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EFFECT OF ELEVATED CO_2 AND TEMPERATURE ON SOIL HEALTH AND FORAGE CROPS -A REVIEW

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SUMMARY

Climate change is a global phenomenon and is occurring continuously since the earth came into existence. Soil is the most important renewable natural resource. It is the medium of plant growth and supports different types of living organisms on the earth. Climate change is threatening the food, fodder and nutritional security globally. Countries like India are more vulnerable in view of the varied physiographic features viz. different types of soils, topography, land slope and local climate that influence the form and species composition of plant communities. Climate change is projected to have significant impact on agriculture production, productivity and livestock production. It is anticipated that global climate change would have a variety of consequences on soil processes and properties which are very important for restoring soil fertility and productivity. Climate change predominantly effects soils by altering soil moisture conditions, enhancing soil temperature, carbon dioxide levels and salt accumulation. In this review we highlighted about the effect of elevated salt ions, phytodesalination, CO_2 and temperature on soil health and forage crops.

Key words : Climate change, forage crops, soil health, soil salinity

Global warming, climate change and industrial pollution will pose a serious challenge to crop production, productivity and livestock production, and soil health across the world. Climate change is predicted to increase the frequency and intensity of biotic and abiotic stress combinations that negatively impact soil health properties (soil nutrients, microbial activity) and plants and pose a serious threat to crop yield and food supply. Soil is the greatest terrestrial carbon sink and can store three times as much carbon in living biomass as it can in soil, or about 75% of the total amount of carbon present on land. Salinity, flooding, high temperature, cold, drought and nutrient availability are abiotic stress factors that have a huge impact on world agriculture and account for more than 50 percent reduction in average potential yield for most major food and fodder crops (Wang *et al.*, 2003). Over 35% of the world's land surface is considered to be arid or semiarid, experiencing precipitation that is inadequate for most agricultural uses. Around 91% of the world's land is under some sort of stress, compared to just 9% of it being suitable for crop production. Among the abiotic stresses, high temperature, salt and drought are the three major stresses causing severe yield losses in crop plants and forages, for example, high temperature (40%), salinity (20%), drought (17%), low temperature (15%) and other forms of stresses (Ashraf *et al.*, 2008). Climate resilient crops such as grasses: guinea grass, bajra - napier hybrids and tri-specific hybrids, dinanath grass, (Dheeravathu *et al.*, 2018, Singh *et al.,*2020, Dheeravathu *et al.*, 2021a, Dheeravathu *et al.*, 2021c, Dheeravathu *et al*., 2022a, Antony *et al*., 2021, Dheeravathu *et al*., 2022b), pulses: cowpea, berseem, *clitoria, centrosema, siratro* (Dheeravathu *et al*.,2017a and b, Dheeravathu *et al*., 2021a, Dheeravathu *et al*., 2021c, Dheeravathu *et al*., 2022b). Forage cereals: oat (Dheeravathu *et al*., 2022a, Malathi *et al*., 2022) and forage millets: pearl millets and sorghum (Singh *et al*., 2010, Prasad *et al.,* 2015, Tara Satyavaathi, 2021), have been proven to be climate smart. Considering the adverse effect of accumulated salts in soil and irrigation water, elevated CO_2 and temperature on soil health as well as forage yield and productivity, it is high time for in depth understanding of physiological and biochemical changes in forage crop varieties/ genotypes/ lines in response to climate change. Adoption of good bio remediates could play a major role in soil health management, sustaining livestock production and will be helpful in future soil health management and breeding programs.

Effect of salt ions on forage crops

Entry of sodium (Na^+) into the plant cells causes very severe ion imbalance and distribution and excess uptake might cause significant physiological and biochemical disorders(s). High sodium concentration, causes antagonistic uptake of potassium ions which is an essential element for plant growth and development that results in lower production and productivity and finally it may lead to plant death (James *et al.,* 2011). Under high salinity stress, the osmotic potential of the cytoplasm and organelles is maintained by the accumulation of organic solutes termed as compatible solutes (Flower *et al.,* 1977; Wyn Jones and Gorham 1983). At lower concentrations these organic solutes work by stabilizing the tertiary structure of proteins and enzymes and function as osmoprotectants (Rhodes *et al*., 2002). Accumulation of réactive oxygen species (ROS) in différent plant cell organelles (tissues) is highly deteriorating as it can cause oxidative damage to proteins, lipids and deoxyribonucleic acid (DNA), (Miller *et al*., 2010). Salt tolerant grasses (STGs), include the halophytes, facultative halophytes. Halophytes have showed increased efficiency of antioxidative enzymes that helps to negate the harmful effects of ROS (Jitesh *et al*., (2006). STGs are capable of surviving at increasing salinity/ salt stress by utilizing different mechanisms that include vacuolization of toxic sodium (Na^+) and chlorine (Cl^-) in senescing and matured leaves, secretion of excess of salts by salt glands, accumulation of osmolytes like glycine betaine (GB) proline and scavenging of ROS by antioxidative enzymes (Swarnendu and Usha, 2014).

Phytodesalination

Several authors encourage the use of Na^+ and Cl^- hyperaccumulating halophytes for soil desalination since species such as *Suaeda maitima, Suaeda portulacastrum, Suaeda fruticosa, Suaeda salsa, Suaeda calceoliformis, Kalidium folium, Sesuvium portulacastrum, Arthrocnemum indicum, Atriplex nummularia,* and *Atriplex prostrata* have been reported to accumulate high concentrations of salt in their above ground tissues, and consequently, saline soils can be upgraded by harvesting the plants on a regular basis (Ravindran *et al.,* 2007; Glenn *et al.,* 1999; Rabhi *et al*., 2009; Chaudhri *et al.,* 1964; Zhao 1991; Critsenko and Chritsenko 1999; Zhao *et al*., 2005). Chaudhri *et al.,* (1964), reported that *Suaeda fruticosa* removed more than 2400 lbs (1088.6 kg) of salt from 1 acre by a single harvest of the aerial parts per year. Studies with *Suaeda salsa* indicated that a density of 15 plants/ m^2 could potentially remove 3090-3860 kg Na^+/ha if the plants were harvested at the end of the growing season (Zhao, 1991). Therefore, salt tolerant grasses are the potential source of salinity/ salt tolerant traits/ genes for varietal development.

Effect of elevated CO_2 and temperature on soil health

According to Fox *et al.* (2007), the aggregate stability of the soil increases at soil temperature above 30°C because of thermal conversion of aluminium and iron oxides, act as cementing agents for clay particles resulting in formation of strong silt sized particles in the soil (Terefe *et al.,* 2008). At low temperature, viscosity of soil increases resulted in reduction in the absorption rate of water, hence low water uptake reduces the rate of photosynthesis (Toselli *et al*.,1999). Increasing CO_2 concentrations affect soil pH that influence the rate of weathering and to a lesser extent the availability of major and micro plant nutrients (Celia *et al.,* 2002). CO_2 cause only small changes in the pH of the nutrient solution of soil (Stolwijk and Thieman (1957). Ravi *et al.,* (2010) reported that there is a negligible changes in pH when high levels of CO_2 are added to the soil. The bulk density of soil is also affected by CO_2 flush (Franzluebbers, 1999). Soil pH increases as a result of organic acid denaturation which increases at higher soil temperatures in the range of 25°C-39°C (Menzies and Gillman, 2003). High temperature encourages microbial activities as a result there is an excess production of CO_2 in the soil (Alliso, 2005). Wang *et al.,* (2003) reported that soil respiration was most influenced by C substrate availability rather than microbial biomass. Sainju *et al.,* (2021) suggested that increased concentration of salt possibly due to enhanced CO_2 evolution by increasing microbial activity causing improved nutrient availability by mineralizing soil amendments and organic matter. At high temperature, organic matter decreases in soil and reduction in clay fraction leads to decrease in the cation exchange capacity of the soil (Certinini, 2005). Water soluble Phosphorus (P) started increasing in soil after 5°C soil temperature and continue upto 25°C due to the increase in the movement of P in the soil controlled by diffusion (Yilvaiaio and Pettovuori, 2012). The availability of P is low because the release of P from organic material is hindered with low soil temperature (Gahoonia and Nielsen, 2003). Kumar and Swarup, (2012) observed that most of the nutrients cycling particularly N directly correlated with carbon cycling so it is driver of climate change such as atmospheric N, variable precipitation, elevated temperatures likely to impact N cycling and possibly the cycling of other plant available nutrients such as phosphorus and sulfur. Upper soil surface of forest, the N content of soil increased linearly during 5 years of exposure to elevated CO_2 (Jastrow *et al.,* 2005). The soil temperature influence the metabolic activities of micro-organisms which plays a critical role in the nutrients cycling in the soil and providing the nutrients in available form to plants. Soil temperature also affects nutrient uptake by changing soil water viscosity and root nutrient transport (Grossnickle, 2000). At low soil temperature, nutrient uptake by plants reduces as a result of high soil water viscosity and low activity of root nutrient transport (Lahti *et al.,* 2002). Atmospheric CO_2 also influences microbial biomass and diversity in the rhizosphere (Paterson *et al.,* 1997). Soil microorganisms are the driving factor of biogeochemical processes, which play a key role in the response of soil ecosystems. Global warming is expected to affect soil processes in ecosystems, including soil respiration, nutrient cycling and the decomposition of soil organic matter (SOM) by influencing the behavior of soil microorganisms (Williams *et al.,* 2000, Vanhala *et al.,* 2008, Schindlbacher *et al.,* 2011., Ronn *et al.,* 2002, Ferey and Lessner, 2008). It was reported that elevated CO_2 enhanced, root growth, root exudation and increased plant biomass (Ronn *et al.,* 2002, Ferey and Lessner, 2008). Perennial forage crops could improve the soil organic carbon by 20% (0-30 cm) and 10% increase in soil profile (0-100 cm) in about 20 years of their establishment (Alicia *et al*., 2020). Therefore, it is important to see the effect of elevated CO_2 and temperature on soil micro flora and fauna as well as on soil.

CONCLUSION

Soils are the basis of agriculture as they provide a medium for plant growth. Soil being filled with smaller and larger micro-organisms convert dead and decaying matter into essential nutrients like nitrogen, phosphorus, and potassium, improves soil structure, which in turn results in improved food and other biomass production. Soil microbes increase soil fertility, clean the environment, control the production and consumption of several key greenhouse gases, including nitrous oxide and methane. As a consequence of high temperature, salinity and drought conditions caused due to global warming and climate change there has been severe effects on soil health properties affecting the production of food and fodder crops including livestock production. The role of micro-organisms, grasses and legume crops in ameliorating soil health are required to be investigated in detail. Hence, a comprehensive study is essential for the identification of good phyto and bioremediators to combat future climate change that helps in achieving sustainable soil health management including a healthy global carbon cycle.

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