Critical abiotic factors affecting implementation of technological innovations in rice and wheat production: A review

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ABSTRACT

Rice and wheat are two major staple food crops in India and worldwide. Over the years the yield potential of the crops has been affected by abiotic factors, which is further projected to increase due to climate change induced environmental adversities. Typically these two crops have different growing conditions, rice requiring high water for cultivation unlike wheat which is water demanding and sensitive to larger variability in temperature regimes. In the recent past drought and disease stress, besides several other stresses, are considered to be critical factors affecting the growth and yield of crops, which is evident in the recent decades. Admittedly, drought stress coupled with biotic stress will further contribute for declining performance of crop varieties and difficult to alleviate even with innovative technological innovations. Few of the technological innovations like high yielding varieties, genetically modified cultivars, integrated nutrient management, integrated pest management, water conservation strategies and prophylactic measures to avoid the disease/pest outbreak, though with potential to augment the yield losses is affected by the stresses. Attempts have also been made to utilize transgenic technologies to build intrinsic tolerance mechanisms by the plants through alteration to functional genes. However, sustainable technologies like classical breeding approaches and integrated farming principles are also being considered to develop crops adaptation and/or enhance the adaptive mechanisms by aligning with technological interventions. Though, several technologies show promise but constrained by the limitations to achieve ‘one-fits-all’ model to overcome the interactive effects of abiotic stressors. Visibly, the crop growth and yield enhancement through technological innovations is call of the day as climate change induced aggravation of these stressors on crop production is imminent. Skilful integration of technological innovations to suit the local and regional scale crop husbandry systems may have promise to address the abiotic stress to realize economic yield of crops like rice and wheat. The review will argumentatively analyse few critical stressors that limit the successful implementation of technological innovations to sustain the rice/wheat crop production and resilience building in the millennia.

Key words: Abiotic stressors, Bi-directional Model, Crop production, Climate change, Growth and yield, Rice-Wheat products, Technological innovations.

The challenge of sustaining the crop productivity in the changing growth conditions and environmental impact is increasingly felt in the recent decade. Several of the factors/stressors have been implicated to drastically affect the goal of achieving potential yield of crop. The exploding population with eventual demand for food, dwindling natural resources, climate change adversities have been considered to be major constraints affecting the growth in agriculture sector- (Morton, 2007; Piao et al., 2010). In view of alleviating these constraints there has been paradigm shift in approaches to enhance the crop production through focused crop improvement programs and technological innovations.

It is evident now that agriculture sector in India is considered to be most vulnerable to climate change.

Intergovernmental Panel on climate change (IPCC) projected rise of temperature by 3-4 degrees by 2050 over current levels (IPCC, 2002; Mehl et al., 2007). The impending climate change adversities are known to alter the abiotic stresses like variable temperature regimes and their associated impacts on water availability leading to drought, increased diseases and pest’s incidence and extreme weather events at local to regional scale. Besides variable temperature regimes may result in unpredictable disease epidemic across the geographic regions (Gregory et al., 2009). Crop improvement programs (Richards, 2006; Richards et al., 2007) are increasingly directed on rice and wheat as the production of these food grains predicted to be affected leading to imbalance in attributes contributing to yield. Given the complexity of stress factors, most challenging is to crop

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adaptation without the loss of water and nutrient use efficiency under extreme climatic events.

Rice and wheat are major food grain crops in India occupy large cultivated area amongst the agricultural crops. However, the productivity of rice and wheat has assumed declining trend and area of cultivation not shown any expansion (Hobbs and Morris, 1996). Moreover, Indian population is predicted to reach 1.68 billion by 2030 from the present level of 1.21 billion (Anonymous, 2009). It calls for intensive crop production practices, which is already affected by abiotic stressors of variable intensity. These stressors are known to cause 30-60% yield losses annually (Dhlamini et al., 2005). However, utilization of promising technologies may pave way for overcoming the effects of various stressors on crop production.

Highly heterogeneous and unpredictable environment pose paramount problems in addition to genetic variability challenges to improve the crop adaptation by technological innovations. Nonetheless, new tools are becoming more refined, accessible and extensively used for building adaptive mechanisms to abiotic stresses in rice and wheat. Moreover, a synergistic approach to genetic improvement in conjunction with innovative crop management practices has been considered to be doubly green revolution (Conway, 1997; Pingali, 2012) and suitable for successful implementation of technological innovations to address crop stress management.

Amongst the several of the crop productivity limiting stressors drought, variable temperature regimes and salinity are considered to be most critical abiotic stress (Zhang et al., 2000; Vincour and Altman, 2005). Since green revolution, in the quest for ensuring food security, the effort has been to avert the effects of these human induced environmental factors. In this direction, crop designing through conventional and modern biological approach has assumed phenomenal importance to increase agricultural production. On the contrary, organic farming is relatively land intensive and regressive in technology usage. Unlike the modern technologies, organic farming technology is characterized by low on chemical inputs (fertilizers/pesticides/herbicides), mixed farming dominated by traditional varieties/cultivars, complex cropping systems, crop rotation to control pests/diseases and soil health maintenance through organic manures (OECD, 2003). Though these sustainable and environmentally friendly technologies have promise but the crop yield potential is less. Moreover, there is large gap between potential yield and realizable yield of the crops, which is again affected by the abiotic stresses.

Designing crop production technologies that are robust and consistently produce desirable results for wide spread adaptation is also a larger constraint. However, the technological innovations must consider a bi-directional relationship (Figure 1) amongst basic science, translational research with consequent technology development as situational event prediction to suite the future growth environments. A focused research and development model with public-private partnership are the source of novel agricultural technologies. Conceptually, it is realistic model of the relationship between research and technological innovations. However, magnitude of scientific output and usefulness of the agricultural technologies developed are under continuous debate as many factors drive their adaptability under climate change scenarios (Chhetri et al., 1996). Further, retrospective analysis of criterion used in targeted technological innovations to address the climatic constraints at multiple scales in specific locations may provide better insights (Esterling, 1996; Parez-Aleman, 2011). A wide range of technological innovations in agriculture like genetic improvement (varieties), fertilizer technology, adaptive microbial technology, pesticides, farm machinery, agronomic and management practices (integrated management of nutrients and pests) have been achieved through focused research programs to understand their implications in enhancing the crop productivity. Unlike in the past, new discoveries and realization of potentials of innovation is difficult but possible to achieve through advances in basic and pre-inventions sciences (Evenson and Gollin, 2003; Huffman and Evenson, 2006), which support the evolution of other crop technologies.

Significant advances made in the modern biology involving molecular genetics technology have allowed understanding the stress resistance mechanisms of plants. For instance, improved tolerance to drought and temperature regimes has been observed in transgenic plants that over express genes regulating molecular mechanisms of tolerance to stress conditions. Despite the evidence of advantages of technological interventions results seem to be not consistent, which is considered to be a limitation to explain the performance of crops, engineered to survive the hostile environments.

**Critical abiotic factors: Mutually inclusive stressors**  
**Drought: An imminent abiotic stress in the future agriculture:** Drought is the most important constraint to realize the potential yields of crops. Moisture stress accounts for about 30 to 70 per cent loss of productivity of field crops during the crop growth period. In India, as in many other parts of semi-arid regions of the world, 78 per cent of the area under agriculture is rainfed and is inescapably linked to the short-fall and erratic rainfall patterns. Out of the total gross cultivated area of the country, 56 m ha is subjected to inadequate and highly variable rainfall. The National Commission on agriculture identified 337 districts of the country as drought prone (http://www.nih.ernet.in/rbis/india_information/draught.htm).
The impending climate change eventualities are likely to aggravate the drought intensity and occurrence, higher evapotranspiration as a consequence of rising temperature regimes. Such a situation creates challenging environment for crop cultivation and ensure food security in the 21st century and demand development of drought tolerant crops (Bush, 1945; Cassman, 1999; Borlaug, 2007; Pennisi, 2008). It is imminent to adapt two trajectories: i) development of integrated soil-crop system management to address constraints in existing crop varieties; ii) newer varieties with high yield potential under water and nutrient limited environment and tolerant to disease and pests as well (Swaminathan, 2005; Baulcombe et al., 2009).

The emerging concept has been to tailor the crops with suitable adaptive mechanism for drought situation and associate environmental constraints (ex. high temperature regimes) while optimizing the water use and nutrients without sacrificing the economical yield potential. Admittedly, with increasing demand for water even the irrigated agro-ecosystem might experience moisture stress, which calls for adapting innovative water conserving technologies (Fan et al., 2011; Ward and Velazquez, 2008). Hence, the emphasis must be to increase the adaptation of crop plants to water limited conditions and to develop crop genotypes that would produce more with less irrigation. From this context, one of the major global agenda has been to improve water productivity of crop plants with an emphasis of achieving 'more crop per drop'. In agriculture, the term drought refers to a situation in which the amount of available water through rainfall and/or irrigation is insufficient to meet the evapotranspiration needs of the crop.

Plants have evolved diverse adaptive strategies to cope with water-limited environments. These mechanisms range from cellular level tolerance leading to adaptation in response to stress and/or specific growth behaviours and morphological characteristics (inherent traits) that avoid stress effects. These diverse plant physiological mechanisms have their relevance in enhancing stress adaptation. However, from the agronomic perspective, mechanisms that can sustain growth under water limited environment need greater emphasis. Furthermore, the drought tolerance mechanisms and their relevance at specific target environment depend on intensity, magnitude, and frequency of occurrence. Therefore, the key to progress towards breeding for drought tolerant crops requires understanding the stress responses of crop plants to identify the relevant drought adaptive mechanisms and/or traits (Kulkarni 2011; Blum, 1988; Federoff et al., 2010). Hence, the major focus has been to device strategies for achieving the formidable challenge of crop designing to suite variable moisture limited situation. However, random and at times lasting drought spells may pose increasing threat to varieties, which are unlikely to have advantages. Variable intensity of drought occurring at plant growth stages like vegetation growth, flowering/pollination and ear filling stages require different definition on tolerance to drought. It implies that achieving drought tolerance at all plant growth stages is impossible proposition (Evenson and Gollin, 2003; Tester and Langridge, 2010). Designing crops...
to escape the drought stress at various growth stages needs different modifications, which is difficult to achieve and the tolerant crop response would be unpredictable.

Temperature regimes
Climate change adversities: The impending climate change is predicted to alter the cropping profiles of the agricultural landscapes, which is attributed to poor adaptation of varieties to high temperature regimes, increased drought due to uneven and/or insufficient rainfall, outbreak of newer diseases and pests. Crop improvement to develop adaptive varieties and design allied technologies to realize optimal yield is Herculean task due to high levels of uncertainty in weather events and variability across the geographic locations. It predicted that the productivity of rice/wheat will increase in few locations but largely assume declining trends due to temperature effects on increased evapotranspiration of moisture with consequent susceptibility of crops to disease and pest incidence. Few lines of evidence suggest that high temperature regimes due to climate change affect the phenology, reproductive biology, flowering times, pollen viability and pollinator populations (Antle and McGuickin, 1993; Evenson and Gollin, 2003; Lake and Huges, 1999; Johnson and Lincoln, 2000) which, will adversely affect the crop productivity. Wheat being self-pollinated may be affected most under such situations. Hence, any technological innovations have limitation to tailor the crops to withstand such morphological changes. However, natural evolutionary process has yielded few wild relatives/land races that show adaptive mechanisms, which can be exploited for developing newer varieties (Springer and Ward, 2007). This has been scientific basis in approaching technological interventions either transgenic technology and/or molecular breeding to generate ecotypes of crops suitable for such environments.

Rice and wheat cultivation is spread across the geographical locations with highly variable growth conditions. The high yielding varieties potential and allied technologies used to boost the productivity of the crops may become counterproductive or ineffective under such environments. Scientific programs have been directed to achieve the goal of developing genetically improved crop varieties through introgression of genes/adaptive traits to genetically superior wild type/landrace in a geographic location (Ziska et al., 2012). Further technological interventions to improve growth conditions have additive influence on realizing the success of the innovations. Uncertainties related to response of improved crop varieties and agronomic practices are still under various stages of research to evolve region specific technological innovations to counter the impact of high temperature regimes and associated stresses.

Salinity: Salinity effect on cultivable land area in India accounts for 6.73 million ha and under acidic soils is 6.03 million ha (Heisey et al., 2003). Salinity is considered to increase in arid environments and highly irrigated basins of rice growing regions. Besides, naturally salt affected soils are not suitable for cultivation of currently available high yielding varieties. Moreover, salt tolerant traditional varieties are low yielding with limited opportunity to exploit the adaptive traits attributable to narrow genetic variability among the genotypes. Empirical evidences suggest that technological interventions have resulted in development of few varieties of rice/wheat, which show potential for tolerance mechanisms to salinity (Jones et al., 2008; Trivedi, 2010).

Productivity of the salt affected soils is inherently poor and not amenable for soil fertility enhancing practices like introduction of biological nutrient fixers/mobilizers. The existing strains of N-fixers, P-solubilizers and mycorrhiza may not survive the salinity to perform their functions (Sairam and Tyagi, 2004; MacKill et al., 2010). It is pertinent to identify novel adapted strains of microorganisms for the salt affected soils that may prove to be beneficial to advance the technological innovations. Introduction of salt tolerant leguminous species is an option but is less feasible practice in rice-wheat system.

Crop improvement through altering the cellular level tolerance mechanisms to exclude the salts and/or selectively uptake the nutrients is considered to be option to develop salt tolerant rice/wheat varieties. Transgenic technology has been effectively utilized to introgress functional genes that regulate the cellular level tolerance (Govindarajulu et al., 2005; Maillet et al., 2011). However, the criticism is that can these introduced genes be stable over generations to retain the adaptive characteristics of varieties. Evidently, salinity tolerance has been examined in model transgenic plants under variable growth conditions (Leung and An, 2004). Large number of reports clearly shows that manipulation of metabolic pathways using genetic engineering is a strategy that improves the performance of plants against abiotic stress. However, in most cases the impact of transgene does not confer high levels of tolerance. There is a possibility to increase the tolerance through simultaneously expressing transgenes involved in several metabolic pathways. Alternatively, transcription factors that regulate the expression of several defence genes at the same time (Takeda and Matsuoka, 2008) is promising observation. Expression of several genes may confer higher tolerance not only at low temperatures, but also to drought and salinity. Accordingly, genomic technologies have a central role in the discovery of genes that regulate the intricate defence networks activated by plants in response to several types of environmental challenges. Understanding complex response factor of introduced technological innovations in such situations makes it impossible to assess the utility, however circumstantial evidences show promise for implementing focused crop improvement programs.
Technological innovations

**Potentials and limitations:** Rice and wheat crops are grown across the world on various agro-climatic and soil fertility conditions. The crop improvement program since the selection to conventional breeding until the green revolution has contributed immensely for developing crop genotypes with desired traits. Post green revolution, introduction of high yielding varieties of rice and wheat, which demand high input management has contributed phenomenally to meet the food grain demands in last 50 years (Ou, 1985). The crop improvement programs to increase productivity alone have contributed for 1% per annum for wheat and 0.8% for rice as consequence of adopting high yielding varieties (Evenson and Gollin, 2003). Few of the technological innovations that have shown potentials and options to improve the crop production of rice and wheat in the future are listed in the Table 1. Nonetheless, these technologies have contributed greatly for achieving the food security in the last decades (Sadras, 2002; Pingali, 2001). Consequently, industrial agricultural activities with the high input management have also adversely affected the natural resources of agricultural landscapes (Haymi and Herdt, 1977). For instance, genetic resources of tolerant traditional varieties/cultivars have been phased out due to introduction of high yielding varieties. It has also resulted in degradation of water resources and introduction of high water demanding varieties has resulted in difficulty to build resilience to increasingly felt abiotic stress affecting the crop production. The effort to counter the impact through advanced technological innovations by genetic manipulation has not been able to alleviate the challenges.

Crop adaptation and resilience building by harnessing the technological innovations has multitude of implications in sustaining the productivity of rice and wheat with variable input management. The germplasms resources of these crops have provided substantial leads to identify tolerant genotypes for abiotic stresses. However, the breakthrough in identifying the adaptive traits and introgression of these traits to genetically superior background has met with mixed outcome. Consequently, scientific understanding of abiotic factors that promote gene flow is of considerable interest and also met with criticism (Johnson and Loncoln, 2000). The scepticism and concern arises from the introduction of genes in domesticated crops that gene flow between genetically transformed to uncultivated relatives may alter the original genetic makeup with subsequent impact on the evolutionary fitness (Fugile, 2010; Hobbs et al., 2000). Furthermore, abiotic factors may differentially affect out crossing and gene flow between species, which influence the population size, genetic diversity, meta-population dynamics and trajectory of evolution (Hobbs et al., 2000). Early inconclusive evidence suggests gene flow in rice systems from genetically modified phenotype, which may result in undesirable biotype of the preferred crop (Ellstrand et al., 1999). The empirical evidences for out crossing rates and gene transfer is limited and how demographic variations in stress factors affect such process is not clear yet (Lu and Snow, 2005; Takebayashi and Morrel, 2001). However, adaptive transgenic technology and molecular breeding strategies are currently considered as panacea technological innovations for crop improvement program. Considerable research progress has been made on golden rice in International Rice Research, Philippines, which have promise for sustaining the yield (Gealy et al., 2003). Preliminary evidence of transgenic rice varieties tolerant to drought and pest stress is also one such example confirming the utility of technological advancement. However, the field scale performance of these transgenics introgressed with adaptive traits and their stability under climate change eventualities and aggravated impact of abiotic stresses is still an unresolved concern. Some of the innovative technologies that show promise especially in rice include aerobic rice technology, which is preferentially suitable for water limited situations with comparable yield potential (Cleland et al., 2007). It is argued that transgenic technology could play a significant role in increasing the productivity to offset the impact of growing demand for cereals. It can also provide option to focus research on developing varieties suitable for semi-arid environments, dominant with drought and temperature stress and also salinity to increase the productivity. The contention is that in the future crop improvement program without transgenic technology it is difficult to develop crops with better nutrient acquisition, improved photosynthetic abilities, increased conversion dry matter to grain, improved water mining and tolerance to disease and pests (Eckert et al., 2009; Hossain et al., 2003). Some of the relevant technologies have been identified with their scientific relevance and limitations (Table 1).

**The way forward:** Do new discoveries and innovations hold the promise?

Crop plants are unable to dislocate in its own environment therefore they have evolved to solve abiotic stress with internal mechanisms of tolerance. Consequently, the gene must evolve to perform and adapt quickly to environmental changes. Over the years, crop growth support technologies like fertilizer, adaptive microbial technologies and several circumstantial cultural practices have been developed and refined to counter the plant stresses at various levels. Evidently, several new technologies are in the horizon and evolving each year. So far, major focus in crop improvement program has been to enhance the yield and also to bridge the gap of achieving the potential yield in crops. In view of the increasing problems posed by abiotic stresses, the technologies development should focus on mitigating the impact of abiotic stress to sustain the productivity.
### Table 1: Technological innovations with implications for rice-wheat production systems

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Approach</th>
<th>Scientific relevance</th>
<th>Utilities</th>
<th>Limitations/Issues</th>
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<tr>
<td>High Yielding</td>
<td>- Conventional breeding</td>
<td>- Robust and slow process</td>
<td>Stable variation, Moderately resistant to pests and diseases</td>
<td>Narrow tolerance to abiotic stresses, input intensive, depleting to soil nutrient resources</td>
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<td>Varieties (HYV)</td>
<td>- Transgenic technology</td>
<td>- Crop tailoring to introgress the adaptive traits/genes</td>
<td>Desirable traits introgression is possible to develop varieties adaptive to one or multiple stresses</td>
<td>Promising but criticised for stability of the introgressed gene and integrity of the variety, suspected gene flow to feral species</td>
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<td></td>
<td>- Molecular breeding</td>
<td>- Marker assisted selection in conjunction with conventional breeding approach</td>
<td>Target breeding is possible to develop mapping population through marker systems</td>
<td>High promise, marker assisted selection can be robust, limited by non-availability of large marker systems for agronomic traits</td>
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<td></td>
<td>- Second generation genomics</td>
<td>- Pathway regulatory approach, regulatory and functional gene mining</td>
<td>Elucidation of Cellular Level Tolerance mechanisms, identification regulatory genes at process level</td>
<td>Cost intensive, difficult annotate the gene functions in a pathways biology</td>
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<td>Gene pyramiding</td>
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<td>Integrated</td>
<td>Skilful management of nutrient resources in combination of organic, chemical and biological sources</td>
<td>Additive effects in maintain the adequate amounts of nutrients in soil solution and readily available forms for plant uptake</td>
<td>Multiple nutrient needs can be met and sustains the soil fertility through improved biological activity, act as buffer mechanism for nutrient release continuum</td>
<td>Amenable for modification, difficult to tailor the practice for soils with high fertility gradients, variability and poor coupling capacity, effectively employed for degraded soils</td>
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<td>Nutrient Management</td>
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<td>Integrated</td>
<td>Prophylactic, escape mechanisms, biological control agents, multiple cropping systems, crop rotation</td>
<td>By passing the lifecycle and outbreak of pests and diseases, controlled use of pesticides, disease control sprays</td>
<td>Effective management of pests and diseases at threshold levels to achieve economic yields</td>
<td>Unpredictability of disease and pest outbreak, target pest/disease management is poor, may affect the beneficial trophic levels</td>
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<tr>
<td>Pest/Disease Management</td>
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<td>Fertilizer</td>
<td>Easily available forms in chemical formulations</td>
<td>Easy source of nutrients and available to plant on application of specific nutrient source formulations, Quantitatively supplied to meet the demand</td>
<td>Deficiency of nutrient can be managed at different growth stages of plants</td>
<td>Cost intensive, non-renewable, Energy intensive, degradable to inherent ability of soils, poor availability, poor NUE, Environmental pollution</td>
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<td>technology</td>
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<tr>
<td>Adaptive</td>
<td>Efficient strains of beneficial microbial consortium in their compatible formulations applicable to soil</td>
<td>Microbial functional groups— N-fixers, P-solubilizers, Nutrient mobilizers, soil-borne pathogen control agents</td>
<td>Enrichment, sustenance and continuous release of nutrients, mobilization of nutrients that are less available due to complexation, additive role in plant tolerance to stresses, control of soil borne pathogens, environmentally friendly, cost, effective, renewable</td>
<td>Poor survivability, few effective strains, lesser cross-inoculation possibilities, competitive inhibitions of strains in formulations, less effective under highly stresses conditions like moisture limited, high temperature, salinity</td>
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<td>microbial technology</td>
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<tr>
<td>Manufactured</td>
<td>Controlled release of nutrients</td>
<td>Surface enrichment of nutrients on metal oxides and controlled release on plant demand, minimal losses</td>
<td>Minimise the losses by supplying a known amounts at given time, cost effective, amenable for formulations</td>
<td>Suspected environmental hazards of metal oxides, contamination of water bodies, inhibitory effects on native beneficial microbial groups, evolving technology</td>
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<td>Nano-particles (MNMs)</td>
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<td>Organic agriculture</td>
<td>Less intensive management of crop using on site resources</td>
<td>Sustainable and adaptable in various agro-climatic and stress conditions, multiple cropping system, open options for resilience building for climate change adversities</td>
<td>Cost effective, environmentally friendly, suitable for small land holders, subsistence farming</td>
<td>Poor yields, Insufficient availability of bio resources, high weed competition, difficult to control the disease/pests, not suitable for HYV cultivation</td>
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<tr>
<td>technology</td>
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<tr>
<td>No till agriculture technology/Resource Conservation Technologies (RCTs)</td>
<td>Natural farming with minimal cultural practices using traditional varieties/cultivars, surface seeding.</td>
<td>Skilful and less intensive cultivation matching the crop type with soil productivity</td>
<td>Comparable yield, highly conserving to resources, less labour intensive, lesser energy and environmental foot prints, less water needs, high biomass</td>
<td>Large scale cultivation and potential yield are not realizable, limited technological innovations, uncertain returns</td>
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<td>Micro-irrigation technology</td>
<td>Precise delivery of water meeting the demand at various growth stages</td>
<td>Monitored delivery of water on demand through drip and mist irrigation on the basis of crop requirement at growth stages</td>
<td>Water economy, supply of liquid nutrients, suitable for water limited situations</td>
<td>Cost intensive, technical snag of clogging, recurring cost for peripherals and maintenance, not suitable for field crops, best suited for semi- and perennial crops</td>
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<tr>
<td>Cultural practice</td>
<td>Incorporation of traditional knowledge with sound scientific basis in crop production</td>
<td>Resilient crop production practice with multiple cropping, strip planting, crop diversification</td>
<td>Efficient utilization of land area, additive role of crop types on sustaining the soil productivity, efficient management of disease/pests, comparable yields, high biomass recycling, suitable integration of stress tolerant crop types, economic with better returns</td>
<td>Suitable for small land holder farming practice, difficult to manage diverse crop demands and competition for resources, less suitable introduction crop management intensive technologies</td>
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<tr>
<td>Plant spacing</td>
<td>Optimal plant population per unit land area</td>
<td>Eliminates the competition between plants and efficiently facilitates equitable utilization of the resources</td>
<td>Control of population in line with the fertility status of the soil and other resources, efficient weed control, judicious application of inputs</td>
<td>Possible crop failure in largely spaced planting systems, wastage of added inputs, poor utilization of soil resources</td>
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<tr>
<td>Hormones</td>
<td>Utilization of synthetic analogs of plant growth promoting chemical agents</td>
<td>Modulation of physiological functions of plant morphological features</td>
<td>Instantaneous growth promotion, shorten the life cycle, achieve desired growth of beneficial plant parts</td>
<td>Cost intensive, precise application of minamounts is difficult to achieve, suitable for selective crops</td>
</tr>
<tr>
<td>Precision farming technology</td>
<td>Judicious resource management through matching the inputs addition with qualitative and quantitative parameters</td>
<td>Supply of precise amounts of various inputs to minimize the wastage and economize the crop production practice</td>
<td>Economizes the input use, control the inputs, predictable yield can be achieved</td>
<td>Cost intensive, poor adaptation due to lack of information management, not suitable for small land holder crop management, evolving technology, best suited for monoculture cropping systems</td>
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<td>Aerobic rice technology</td>
<td>Water conserving and judicious input management in rainfed rice cultivation</td>
<td>Rice cultivation with minimal growth support soil moisture conditions and efficient management of growth promoting inputs</td>
<td>Wider adaptability in various geographic regions, suitable drought prone areas, rainfed drylands</td>
<td>Few adaptive varieties/cultivars, high weed competition, faster degradation of organic matter, suitability in various soil types is not proven yet</td>
</tr>
<tr>
<td>Herbicide technology</td>
<td>Application of synthetic chemical agents</td>
<td>Alteration of physiological functions of plants through blocking the target enzyme activity in weed species</td>
<td>Wide spectrum control of weeds, suitable monoculture crops</td>
<td>May damage crops at intensive application, detrimental to biological agents and soil microflora, cost intensive</td>
</tr>
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<td>Micro-nutrient technology</td>
<td>Supply of micronutrient formulation to alleviate the deficiencies</td>
<td>Precise supply of micronutrient to meet the crop requirement for normal growth</td>
<td>Specific micronutrient and/or multiple micro nutrients can be supplied, Easy to manage the deficiencies in nutrient poor soils</td>
<td>Cost intensive, complexon, differential availability at various soil pH range</td>
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<tr>
<td>Mechanization of crop production</td>
<td>Integration of several machinery for planting, weeding, harvesting and processing</td>
<td>Minimize the difficulties for labour intensive management practices</td>
<td>Efficient and timely practice of weeding, harvesting with minimal loss, minimizes the labour need, highly</td>
<td>Cost intensive, not suitable for small land holder farming and resource poor farming activities, takes away part of profit</td>
</tr>
</tbody>
</table>
Second generation molecular technologies like rapid DNA sequencing followed by selection on genomic traits, marker assisted breeding including functional markers, doubled haploids, random DNA markers for associated with desired traits, biostatics analytics coupled with the experience and methods of classical geneticists will contribute for realizing the increased crop production under abiotic stress with special reference to rice-wheat (Ju et al., 2009; Sutton, 2009; Raul et al., 2005). These technologies can be applied for most of the abiotic stress to elucidate the genetic mechanisms of tolerance and their variability under similar stress conditions to identify superior genotypes to evolve as varieties. Predictably, better impacts can be visualized as those observed during the green revolution (Pingali, 2012) paving way for second green revolution through skilful technological innovations.

Several lines of evidence support cross-talk between abiotic stress responses. It is one the major constraints in successful implementation of technological innovations in rice and wheat crop production. However, the modern biological techniques provide wider options to develop genetically improved crop varieties and allied growth support technologies to counter the abiotic stresses to sustain the growth and productivity of crops.

**Summary and perspectives**

The predicted population growth by 2050 requires increase of 70% in food production to meet the demand (Leung, 2008). The demand for staple food grains (rice-wheat) will phenomenally increase calling for continued focus on shifting the yield frontiers. Meeting such a paradigm requires focus on improving tolerance to abiotic stresses. However, implementation of technological innovations in the future crop production systems must critically consider productivity enhancement in marginal environments through the mitigation of abiotic stresses and also to provide tools for adaptation to climate change.

Despite several promising technologies for crop improvement with consequent realizable yield improvement, success in comprehensively address the stresses like drought and diseases affecting the crop growth and performance has not been achieved to the satisfaction. Transgenic adaptation strategy has paved way for genetic capability enhancement and/or adaptive plant trait pyramiding to address the stressors (Yano and Tuberosa, 2009; Cancado, 2009). However, the challenge has been to convincingly prove any advertent effects of transgenics on original genetic resources of other species and any health hazards. Admittedly, policy changes relevant to crop improvement using modern biological tools/techniques also have been a constraint. The policies changes must not become structural impediments rather promote and contribute for sustaining agricultural resources for staple crop (rice-wheat) production. These technological innovations have provided leap frog progress in understanding plant physiological response to abiotic stressors in rice and wheat.

Sustainable technologies have also been tested in an innovative approach with un-economical yield of crops under intensive abiotic stress. The crop improvement program must consider a holistic approach to skilful utilization of modern biological tools/techniques to develop crops while integrating the sustainable technologies to overcome the limitation offered by abiotic stressor in crop production. It paves way for development of resilient crop genotypes for these stressors with improved adaptive mechanism to climate change adversities. The abiotic stressors like drought and diseases limiting the technological interventions to achieve improved crop yields in rice and wheat is need not be a constraint but has not been possible to achieve high level of tolerance. However, the genetic improvement of crops for abiotic, through technological interventions, has the promise for sustenance of crop production, if not higher productivity, in resource poor and growth limiting environments. Admittedly, the challenge posed is how to integrate these productivity enhancing technologies in small-holder and marginal environments with profitability. The impending climate change adversities will exert compounding effect on agricultural systems especially rice-wheat in resource poor countries. Thus implementing doubly green revolution will require sequencing the technological innovations with time to overcome the challenges posed by abiotic factors in crop improvement to achieve sustainable change. The competitive technologies that mitigate the impact of abiotic factors are needed to realize the sustainable and economic productivity of crops.

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