Novel Approach Towards Mitigation of Modern Agricultural Scenario: With A Special Reference to Amelioration of GCC Impacts

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Abstract: Engineering of genetically modified (GM) crop opens an avenue to, reduce the loss of yield, promote plant growth, and provide impregnable nutrient supply that could meet the need of proliferating population explosion. The arena of complex environment, comprising heterogenic conditions, combinations of abiotic stressors, and global climatic changes (GCC) attributes to major challenges on modern agricultural practices. In light of the above note, it can be inferred that agricultural crops expressing stress under natural environmental conditions, even after getting acclimatization at field level. The resultant change occurs due to the human activities, by being responsible for more green house gas emissions (*i.e.* as CO_2, N_2O, and CH_4) than that of last two centuries. It is projected that increasing green house effect induces global warming, by adding 3–5°C on global average temperature in near future. The heart of GM crop development is to harness enhanced tolerance against the environmental stressors. This attributes to the adaptation of morphological, physiological, whole-plant mechanisms and like. At field level, these responses are utilized either by activating stress-response promoters, or by introducing genetic material adapted from arid, arctic or halophytic organisms. This differential approach might promote the value-added crop development that could quench the need of mankind sustainably.

Keywords: Transgenic plant, modern agriculture, GHG, stress-response promoters, arid.

I. INTRODUCTION

Genetically modified crops have a potential impact on biodiversity and have become recent research interest, particularly in context with biodiversity conservation and sustainability. The main focus of environmental impact on human is to minimize the usage of water, pesticides and herbicides in modern agriculture. The complex environmental factors, comprising heterogenic conditions, in combinations of abiotic stressors and global climatic changes (GCC) attributes to major challenges on modern agricultural practices. For enhancing the tolerance to abiotic stress, advancement is done to increase the progress for generating transgenic crops [1]. Here abiotic stress is defined as the condition in which either suboptimal climatic or edaphic conditions adversely affecting the cellular homeostasis ultimately causing impaired growth and health effects.

Variation in climate since last thirty years poses high challenge on cultivation of crops attributing to abridged irrigation potential and cynical food security. The adverse effects on growth, production and quality of crops are posed by transient and chronic stresses that include flooding, drought, salinity, nutrient deficiency, temperature extremes and like. Primarily, abiotic stressors induce reduction in yields of crop, considerably diminishing the productivity during reproductive stage than in vegetative stage. These stressors are interconnected and cause specific or non-specific reaction which affects the plant growth and productivity, imposed due to a series of anatomical, physiological, biochemical and molecular changes. The resultant effects are termed as primary and secondary damage. The reactive oxygen species (ROS) is responsible for secondary stress damage [2], while primary stress is generated basically due to imbalanced electron transport, chillness or abundance of light energy [3].

Several constraints that are related to abiotic stresses comprises, (i) reduction in rate of photosynthesis, (ii) lower water potential, (iii) reduced osmotic regulation, (iv) increased cytotoxicity, (v) deficient nutrient assimilation, (vi) membrane damage and (vii) impaired cellular function.

Plants in general adopts either tolerance or avoidance mechanism in order to acclimatize and adapt to the abiotic stress conditions. Multi-factorial syndrome is the main issue of stress tolerance than single reaction [1]. Through gene transfer, tackling of first as well as second stress could possibly be alleviated and higher rate stress tolerant plant can be generated [4]. Thus, transgenic crops could play a vital role in ameliorating the global climate change attributing with reduction of loss, enhanced growth, and promising food security to the needs of growing population sustainably [5, 6].

II. AMELIORATION OF AGRICULTURAL CROPS FROM ABIOTIC STRESSORS INDUCED BY GLOBAL CLIMATE CHANGE

In the recent past the raise in global temperature is impacted due to rapid climatic change generated through global warming [7, 8]. Anthropogenic sources, emitting green house gases remarkably raised the global temperature [9]. These raising extreme events which are a real and daunting problem might lead to global average temperature of 2–3°C by 2050 and by the end of the century reaching 6.5°C [10]. Some of the significant environmental factors posing challenges in modern agriculture are flooding, drought, salinity, temperature extremes, nutrient deficiency, metal toxicity, and like (Figure 1).

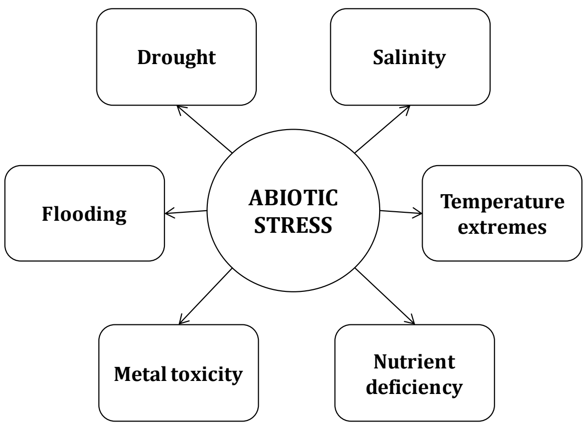

Fig. 1: Environmental factors challenging modern agriculture.

World's agricultural productivity is governed by rainfall and is considered most significant among environmental stress [11]. The chronic solution for escaping from flooding is adapting rapid inter-nodal growth and development of aerenchyma cells. Submerged plants exhibit production of a phyto-hormone ethylene promoting SUB1 (SUBMERGENCE1) gene expression [12]. One of the SK loci (Snorkel gene) that are closely related to SUB1 gene stimulates gibberellins inducing inter-nodal elongation. Aeration is facilitated in waterlogged crops by aerenchyma cells through transport of gases from submerged to non-submerged tissues.

Enormous effort being made by agronomist to improve crop yields with least water availability. It is associated with modification in morphological, physiological, and whole-plant mechanisms like habitat variation, leaf area index reduction, and adjustments to source–sink by altering root growth and development (*i.e.* depth, density, hair development, and hydraulic conductance *etc*.). Development of drought tolerant crops is highly challenging since tolerance is dependent on temporal and spatial variations [13]. Multiple mechanisms for drought tolerance is achieved by enhancing abscisic acid (ABA) for controlling transpiration loss and/or incorporation of DRO1-kp (Deeper Rooting phenotype) results in higher production under drought condition.

Salinity is another factor that limits agricultural productivity that is induced by both natural and anthropogenic activities. The adaptation that could mitigate the salinity problem is to control the osmotic regulation across plasma membrane and tonoplast so as to maintain the turgor pressure [14, 15]. K^+/Na^+ ionic salt tolerance and homeostasis has evidently occurred due to HKT1 (*High–Affinity K^+–Transporter1*), SOS1 (*Salt Overly Sensitive1*) and NHX (*Na^+/H^+ Exchanger*) locus and alleles. Agricultural productivity reduces with nutrient deficiency in the soil. It could be overcome by integrating transport protein that could function for root sensing and nutrient acquisition. Among the limiting nutrient affecting crop yield, most significant attention is posed on phosphorus. Presence of PSTOL1 (*Phosphate Starvation Tolerance1*) gene is responsible for enhancing the acquisition of phosphorus [16].

Human activity increased concentration of essential and non-essential elements in the cultivable land. Higher levels of these metals are toxic to organisms due to cellular accumulation. The cause effects could be overcome by enhancing compartmentalization and or inducing efflux organic ions to chelate toxic ions. For instance, tolerance for the metal toxicity is exhibited through TaAlMT1 (*Al^{3+} activated Malate Transporter*) alleles.

Temperature extremes such as near or sub-freezing and hotness reduce the yield specifically through deteriorating reproductive growth. Overwintering and thermo tolerance is achieved through adopting alteration in the membrane composition. The transcription factor responsible for overwintering and productivity are FR1 (*Frost Resistance 1*), FR2 (*Frost Resistance 2*), and VRN1 (*Vernalization 1*) locus containing CBF gene (*C repeat/dehydration responsive element-binding factors*). Thermo tolerance is involved with the higher concentration of heat shock proteins (HSPs) regulating protein in multiple cellular compartments.

III. CLIMATE RESILIENT CROPS FOR SUSTAINABLE DEVELOPMENT

The engineered crops play significant role for sustainability, due to the characteristic features encompassing, biodiversity conservation, biofuel *cum* energy production, food security, economical, environmental conservation, and climate change mitigation (Figure 2).

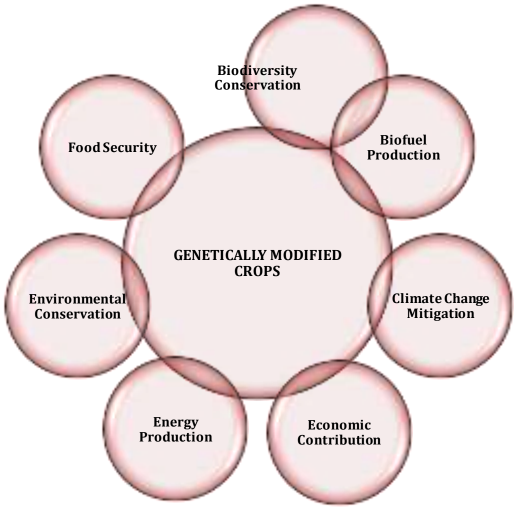

Fig. 2: Characteristics of genetically modified crops (GMCs) contributing to global sustainability

Biotechnological crops are characterized with higher productivity *per hectare*, thus encroachment of forest land for agricultural forming is conserved. Thus, GM crops contribute towards forest and biodiversity conservation. Optimized productivity of first generation crops such as food, fodder and fiber crops in biomass/hectare and second generation energy crops is achieved at low cost [3, 9, 5]. Biotic and abiotic stress tolerant plants with triggered ceiling potential in terms of yield per hectare is made possible by inducing the plant metabolism. Additionally, retrofitting biotechnology brings opportunity to develop more efficient enzymes that could produce biofuel through down-stream processing. This evidenced from higher cellulose content for ethanol production, harvested from transgenic hybrid sorghum and switch grasses. Utilization of GMCs (*i.e.* herbicide and pesticide tolerant plants) impacts dual benefit towards environmental conservation. On one hand reduces the utility of herbicides, pesticides there by limiting fossil fuel deterioration and CO_2 emission, optimized farming investment and efficient water usage on the other hand. Higher productivity of GM crops per hectare plays pivotal role by contributing the food security [3, 17]. Availability of engineered crops reduces the production cost by decreasing the investment through modest ploughing and least pesticide application. It also mitigates the global carbon emission that is associated with climate change, by reducing the utility of fossil fuel for running the agricultural implements. The recent survey on global net economy contributed by GM crop farming reveals that six billion dollars were achieved from developing countries and four-billion-dollar worth money from industrial countries. Thus, it is concluded that the growth of transgenic crops, could contribute to sustainability, i.e. three pillars categories of economical, environmental, and social development [1]. The contribution of transgenic crops attributes to (i) efficient reduction of pesticide requirement. This limits the production and conserves the wastage of fuel form the same process; (ii) Broad spectral usage of conservational tillage systems are adopted to conserve the soil nutrient losses; (iii) Considerable remarks could be achieved from the use of transgenic crops for green energy and biofuel production; (iv) Drought tolerance is the another milestone reached by transgenic crops that had increased crop productivity in arid regions.

IV. CONCLUSION

Greatest threat is posed on global agricultural productivity due to unprecedented and brutal impacts of global climate change. Abiotic stressors such as flooding, drought, salinity, nutrient deficiency, metal toxicity, temperature extremes and like, are some the significant facts deteriorating and causing vulnerability to global food security. Retro-fitting techniques were adopted in addition to conventional breeding techniques to accomplish growth and productivity under stress tolerance. In contrast, these GM plant species adopting abiotic stress tolerance needs to be assayed for environmental safety assessment before being approved.

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