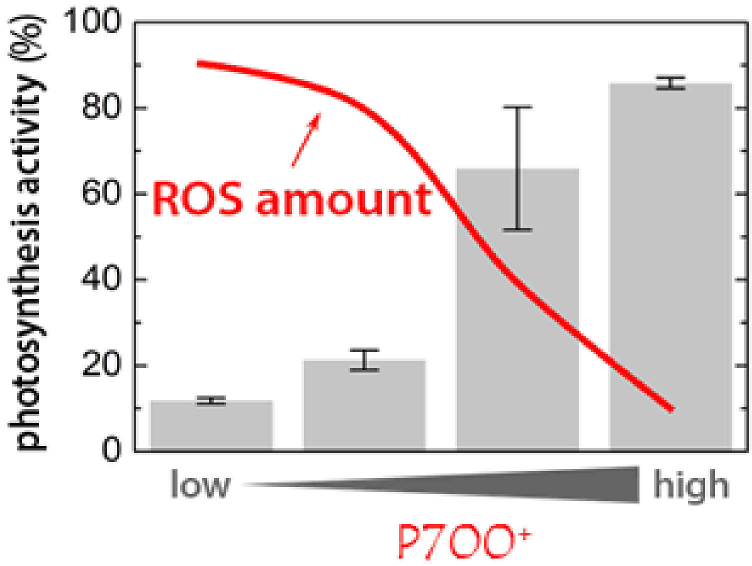

Figure-6 Repetitive Short-Pulse Light Mainly Inactivates Photosystem I in Sunflower Leaves.

Plants use sunlight for photosynthesis, but too much light can be a bad thing. Inside plant cells, there is a molecule called P700 that acts like a traffic light for capturing light energy. Normally, P700 is active (like a green light) and captures light for photosynthesis. But with too much light, P700 gets overloaded and stuck in an inactive state (like a red light). This is bad because it reduces energy production for the plant. It can create harmful molecules called reactive oxygen species (ROS) that damage the cell (Figure 6). The good thing is that plants have ways to deal with this overload: When P700 gets stuck, it acts like a signal to the cell to slow down light capture. This prevents further overload and ROS production. Plants also have two main strategies; They can adjust their light-harvesting system to absorb less light and have other pathways to get rid of the extra light energy trapped in P700 (Sejima 2014).

Most of the research is based on Arabidopsis- a model organism, as it is having short life span, small genome and its various physiological processes can be monitored and recorded (Somerville et al. 2002). Arabidopsis acquires resistance to various biotic components or pathogens (Uknes et al, 1992). Common beans (*Phaselus vulgarus*) are specific glycophytes, very sensitive to low salinity level and drastically reduce plant productivity (Al Hassan, 2016).

3. Potential Salinity Stress Inhibitors

Various possibilities of agriculture and pharmaceutical residue of being potential salinity stress inhibitors are being investigated. Farm and agricultural residue Biochar, processed by partial decomposition of harvest residue and animal dung can overcome salt stress in various crop plants (Ali et al, 2017).

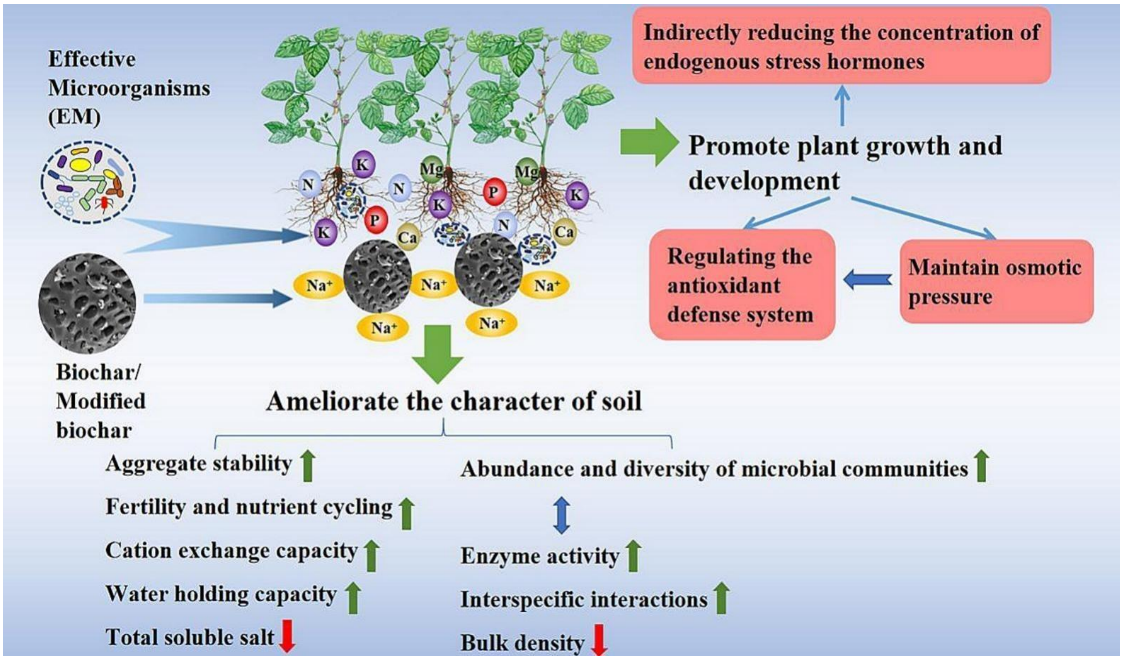

Figure-7 The potential and prospects of modified biochar for comprehensive management of salt-affected soils and plants (Guang Gao 2023).

Biochar is a charcoal-like material created by heating organic materials like harvest residue (leftover straw, stalks, etc.) and animal dung in an oxygen-limited environment. This process, called pyrolysis, preserves the carbon structure of the material while driving off volatile components (see Figure 7).
Salt stress occurs when high levels of salt (sodium chloride) accumulate in the soil. This disrupts a plant's ability to take up water and nutrients, thus leading to stunted growth, wilting, and even death. Biochar can help mitigate these effects in several ways. It has a porous structure with a large surface area. This allows it to hold onto water and nutrients, making them more available to plants even in salty soils. By improving soil structure, biochar can enhance water infiltration and drainage, those preventing waterlogging that can worsen salt stress.
Biochar can absorb and bind some of the salt ions in the soil. As such, it reduces their direct impact on plant roots. Thus a hypo saline condition around plant is generated.
Biochar is a source of mineral elements like calcium, magnesium, zinc, potassium sodium etc. These minerals are very important for the plant growth, metabolism and reproduction. Biochar guarantees that these minerals are slowly released inside the soil and hence due to the microbes growing inside the biochar there is a slow degradation of organic matter of biochar releasing the minerals in soil and making it available for longer period of time. Hence, whenever, plants come under a stressful condition, a biochar supplying the essential nutrients that can balance against the plant coming in stress and hence more water can be absorbed by the plant even during salt stressful conditions.
Water productivity is the amount of agricultural production achieved with the water consumed through evapotranspiration. Thus, the use of Biochar helps to minimize the amount of consumed water (see Figure 8). This can be a valuable tool for improving food security in arid and semi-arid regions that rely on groundwater for irrigation.

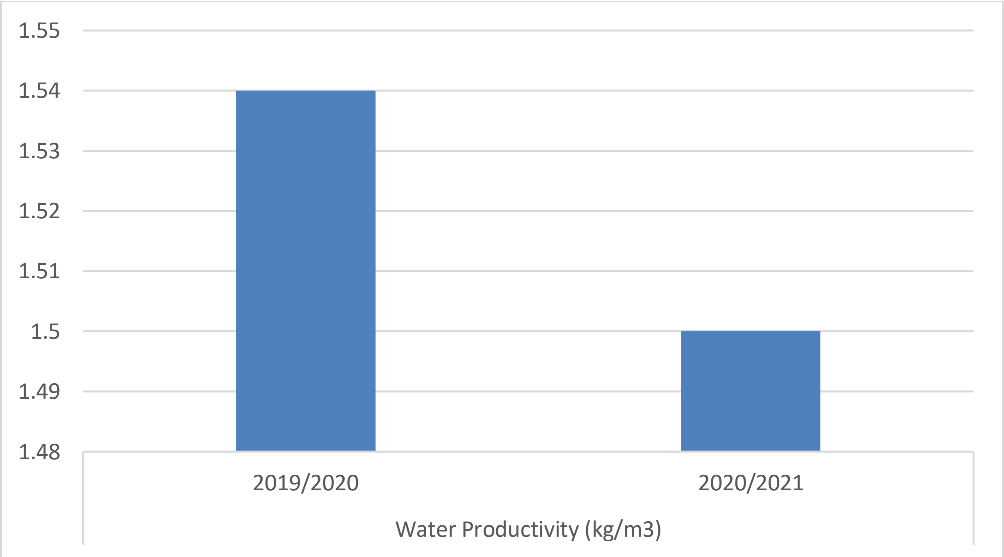

Figure-8 Biochar help to minimize water consumed in two different years.

Rhizobacteria ameliorates Sodium Chloride stress on Tomato plants (Neelam and Saraf, 2021). Rhizobacteria are naturally occurring soil bacteria that live in close association with plant roots. These friendly microbes can form beneficial partnerships with tomato plants, helping them overcome various challenges, including salt stress. Some Rhizobacteria can solubilize nutrients like phosphorus and iron, making them more readily available for the plant to absorb, even in salty soils where nutrient availability can be limited.
Rhizobacteria can produce plant growth that promotes hormones and other beneficial compounds that help tomato plants cope with stress, including salt stress. These compounds may improve root development, increase water uptake efficiency, and enhance the plant's overall stress response. Their strains might be able to directly influence the soil chemistry around the plant roots. They may help reduce the negative effects of sodium ions by altering their availability or by influencing the movement of water and nutrients in the soil.
The current study involves Isolating and identifying different strains of rhizobacteria from the soil environment. It has grown tomato plants in controlled conditions with and without inoculation by the selected Rhizobacteria strains, Exposed tomato plants to different levels of salt stress (varying NaCl concentrations), and measured various plant growth parameters like shoot and root length, biomass, and fruit yield.
Tomato plants were inoculated with specific strains of Rhizobacteria performed better under salt stress conditions and compared to non-inoculated control plants. This suggests that these beneficial bacteria can indeed help alleviate the negative effects of salt stress on tomato plants.

Treatments	Salinity Conditions	Plant Height (cm)
Control	Normal	65.4 ± 1.2
	Saline	59.3 ± 0.9
BAZ-coated urea	Normal	80.0 ± 0.8
	Saline	71.3 ± 0.9

Figure-9 The impact of BAZ (Bacillus augmented ZnO)-coated urea on growth parameters of wheat under salinity stress. (Adopted from Ain et al 2020).

In both normal and saline conditions BAZ- coated urea helped salt stressed plant to exhibit better growth (see Figure 9).

Various sources of nitrogen in fertilizers like urea runoff can be a potential agricultural residue that helps crops and vegetation to overcome salt stress as investigated in maize crops (Irshad, 2008). An investigation of neem oil coated urea and castor oil coated urea significantly improved yield in *Triticum* species. This exposure upgrades antioxidant activities and increases osmoregulatory compounds, thus enhancing wheat production. The nitrogenous compounds like purine catabolize to produce ureides, allantoin that accumulate under stress condition and reduces oxidative stress in plants (Khan et al 2023). Urea phosphite is a systemic fertilizer that is translocated in plant and overcomes salt stress by reducing oxidative stress. It also prevents diseases and nutrient deficiencies in plants.

Various pharmaceutical residues like *Penicillium* (pharmaceutical potential) have been investigated to produce Gibberellins in plants that can modulate plant growth and development during salt stress condition (Leitão et al, 2016). Seed priming by melatonin hormone helps in coping with salt stress Essential Oil Compounds and Antioxidant Activity of *Ocimum basilicum (*Bahcesular, 2020.) Many medicines and drugs come in the form of gelatin capsule. Gelatin is a biopolymer which is prepared by thermal denaturalization of collagen (see Fig.10).

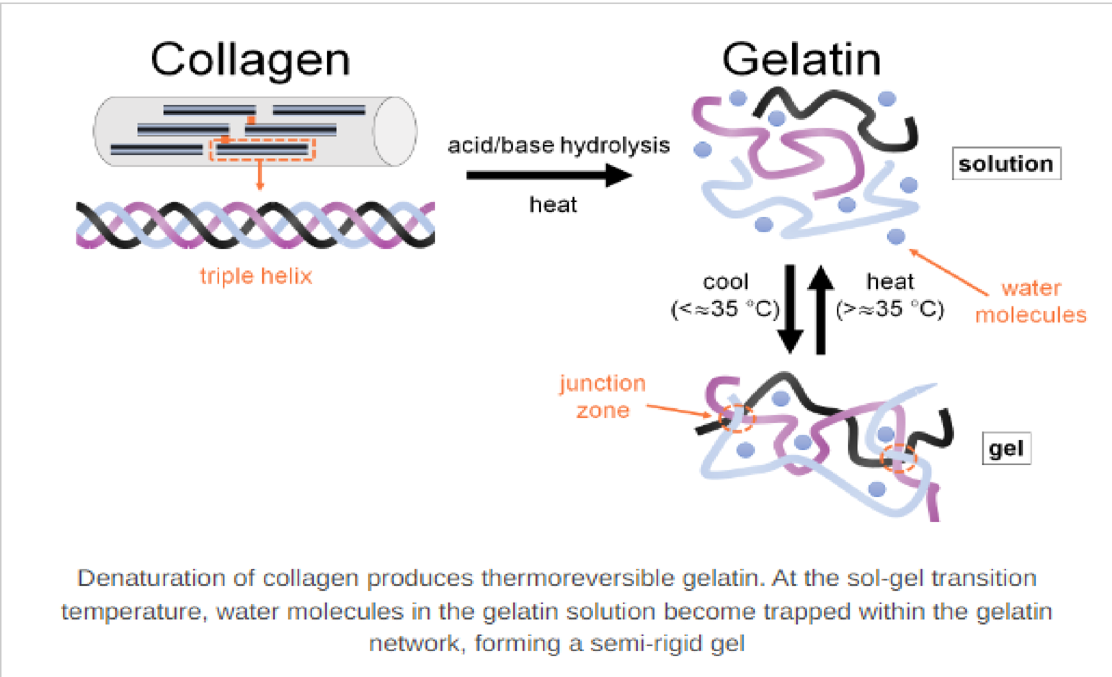

Figure-10 Synthesis of gelatin.

Gelatin acting as a bio stimulant for seed treatment to improve plant performance is well established (Wilson, 2018). but there is of investigation of salt stress. Pharmaceutical capsules are made up of gelatin shells generally derived from acid, alkaline, enzymatic, or thermal hydrolysis of collagen.

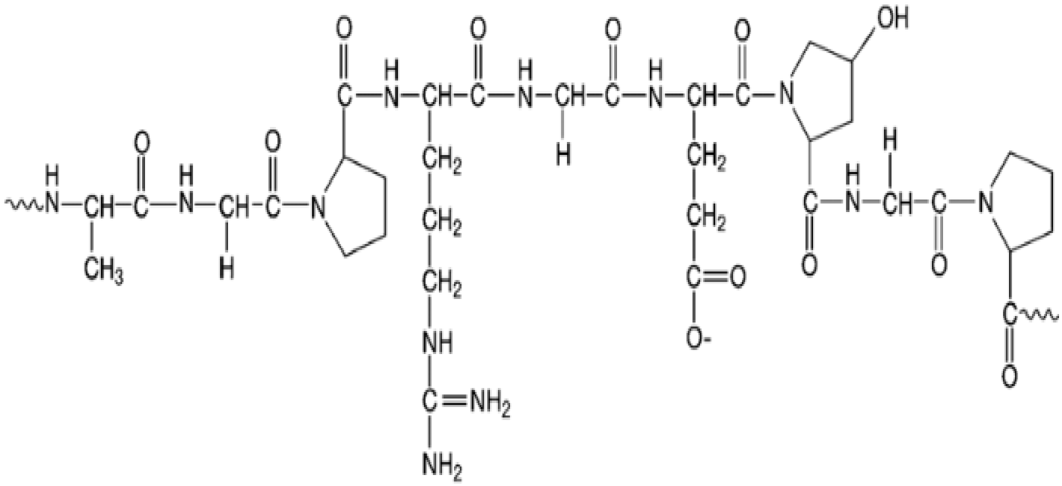

Figure-11 Basic chemical structure of gelatine.

Overall, the chemistry of gelatin capsule breakdown involves the enzymatic hydrolysis of peptide bonds in the gelatin protein by microbial enzymes. This breakdown process ultimately converts the complex protein structure into simpler molecules that can be utilized by microbes and becomes a part of the soil ecosystem.

Effect of cucumber seed gelatin treatment on plant growth and nitrogen content, shows total leaf area (in cm^2) of cucumber plants at two different time points: Leaf 1 (soon after emergence) and Leaf 2 (later stage of growth). The treatments include a control group and a group that received gelatin capsules (dosage not specified in the image). Overall, the cucumber plants treated with gelatin capsules seemed to have larger total leaf area compared to the control group. This is evident at both Leaf 1 and Leaf 2 stages. The difference in leaf area appeared to be more pronounced at Leaf 2. The gap between the control and gelatin-treated groups widened at the later growth stage (See Figure 12).

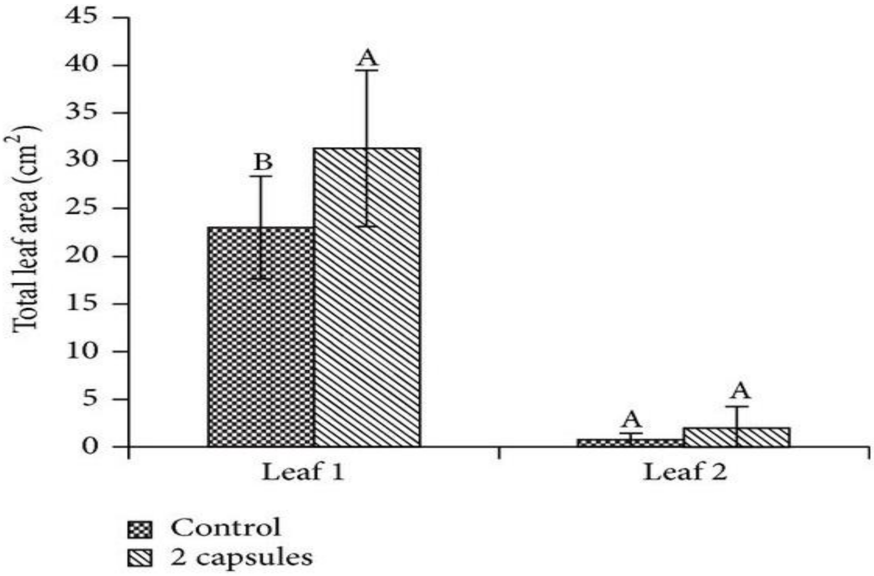

Figure-12 Effect of cucumber seed gelatine treatment on plant growth and nitrogen content.

Gelatin is a protein source that provides essential nutrients to seedling growth and development. The gelatin capsule acts as a slow-release fertilizer, delivering nutrients to the seedlings gradually. Gelatin treatment influences plant hormone production, thus promoting leaf growth.

4. Discussion

Sodium chloride (NaCl) salt does fetch plant under stress by decreasing their seed germination (Sholi, 2012), plant growth (Läuchli, 2021), biomass (Gama, 2009) and production of primary and secondary metabolites (Ashraf, 2018). The plants acquire various natural mechanism to overcome salt stress up to a tolerant level. Salinity stress sends signals to Transcriptome, Genome and proteome to overcome adverse condition generated due to excess salt (Deinlein et al, 2014). Most of the plant used in the investigations are those that have short life span with visible effect of salt stress and that acquire resistance / tolerance to salt stress. A variety of materials have been experimented by many researchers to overcome salinity stress but the studies are still restricted to only few crop plants.

5. Conclusion

Agricultural and pharmaceutical residue might have surplus scope and potential to overcome salt stress by switching ON/OFF of certain genes, thus modulating the protein synthesizing machinery of plant cells exposed to excess salt conditions, ROS production and altering physiological phenomenon.

6. Limitations

Biological organisms are subjected to random behavior and uncertainty even after most of the control variables are fixed. Absorption of salt or salinity stress inhibitors by plant exposed to increasing salt concentration, agricultural and pharmaceutical residue, depends upon membrane permeability of root cell. This might limit the affectivity and hence the results of the investigations. Rooting pattern in plants affects absorption, difference in length and branching of roots affects surface area of absorption and hence might affect the results.

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Conflict of Interest

The authors declare that no conflict of interest in the manuscript.

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