

Major Challenging Constraints to Crop Production Farming System and Possible Breeding to Overcome the Constraints

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Abstract: Agriculture is the major economic backbone of the world in improving the livelihood the population and contributing the highest GDP of the world. However, agricultural productivity is limited by diverse biotic and abiotic constraints. Biotic stress is the adverse conditions for crop growth and production caused by biological factors. These are diseases, insects, wild animals, lack of high yielding crop variety and parasitic weeds. These all are the major impeding factors and contributing to the low productivity of crop production. An abiotic stress is the adverse conditions for crop growth and production caused by environmental factors. Such as deficiency or excess of nutrition, moisture, drought, salinity, soil acidity, light, freeze, chill, heat, shortage of agriculture inputs like fertilizers, herbicides and air pollution. All are already important abiotic stress factors that cause large and widespread yield reductions. Crop losses are a major threat to the wellbeing of rural families, to the economy of traders and governments, and to food security worldwide. Agricultural production in the world is characterized by subsistence orientation, low productivity, low level of technology and inputs, lack of infrastructures and market institutions, and extremely vulnerable to rainfall variability. Productivity performance in the agriculture sector is critical to improvement in overall economic well-being in world. Low availability of improved or hybrid seed, lack of seed multiplication capacity, low profitability and efficiency of fertilizer, lack of irrigation development, lack of transport infrastructure, inaccessibility of market and prevalence of land degradation, unfertile soil, over-grazing, deforestation and desertification are among the constraints to agricultural productivity in the world. Future crop yields and global food security may well hinge on the ability of farmers around the world to narrow the gap between current yields and yield potential ceilings, especially as progress in the latter may slow because of climate change and diminishing returns in breeding. Because average crop yields are critical drivers of food prices, food security, and crop land expansion, there is tremendous value in better quantification and understanding of yield gaps. Generally, the causes of climate change, stresses produced due to climate change, impacts on crops, modern breeding technologies, and biotechnological strategies to cope with climate change, in order to develop climate resilient crops. Revolutions in genetic engineering techniques can also aid in overcoming food security issues against extreme environmental conditions, by producing transgenic plants. Overall, improvement in agricultural sustainability by means of increasing yields of low-input production systems is not only possible, but also urgently needed. By using breeding methods that are geared to the common limitations experienced by farmers around the globe, varieties with superior traits and adaptations can be achieved. Increasing the availability of superior varieties specifically bred to low-input systems, either through traditional or advanced breeding methods will improve agricultural sustainability and global resource management, as well as decrease the energy demanded for food production during a time of historic global relevance as population peaks and valuable finite resources decline

Keywords: Constraints; Climate Change; Biotic Stresses; Abiotic Stresses; Yield Gap; Resistance, Tolerance.

1. INTRODUCTION

Stress is an alteration of physiological condition caused by the various numbers of factors that tend to interrupt the equilibrium state (Gaspar *et al.*, 2002). Stress in plant refers to external conditions that adversely affect growth, development and productivity of crop plants (Lerner, 1999). The origin of new pathogens and insect races due to climatic and genetic factors is a major challenge for plant breeders in breeding biotic stress resistant crops. Yield losses due to biotic stresses have resulted in 800 million people underfed in the world. Reduced yield due to biotic stresses and increasing food demand put international food security at risk as 70% more food will be required in 2050. This review describes and compares the conventional and molecular genetics methods being used for breeding

biotic stress resistant crops. In the past, classical breeding approaches like introduction, hybridization, composite crossing, multiline, and backcross breeding were utilized for this purpose. However, these methods were slow, expensive, and hectic for developing resistance in crops. Furthermore, breakdown of resistance due to fast evolving pathogens could not be coped with using these time consuming methods. Therefore, molecular genetics approaches like mutation, marker assisted selection, genomics, recombinant DNA technology, targeted induced local lesions in genome, and virus induced gene silencing were adapted by breeders to develop effective resistance in crop plants in a shorter time.

Abiotic factors are the major yield-limiting factors for crop plants (Canter, 2018; Zorb *et al.*, 2019). Abiotic stresses, such as temperature extremes, drought, flooding, salinity, and heavy metals are major factors limiting crop productivity and sustainability worldwide (Waqas *et al.*, 2017; Vaughan *et al.*, 2018; Zafar *et al.*, 2018). Abiotic stresses disturb plant growth and yield formation. Several chemical compounds, known as plant growth regulators, modulate plant responses to biotic and abiotic stresses at the cellular, tissue, and organ levels. About 90% of arable lands are prone to one or more of the above stresses (Dos Reis *et al.*, 2012), which cause up to 70% yield losses in major food crops (Mantri *et al.*, 2012). Estimates based on the integration of climate change and crop yield models have predicted further loss in the productivity of major crops, including rice, wheat, and maize, which may have serious consequences for food security (Tigchelaar *et al.*, 2018).

Key constraints to agricultural productivity in the developing country include low availability of improved or hybrid seed, lack of seed multiplication capacity, low profitability and efficiency of fertilizer use due to the lack of complimentary improved practices and seed, and lack of irrigation and water constraints. In addition, lack of transport infrastructure and market access decreases the profitability of adopting improved practices. The scarcity of quantifications of crop losses and analyses of their causes is related mainly to the difficulty of their assessment. Most attempts to measure yield reductions (losses) were based on relationships between yields and an indicator of a given pest or disease. However, farmers usually do not face only one pest or disease, and their crops can be exposed to different conditions (Savary *et al.*, 2008). Such relationships therefore can be masked by several confounding factors such as interactions with other pests and diseases, and interactions with other factors such as environment (temperature, rainfall), soil fertility and others (Cooke, 2006). Apart from the yield reduction of a specific year, there can be reduction of the yielding capacity in the future, which in annual crops, for instance, is given by the negative effects of pathogens inoculum that remains in soil; whereas in perennial crops is given by the death of tissues and/or reduction of reserves.

The economic valorization of losses needs basically the data of yield losses, but also other variables such as the costs of production, prices and other economic drivers (Avelino *et al.*, 2012) which may make difficult the task. To overcome these difficulties a holistic view is needed, involving multidisciplinary research (ecology, epidemiology, biology, agronomy, economics and others) (Savary *et al.*, 2012). A complexity of abiotic, biotic, and socioeconomic constraints and those related to crop management (Dixon *et al.*, 2002) reduce yields and productivity of food crops for smallholders in farming systems throughout the developing world. If research can identify and address the most severe constraints, there is substantial potential to further increase crop yields of smallholders, food security and farm incomes in developing countries. The importance of individual constraints and their associated yield losses will vary by crop, management and the environmental and socio-economic characteristics of the farming system. From an appreciation of constraints and losses (complemented by other factors such as potential opportunities, the probability that a loss/opportunity can be effectively addressed, and the benefits it may then have), technology experimentation, training, socio-economic and policy support investments can be prioritized (Mills *et al.*, 1998).

Demand for both food and energy is quickly rising and will continue to rise with increases in global population and average income. World population is projected to reach its maximum (~10 billion people) by the year 2050. This 45% increase of the current world population (approaching seven billion people) will boost the demand for food and raw materials. However, Modern agriculture is fundamentally based on varieties bred for high performance under high input systems (fertilizers, water, oil, pesticides), which generally do not perform well under low-input situations. Crop breeding programs that are more focused on nutrient economy and local environmental fitness will help reduce

energy demands for crop production while still providing adequate amounts of high quality food as global resources decline and population is projected to increase (Bruinsma J, ed, 2003). Estimation of yield gaps, identification of production constraints and future yield potentials for individual crops require a thorough knowledge of natural resources (soils, climate) and crop production systems. The average (farm) yield is the average yield achieved by farmers in a defined region and period. The potential yield is defined as the maximum yield of a crop cultivar grown in an environment to which it is adapted, with nutrients and water non-limiting and pests and diseases effectively controlled (Evans and Fischer, 1999).

In general, maximum potential yields can be estimated using results of highly controlled on-station experiments or crop models calibrated using crop characteristics of the latest varieties (Fischer *et al.*, 2009). The yield gap analysis, i.e. the difference between current average farm yields and potential yields. Yield potential is a concept, rather than a quantity, which makes estimation both challenging and complicated (Cassman KG, 1999). By definition, yield potential is an idealized state in which a crop grows without any biophysical limitations other than uncontrollable factors, such as solar radiation, air temperature, and rainfall in rain-fed systems. Therefore, to achieve yield potential requires perfection in the management of all other yield-determining production factors (such as plant population; the supply and balance of 17 essential nutrients; and protection against losses from insects, weeds, and diseases) from sowing to maturity. Such perfection is impossible under field conditions, even in relatively small test plots let alone in large production fields. Thus, yield potential is sometimes estimated by crop models that assume perfect management and lack of all yield-reducing factors.

The validity of such models relies on validation under field conditions, which can never achieve perfect management. Global food security threatened by climate change and it's one of the most important challenges in the 21st century to supply sufficient food for the increasing population while sustaining the already stressed environment. Climate change has already caused significant impacts on water resources, food security, hydropower, human health especially for African countries, as well as to the whole world. Studies on climate impacts and adaptation strategies are increasingly becoming major areas of scientific concern, e.g. impacts on the production of crops such as maize, wheat and rice, water resources in the river basin catchments, forests, industry and the native landscape. Crop productivity and soil water balance have been studied with crop growth models by using parameters from different climate models. Meanwhile, climate variability is one of the most significant factors influencing year to year crop production, even in high-yield and high-technology agricultural areas. In recent years, more and more attention has been paid to the risks associated with climate change, which will increase uncertainty with respect to food production. Water availability will be one of the limiting constraints for crop production and food security. Plant breeding activities are broadly concerned with improving the yield and quality of the crop product and improving or maintaining the resistance of the crop to diseases (bacterial, fungal or viral) and insect pests.

To overcome all the above constraints, the breeder strives for early maturity, increased winter hardiness, resistance to heat, drought, disease, and insect damage. Cultural practices to increase yield-fertilization, irrigation, and application of chemicals for pest control. In order to achieve the sustainable intensification necessary for increased food production, they need to be supported by additional management practices. The use of well adapted, high-yielding varieties with resistance to biotic and abiotic stresses and improved nutritional quality; enhanced crop nutrition based on healthy soils, through crop rotations and judicious use of organic and inorganic fertilizer; integrated management of pests, diseases and weeds using appropriate practices, biodiversity and selective, low risk pesticides when needed; efficient water management, by obtaining "more crops from fewer drops" while maintaining soil health and minimizing off-farm externalities. The objective/s of the paper was to understand the major constraints those adversely affect the crop production and productivity & to understand the possible breeding methods to solve the crop production and productivity constraints.

2. MAJOR CHALLENGING CONSTRAINTS TO CROP PRODUCTION SYSTEM

Production constraints have been identified that contribute to explaining the yield gap, i.e. limited water availability, limited nutrient availability, inadequate crop protection, insufficient or inadequate

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use of labour or mechanization, and deficiencies in knowledge. Water shortages during the growing season can be reduced using irrigation; nutrient limitations can be lifted by applying organic or inorganic fertilizers. Yield reductions due to inadequate control of weeds, pests and diseases can be avoided by introduction of proper crop protection including the use of biocides, phytosanitary methods and crop rotations. Especially for operations where timeliness is crucial, such as sowing or planting, limited application may result in yield reductions, e.g. when delayed sowing is done under unfavourable weather conditions (Cirilo and Andrade, 1994). In other cases, seasonally specific cultivation patterns may cause temporal labour shortages that, in their turn, reduce the adoption of new technologies (White *et al.*, 2005). In Africa, where many production situations are based on manual labour, the availability of labour may be limited during the period crucial for weeding. Under these conditions, poorly controlled weed populations may reduce crop yields (Riches *et al.*, 1997).

The other production constraint explaining yield gaps refers to deficient knowledge resulting in inadequate crop management other than discussed above. This may affect crop yields in many ways, e.g. by applying poor quality seed or planting material, inappropriate plant densities or by selecting poorly adapted crop varieties, damaging plants by inadequate applications of fertilizers or crop protection agents. It may also include incorrect, premature or late harvesting. Obviously, these production constraints are interrelated and their effects difficult to separate. For example, weather conditions may limit the accessibility of fields to fertilizer application machinery, resulting in decreased nutrient availability and thus reduce crop yields. It is, however, not possible to identify or account for possible interactions and synergies and the production constraints are treated as independent constraints, each individually contributing to the yield gap in a particular region. The relative contribution of production constraints contributing to the gap between potential and current yields differs among crops and regions. The crop growth and development are constantly influenced by environmental conditions such as stresses which are the most important yield reducing factors in the world (Dennis, 2000).

Table1. Past, current, and projected future population sizes, along with changes in food production and resource consumption.

Production Demands	Year		
	1960	2000	2050
Population (billions)	3	6	8.7–10
Food production (Mt)	1.8×10^9	3.5×10^9	6.5×10^9
Agricultural water (km^{-3})	1500	7130	12–13,500
N fertilizer use (Tg)	12	88	120
P fertilizer use (Tg)	11	40	55–60
Pesticide use (Tg, active ingredient)	1.0	3.7	10.1

Mt, Metric ton; km^{-3} , cubic kilometer; Tg, 10^{12} g or million metric tons.

Source: A Sustainable Response to Feed a Growing World Population, 2011.

Table2. Average annual change in cultivated crop areas (%) in the periods 1970-1979; 1980-1989; 1990-1999; and 2000-2007 compared to the average cultivated area in the previous decade in the world.

Crop	1970-1979	1980-1989	1990-1999	2000-2007
Wheat	0.4	0.3	-0.4	-0.4
Rice	1.0	0.4	0.3	0.3
Maize	1.0	0.6	0.7	0.7
Soybean	3.1	2.8	1.6	3.4
Barley	2.0	0.2	-1.5	-2.6
Tropical cereals	-0.1	-0.2	-0.7	-0.2
Cotton	0.4	-0.5	0.2	-0.1
Rape seed	2.9	3.4	3.6	1.7
Dry beans	0.0	0.9	-0.3	0.3
Groundnut	0.4	-0.2	1.2	0.7
Sunflower	2.5	3.0	2.8	1.2
Sugar cane	2.1	2.1	1.6	1.3
Potato	6.3	-0.8	0.0	0.5
Cassava	1.5	1.0	1.1	1.0

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Oil palm	0.3	2.7	3.8	4.4
Sugar beet	1.0	0.4	-1.3	-4.6

Source: Yield trends and yield gap analysis of major crops in the world, 2009

Table3. Common factors that contribute to yield losses in farmers' fields

Biophysical factors	Socioeconomic factors
Nutrient deficiencies and imbalances (nitrogen, phosphorus, potassium, zinc, and other essential nutrients)	Profit maximization
Water stress	Risk aversion
Flooding	Inability to secure credit
Suboptimal planting (timing or density)	Limited time devoted to activities
Soil problems (salinity, alkalinity, acidity, iron, aluminum, or boron toxicities, compaction, and others)	Lack of knowledge on best practices
Weed pressures	
Insect damage	
Diseases (head, stem, foliar, root)	
Lodging (from wind, rain, snow, or hail)	
Inferior seed quality	

Source: Crop Yield Gaps: Their Importance, Magnitudes, and Causes, 2009

2.1. Drought

Drought stress is characterized by the reduction of water content, reduces leaf water potential and loss in turgidity, closure of stomata and decrease in cell division, elongation, enlargement and finally growth. Extreme water logging situations may result in the reduction of seed germination, photosynthesis, and disturbance of metabolism and finally the death of plant (Jaleel *et al.*, 2008c). It reduces plant growth and development by affecting the various physiological and biochemical processes, such as photosynthesis, respiration, translocation of biomass, ion uptake, carbohydrates, nutrient metabolism and growth regulators (Jaleel *et al.*, 2009a-e). Water ability in plants, is a major driving force behind the regulation of fitness and survivality. Water deficit and salt stresses are the major global issues to ensure survival of agricultural crops sustainable food production and food security (Nakayama *et al.*, 2007). It has severe effect on the seed germination, growth, phenology, water and nutrient relations, photosynthesis, assimilate partitioning, respiration, and yield component in plants. Drought stress is coping by the various morphological, physiological, molecular and genetical approaches. The crop growth and development are constantly influenced by environmental conditions such as stresses, which are the most important yield reducing factors in the world (Dennis, 2000).

Drought is the most important abiotic factor that adversely affects growth and crop production, especially in warm and dry areas (Fathi, A *et al.*, 2016). Drought is actually a meteorological event which implies the absence of rainfall for a period of time, long enough to cause moisture-depletion in soil and water deficit with a decrease of water potential in plant tissues. But from agricultural point of view, drought is the inadequacy of water availability, including precipitation and soil-moisture storage capacity, in quantity and distribution during the life cycle of a crop plant, which restricts the expression of full genetic potential of the plant. It acts as a serious limiting factor in agricultural production by preventing a crop from reaching the genetically determined theoretical maximum yield. Increased crop yield is required to meet the needs of future population growth, but drought causes significant yield reductions for rainfed and irrigated crops.

Climate changes will increase the frequency of droughts, particularly in many countries in Africa that are already drought-prone. For instance, by 2050, water shortages are expected to affect 67% of the world's population (Ceccarelli *et al.*, 2004). Climate extremes are expected to increase with climate change, which may negatively affect crop production (Troy *et al.*, 2015). In most areas where crop production is dependent on rainfall there is always risk of crop failure or yield loss due to moisture stress. In the semi-arid tropic areas, moisture is always inadequate for crop growth because of low precipitation and erratic distribution and poor soil moisture storage capacity of soils. In severe cases the stress could lead to total crop loss (Sinha, 1986). Drought is the major limiting factors for yield

stability in the semi-arid tropics, where rainfall is inadequate, non-uniform and erratic in distribution (Hamblin *et al.*, 2005). Worldwide, the yield loss each year due to drought was estimated to be around USD 10 billion (Mutava *et al.*, 2011). Agricultural drought, namely water deficiency, adversely affect plant and crop production by reducing leaf size, stem extension and root proliferation, disturbing plant water and nutrient relations, and inhibiting water-use efficiency. During periods of severe drought, these losses can be much higher and can potentially result in complete crop failure (Mutava *et al.*, 2011).

2.2. Important Crop Pests

Attacks of pests can occur in the agricultural land during the production cycle (pre-harvest) and/or during the storage (post-harvest). In both stages, the yield of the crop product as well as its quality can be reduced (Savary *et al.*, 2006b), which implies that financial returns will be also compromised because of less production to sell and/or less quality to offer to buyers (Nutter *et al.*, 1993). Furthermore, implications of crop losses can reach levels far beyond farms, given that a reduced production can affect entire rural communities and regions, national markets and exportations, and at broadest level, the food availability for the world population. Given the negative implications of crop losses, strategies and measures at different levels (from farms to governments) are needed to reduce them, and must be based on reliable assessments. Quantification of crop product losses and a better understanding of their drivers have been mentioned as essential to (i) evaluating the efficacy of crop protection practices (Oerke, 2006), (ii) making better decisions for integrated pest management (Savary *et al.*, 2008a), (iii) assessing the sustainability of agricultural production systems (Cooke, 2006), (iv) evaluating the effectiveness of pest and disease regulation as an ecosystem service (Allinne *et al.*, 2016), and (v) guiding government agencies and other potential donors about where, how and when allocate resources for better control of pests and diseases, and therefore avoid crop losses (Cooke, 2006). The results of these evaluations and guidance could contribute to the design of better practices to reduce the incidences of pests and diseases, as well as to the design of agroecosystems with characteristics (structure composition-management) aimed to reduce crop losses (Avelino *et al.*, 2015).

- **Diseases**

Biotic stresses are the damage caused by other living organisms like viruses, fungi, bacteria, nematodes, insects, and weeds to crop plants. These stresses are of historical significance unlike the abiotic stresses that appeared to be important recently due to climate change. There are some historical events when biotic stresses (diseases) led to complete failure of the crops, resulting in famine in those regions; examples include potato blight in Ireland, coffee rust in Brazil (Rogers, 2004), and maize leaf bight in the USA (Ullstrup, 1972). The Great Bengal Famine in 1943 is another example of crop failure due to diseases (Padmanabhan, 1973). All of these events led to millions of deaths and migration of people to other regions. Biotic stresses like insects and diseases cause considerable reduction in grain yield, i.e. only diseases reduce 10% global food production, leaving 800 million people underfed (Christou and Twyman, 2004). One of the most important factors that will play a role in disease spread is climate change. As temperature is expected to increase in the near future, diseases caused by thermophilic bacteria are expected to appear. There are chances that diseases may appear earlier during the crop season. Another important factor is that both insects and pathogens change their races very rapidly, making resistance a non-durable process. Similarly, non-availability of durable resistance sources makes the development of crop plants resistant to biotic stresses a difficult job (Strange, 2005). However, one or more genes provide resistance to plants against biotic stresses. Therefore, this genetic basis can be exploited by plant breeders to develop resistance in crop plants against diseases and insect pests.

- **Insects**

Crop losses due to pest and diseases are a major treat to incomes of rural families and to food security worldwide (Savary, S and Willocquet, L, 2014). Insect cause damage to plant either or directly or indirectly in their attempts to secure food and almost the portions viz roots, stems, shoots, leaves, flower and fruits of plants are affected by insects (Dhaliwal *et al.*, 2015). The losses of crops caused by insect pests are quite high in both developed and developing countries. It is estimated to that food plants of the world are damaged by more than 10,000 species of insects (Dhaliwal *et al.*, 2010).

Herbivorous insects damage 18% of world agricultural production. Despite this damage less than 0.5 percentage of the total number of the known insect species are considered pests. Insect pests are created through the manipulation of habitats by humans, where crops are selected for larger size, higher yields, nutritious value, and are cultivated in monocultures for maximum production. This provides a highly favourable environment for the population increase of herbivorous insects. To ensure stable crop yields we need to change the management strategies of agroecosystems.

- **Weeds**

Weeds are one of the most limiting factors in crop cultivation. Weeds compete with crop plants for water, nutrients, sunlight and space and also carry insect-pests and diseases. If not controlled in the beginning, weeds can cause significant reduction in crop yield and also deteriorate the quality. Gharde *et al.* (2018) have reported that in India alone, the losses due to weeds are estimated to be 11 billion USD per year, which varied from 13.8% in transplanted rice to 76% in soybean. Among all biotic stresses, weeds cause the highest potential loss (34%), with insect (18%) and pathogens (16%) being less important (Oerke E.C, 2006). Thus, effective weed control in any crop production system is a pre-requisite if high yields and good quality are to be achieved. With continuously increasing labor cost, manual weeding has become an expensive field operation for any crop and farmers are increasingly opting for cultivars tolerant to herbicides.

2.3. Plant Nutrients

There are over 100 chemical elements, yet scientists have found that only 17 of them are essential for plant growth and development. In addition to oxygen, carbon dioxide and water, plants require at least 14 mineral elements for adequate nutrition (Mengel *et al.*, 2001). Deficiency in any one of these mineral elements reduces plant growth and crop yields. Plants generally acquire their mineral elements from the soil solution. Six mineral elements, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S), are required in large amounts, whilst chlorine (Cl), boron (B), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), nickel (Ni) and molybdenum (Mo) are required in smaller amounts. Nutrients are classified as essential; the element needs to meet the following criteria: - The plant cannot complete its life cycle (seed to new seed) without it. - The element's function cannot be replaced by another element. - The element is directly involved in the plant's growth and reproduction. Most plants need this element to survive. The fourth criterion is used because some specific plants need certain elements. For example, cobalt (Co) is required by bacteria responsible for nitrogen (N) fixation in legumes; therefore, Co is classified as 'beneficial', rather than essential. Silica (Si) is not 'essential', but highly 'beneficial' to help plants cope with multiple stresses. Other beneficial elements include sodium (Na) and vanadium (V). Essentiality is generally determined by growing plants in nutrient solutions with or without a specific element, and observing differences in plant growth or function. In geographical areas of low phytoavailability, essential mineral elements are supplied to crops as fertilizers to achieve greater yields.

In addition, fertilizers containing essential mineral elements for human nutrition are occasionally supplied to crops to increase their concentrations in edible portions for the benefit of human health. Each plant nutrient is needed in different amounts and varies in how mobile it is within the plant and the soil. It is useful to know the relative amount of each nutrient that is needed by a crop in making fertilizer recommendations. In addition, understanding plant functions and mobility within the plant are useful in diagnosing nutrient deficiencies. Soil characteristics that affect nutrient availability to plants are also presented, as they influence nutrient management decisions. The use of mineral fertilisers is among key factors driving the increased global agricultural production required to feed the rising human population. Synthetic N compounds produce roughly half of today's world food (Erismann *et al.*, 2008). Depending on food demand, improvements in nutrient uptake efficiency, production of biofuels and efficiency of nutrient recycling (Cordell *et al.*, 2009), the projected consumption of N fertilisers is likely to change from the current 105 Mt (million tonnes) in 2010 to 80-180 Mt by 2050.

Similarly, the consumption of phosphate (P_2O_5) could change from the current 40 Mt to 35–70 Mt (Sutton *et al.*, 2013), while current potash(K_2O) consumption, approximating 29 Mt, may increase by 1 to 2 % per annum, reaching about 32 Mt in 2015 (Zorb *et al.*, 2014). As a precondition for growth, health and the production of nutritious food, plants require essential nutrients (macro and

micronutrients) in sufficient quantities. The nutrients of primary environmental concern in agriculture are nitrogen and phosphorus. In time, the shortage of the essential plant nutrient phosphate may also seriously limit crop production. The major plant nutrients are nitrogen (N), phosphorus (P) and potassium (K). Of these, N is abundant in the air, and deposits of K are ample, but the phosphate reserves will become scarce. This may lead to conflicts for a share of phosphate fertilizers long before the phosphate rock (PR) deposits are exhausted. Only strict rules for recycling and efficient use could postpone this first serious shortage of an essential plant nutrient.

- **Soil salinity**

Soil salinity problems generally occur in arid and semiarid regions and reduce crop production at different levels. Salinity is also a major limiting factor for crop yield in poorly drained soils (Patel *et al.*, 2002). In some areas of the world where salinity is a major problem, it is rather difficult to monitor the required ground information in the areas affected by salinity (Gates *et al.*, 2002). Multi temporal analysis might be effective in detecting salt dynamics in a certain region and assessing the degree of damage on both crops and yield. It was estimated that about 20% (45 million ha) of irrigated land, producing one-third of the world's food, is salt-affected (Shrivastava, P and Kumar, R, 2015). Soil salinity affects an estimated 1 million hectares in the European Union, mainly in the Mediterranean countries, and is a major cause of desertification. In Spain, 3% of the 3.5 million hectares of irrigated land is severely affected, markedly reducing its agricultural potential, while another 15% is under serious risk (Stolte, J *et al.*, 2015). In the Mediterranean region, land degradation associated with soil alkalization may worsen at increasing rates in the coming decades, owing to the expected increase in irrigated areas and the increasing scarcity of good quality water (Bowyer, C *et al.*, 2009). The amount of world agricultural land destroyed by salt accumulation each year is estimated to be 10 million ha (Pimentel, D *et al.*, 2004). This rate can be accelerated by climate change, excessive use of ground water (mainly if close to the sea), increasing use of low-quality water in irrigation, and massive introduction of irrigation associated with intensive farming and poor drainage.

Salts affect plant growth due to increasing soil osmotic pressure and to interference with plant nutrition. A high salt concentration in soil solution reduces the ability of plants to acquire water, which is referred to as the osmotic or water-deficit effect of salinity. Damage occurs when the concentration is high enough to begin reducing crop growth. The osmotic effect of salinity induces metabolic changes in the plant identical to those caused by water stress-induced "wilting" (Munns, 2002) and shows few genotype differences (Lauchli, A. and Grattan, S.R, 2007). Moreover, salt stress reduces plant growth due to specific-ion toxicities and nutritional imbalances (Lauchli, A. and Grattan, S.R, 2007) or a combination of these factors (Munns, R and Tester, M, 2008). Land degradation due to increasing soil salinization in arid and semi-arid regions of the world is evolving as the major menace for sustainable agricultural production and food security for the rising population (Hasanuzzaman *et al.*, 2014).

Globally, over 1,000 million ha of land is affected by the twin problems of salinity and sodicity (Wicke *et al.*, 2011). Currently, 33% of the irrigated area (76 million ha) is affected by different levels of salinity and it is estimated that by 2050, more than 50% of the farms around the world will be salt-affected (Kumar and Shrivastava, 2015). Soil salinization affects 19 million ha of land in sub-Saharan Africa (Tully *et al.*, 2015). They are found largely in the countries of Eastern Africa, along the coast of Western Africa, the countries of the Lake Chad Basin, and in pockets of Southern Africa. Main drivers of salinity development in these regions are poor irrigation practices, rising groundwater levels due to inefficient drainage, and sea water intrusion into coastal farming areas due to the rising sea level and over-pumping of ground water.

- **Soil acidity**

Soil acidification is a complex set of process resulting in the formation of an acid soil. In the broadest sense, it can be considered as the summation of natural and anthropogenic processes that lower down the pH of soil solution (Krug and Frink, 1983). Inefficient use of nitrogen is one of the causes of soil acidification, followed by the export of alkalinity in produce (Guo *et al.*, 2010). Ammonium based fertilizers are major contributors to soil acidification. Ammonium nitrogen is readily converted to nitrate and hydrogen ions in the soil. Soil acidity is one of the major constraints affecting crop

productivity. To fulfil the increasing demand for food and raw materials, soil health and fertility has remained as the major factor to increase and sustain crop yields. In the world, the gap between potential and actual yield is very wide because of soil acidity and associated nutrient availability. Soil acidity is among the major land degradation problems, which affects ~50% of the world's potentially arable soils (Kochian *et al.*, 2004).

Naturally, soils tend to become acid because of the leaching mechanism of carbonic acid (CO₂ dissolved in rain water). Acidification continues until a balance is reached between removal and replacement. Basic cations such as calcium (Ca) and magnesium (Mg) are removed through leaching and crop harvest but at the same time these bases are replaced due to organic matter decomposition and from the weathering of minerals (Abebe, 2007). Geologically, soil acidity increases as rainfall increases. The availability of micronutrients such as Aluminium (Al), manganese (Mn) and iron (Fe) increases as the pH decreases. The major causes for soils to become acid are high rainfall and leaching, acidic parent material, organic matter decay, and harvest of high yielding crops (Eswaran *et al.*, 1997b). Crop management practices, removal of organic matter, continuous application of acid forming fertilizers and contact exchange between exchangeable hydrogen on root surfaces and the bases in exchangeable form on soils, microbial production of nitric and sulfuric acids can also contribute to soil acidity (Behera and Shukla, 2015). Roem and Berendse (2000) indicated that increasing N: P and N: K ratios appear to have adverse effects on the abundance of endangered species owing to soil acidification. Soil acidity is expanding in scope and magnitude in Ethiopia, severely limiting crop production. For example, in some barley, wheat and faba bean growing areas of central and southern Ethiopian highlands, farmers have shifted to producing oats which is more tolerant to soil acidity than wheat and barley (Haile and Boke, 2009).

3. POSSIBLE BREEDING OBJECTIVES TO OVERCOME EACH CONSTRAINT

In developed nations, modern agriculture is based on high-input agricultural systems, which is not sustainable given resource limitations projected to occur in the near future. High-input production systems often consist of large acreage monocultures relying on heavy machinery, high-yielding varieties, synthetic and natural fertilizers, frequent pesticide applications, and the use of irrigation. Developed mainly during the Green Revolution, modern high-input agriculture provided new and convenient farming practices allowing for adequate production, significantly reducing world famine and malnutrition. The focus of this type of agricultural system has been to create an environment that maximizes productivity and profitability, along with providing a relatively inexpensive food supply. Although high-input systems may provide large yields, they create a fundamentally unsustainable environment that requires frequent and heavy applications of water, nutrients, and pest controls. In modern breeding programs, varieties are often developed by crossing parental genotypes possessing the most desired traits (example, yield, early flowering, vigor, plant architecture), and selecting offspring are under optimal growth conditions.

The most successful individual plants are selected in successive generations to ensure consistent uniformity (Phillips, S.L and Wolfe, M.S, 2005) in the case of self-pollinating crops. Even in outcrossing crop species for which heterozygosity confers advantage through heterosis at the individual level, genetic variability is restricted in the breeding program pipeline by using only a few elite highly-inbred parental lines generated from distinct plant populations that are finally combined to produce genetically homogenous hybrids. Modern crop improvement programs generally select under optimal conditions, therefore the focus is on genotypic selection based on increased yield performance or fruit/grain weight. This method of artificial selection results with a predictably uniform crop, in which genetic variability is restricted. Due to the field conditions provided by high-input production system, this breeding regime has been the dominant approach during the last century. Genotypes selected for high performance in high-input conditions likely do not maintain those same high yields under low-input or stress conditions due to the lack of natural genetic variation (Murphy, K *et al.*, 2005).

Several biotic and abiotic stresses affect plant growth, development and crop productivity. To cope up all these stresses, plant develops certain efficient strategies to avoid or tolerate the stresses which allow them to adapt and defense themselves from stress situations. Such adaptation strategies are at morphological, anatomical, biochemical and molecular levels. Molecular crosstalk, epigenetic

memories, reactive oxygen species (ROS) signalling, accumulation of plant hormones such as salicylic acid, ethylene, jasmonic acid and abscisic acid, change in redox status and inorganic ion fluxes, R-gene resistance and systemic acquired resistance (SAR) are some of the modifications or mechanisms adopted by plants to adapt and defend themselves from the environmental stress.

The novel “omics” technologies allow the researchers to identify the genetics behind plant stress. To increase crop production, four important inputs need major attention: water, fertilizer, pest control, and crop variety. The first three-water, fertilizer, and pest control-relate to cultural practices that provide a more desirable environment in which to grow the crop. The fourth- the crop variety relates to the inherent ability of the plant to produce within the environment provided. In other words, more productive plants and greater food production may result both by improving the environment for crop growth and by improving the heredity of the crop.

3.1. Breeding for Yield Enhancement

Yield is the endpoint of the interaction of a large number of physiological and biochemical processes in the plant. Therefore its genetic control is complex and its heritability is usually low. Yield can be regarded as a quantitative character, in which case use is made of quantitative genetics in both the choice of potentially useful parents and in selection procedures (Kramer, T, 1984). Yield increase in crops has been accomplished in a variety of ways including targeting yield per ha or its components, or making plants resistant to economic diseases and insect pests, and breeding for plants that are responsive to the production environment. Yield gaps are estimated by the difference between yield potential and average farmers’ yields over some specified spatial and temporal scale of interest. Yield potential, in turn, can be defined and measured in a variety of ways, which has resulted in lack of consistency in yield gap analysis in the literature (Rabbinge R, 1997).

Here, yield potential as the yield of an adapted crop variety or hybrid when grown under favorable conditions without growth limitations from water, nutrients, pests, or diseases (Evans LT, 1993). For any given site and growing season, yield potential is determined by three factors: (a) solar radiation, (b) temperature, and (c) water supply. The terms yield potential for irrigated systems because it is assumed that an irrigated crop can be provided with adequate water supply throughout growth. In contrast, we refer to maximum possible yields under rain-fed conditions as “water-limited yield potential” because most rain-fed crops suffer at least short-term water deficits at some point during the growing season. All three environmental factors vary throughout the year, and therefore yield potential will depend not only on location but also on the crop-sowing date and maturity rating. The latter is a genetic trait that determines the length of the growing season when a crop is sown on a given date, with longer maturity cultivars or hybrids requiring more growing-degree days to reach maturity than shorter maturity varieties. In fact, crop yield potential at a given location can vary considerably owing to different planting dates and maturity ratings.

3.2. Breeding for Pest Resistance and Tolerance

Disease resistance is often defined as reduction of pathogen growth on or in the plant. It denotes less disease development in a genotype than that in the susceptible variety and is a relative attribute. Generally, the rate of reproduction is considerably reduced which limits the spread of disease. Plants are almost always resistant to certain pathogens but susceptible to other pathogens; resistance is usually pathogen species-specific or pathogen strain-specific. Disease resistance crop plants have a genetic capacity to minimise the effects of disease attack which is manifested either as resistance or tolerance of the plant to the disease (Browning, J. A and Frey, K. J, 1969). Resistance includes those mechanisms which prevent or restrict the growth of the disease on the plant.

The result of resistance is that the disease organism is found on the host plant in severely limited quantities and its normal growth and reproduction are restricted. Breeding for disease and insect resistance is one of the primary objectives in plant breeding programs. Its purpose is to ensure the continued productivity of the crop in situations where pest attack is significant in reducing yields or where the expansion of the crop into new environments is severely limited by the likelihood of pest attack. The term pest resistance embraces both disease and insect resistance. Crop plants are subject to attack by a wide range of disease organisms such as fungi, bacteria, viruses and mycoplasma. Within particular disease-causing organisms there is usually wide variation in the capacity for, and degree of,

infection of the host plant often resulting in characteristic symptoms. Plant breeders focus a significant part of their effort on selection and development of disease resistant plant lines. Plant diseases can also be partially controlled by use of pesticides, and by cultivation practices such as crop rotation, tillage, planting density, purchase of disease-free seeds and cleaning of equipment, but plant varieties with inherent (genetically determined) disease resistance are generally the first choice for disease control.

Breeding for disease resistance has been underway since plants were first domesticated, but it requires continual effort. This is because pathogen populations are often under natural selection for increased virulence, new pathogens can be introduced to an area, cultivation methods can favor increased disease incidence over time, changes in cultivation practice can favor new diseases, and plant breeding for other traits can disrupt the disease resistance that was present in older plant varieties. A plant line with acceptable disease resistance against one pathogen may still lack resistance against other pathogens. Crossing of a desirable but disease-susceptible plant variety to another variety that is a source of resistance, to generate plant populations that mix and segregate for the traits of the parents. The methods of crossing include selection, introduction, marker assisted selection, genetic engineering; hybridization includes backcross, pedigree, bulk methods. Among these methods marker assisted selection & backcross methods are important. Breeding for any crop trait is depending upon the availability of variation for that trait, if not available, creation of variability and their subsequent utilization in crop improvement. Plant breeding is not concerned only with disease resistance, but also with local adaptation, resistance to abiotic stresses, quality and yield. Similarly, while plant pathologists often regard genetic disease resistance as the best means of attack, agronomic practices hygiene, rotations and tillage and chemical control are also effective and necessary components of productive agricultural systems.

The term tolerance includes those situations which allow some growth and reproduction of the pathogen on the plant but without a significant negative effect on crop yield or quality. Major genes for resistance and tolerance can also be incorporated into new varieties using the single seed descent or pedigree selection methods for self-pollinated crops and recurrent selection methods for cross-pollinated crops. When resistance is controlled by multiple minor genes these methods can also be used in breeding for resistance; however, the backcross method is not suitable. Insect resistance methods of breeding for plant resistance or tolerance to insect attack employ approaches similar to those used for disease resistance and tolerance. There are three main approaches which plant breeders employ to minimise yield losses from insect attack in crop plants. These approaches are antibiosis, physical resistance and non-preference. The use of antibiosis involves the incorporation of genes which modify the metabolism of the plant such that the insect through its feeding is adversely affected in growth and reproduction.

In this way the size of the insect population is restricted and hence losses in productivity are minimised. Breeding for increased physical resistance of plants (leaves, stems) to attack by sucking or boring insects has been effective in producing varieties with higher resistance to such insects (Knott, D.R, 1972). Non-preference breeding involves the use of genes which modify the morphology or palatability of the plant tissue to deter the insect from feeding and reproducing on the plant. Pubescence (or hairiness) of leaves or stems is a character which is often incorporated to confer non-preference in the host to the insect species. One of major causes of yield loss is crop competition with weeds. With a push towards reduced pesticide use there is now interest in characters such as allelopathy and competitiveness against weeds importance plant breeding a ways to maintain or increase yield. Herbicide tolerant cultivars have been developed in many crops by exploiting already available genetic variability in the germplasm or by creating mutations or by transgenic.

Herbicide tolerance in germplasm or in mutant lines may be due to altered binding site of target enzyme for herbicide, improved herbicide metabolism, sequestration of herbicide molecule and overexpression of target protein. Herbicide-tolerant cultivars offer opportunity of controlling weeds through need-based applications of herbicides. Integrated Pest Management (IPM) is an effective, environmentally sound approach to pest management (Kabir and Rainis, 2015). It provides for the protection of beneficial insects, as well as prevention of secondary pest outbreaks, pest resurgence, and the spread of disease. IPM strategies aim to protect air, water, and soil resources while meeting specific production objectives (Kogan, M., 1998). IPM combines the use of a variety of pest-control

methods in a way that facilitates biological control of pest insects in crops in order to improve economic, public-health, and environmental outcomes. Key components of effective IPM strategies are monitoring of pest populations, recognizing pest-resistant plant varieties, and modifying cultural, mechanical, chemical, and biological controls as needed to achieve production goals (Adams *et al.*, 1996).

3.3. Breeding for Improved Quality

Crop breeding largely deals with the creation, selection, and fixation of superior phenotypes for the development of improved lines or cultivars to fulfil the needs of farmers and consumers both locally and globally. However, for a long time, grain quality breeding was not a major focus of crop breeders; rather increasing yield per unit area has been the major concern. Recently, considering food and nutritional insecurity, grain nutritional improvement has become essential in major staple crops (Ashok Kumar *et al.*, 2012; Govindaraj *et al.*, 2016a, b). The term quality in crop production has different meanings according to the demands made of the crop products in industry and commerce. It can mean the suitability of the crop product to the technological demands made of it in its extraction or processing (the milling quality of wheat which is an evaluation of the ease of extraction, and the total amount of flour able to be extracted from the grain). Quality can also mean the extent to which the crop product meets the specifications of commercial demand (baking quality of wheat; malting quality of barley; taste, size and shape of fruit; fibre length, diameter and strength of cotton; grain size, colour, taste, protein content, and cooking time in pulses). The term nutritive quality is used to denote the dietary value of the crop product for human or animal consumption. It usually embodies an evaluation of the total carbohydrate, protein and fibre content and the available minerals. It often also includes estimates of the amino acid composition of the protein. The level of quality is usually strongly influenced by environmental factors during the growth and ripening of the crop. Quality is an important aspect for plant breeders that characters vary from one crop to another.

3.4. Breeding for Drought Resistance or Tolerance

Drought is a major constraint in crop production worldwide and is considered as the most important cause of yield reduction in crop plants (Sabadin *et al.*, 2012), especially in water-limited areas of the world including parts of eastern and southern Africa. Drought is the most important abiotic factor limiting growth, adversely affect growth and crop production and one of the most important environmental stresses, especially in warm and dry areas of crop yield are limited (Porudad and Beg, 2003). Drought stress is a serious agronomic problem contributing to severe yield losses worldwide. This agricultural constraint may nevertheless be addressed by developing crops that are well adapted to drought prone environments. The mechanisms that enable the crop to survive under these harsh conditions are complex and not well understood. Previous researches suggest three general strategies for plant survival in drought environments (Ludlow and Muchow, 1990). These strategies are drought escape, avoidance and tolerance. However, crop plants use more than one mechanism at a time to resist drought.

Drought resistance is a complex trait, expression of which depends on action and interaction of different morphological (earliness, reduced leaf area, leaf rolling, wax content, efficient rooting system, awn, stability in yield and reduced tillering), physiological (reduced transpiration, high water-use efficiency, stomatal closure and osmotic adjustment) and biochemical (accumulation of proline, polyamine, trehalose, etc., increased nitrate reductase activity and increased storage of carbohydrate) characters. Drought resistance is of enormous importance in crop production. The identification of genetic factors involved in plant response to drought stress provides a strong foundation for improving drought tolerance. Drought resistance is the mechanism(s) causing minimum loss of yield in a drought condition. Drought escape, dehydration avoidance, reduced transpiration or physiological factors are some drought resistance mechanisms. Drought resistant genotypes maintain high photosynthesis under moisture stress condition by restricting transpiration water loss. Osmotic adjustment, abscisic acid (ABA) (involved in stomatal function), cuticular wax, leaf characteristics, increased water uptake. Existence of genetic variation for resistance to drought has been demonstrated in many crop species.

Drought resistance is estimated as yield stability in crops like wheat, rice maize, barley and sorghum; leaf water potential in sorghum, soybean, cotton wheat and rice; leaf rolling in rice; root growth in

sorghum, rice, oat, wheat and maize; osmotic adjustment in wheat and sorghum; stomatal conductance in crops like upland cotton. The genetic control of these traits ranged from oligogenic to polygenic in nature (Jensen, N.F, 1959). The trait that is expected to associated positively with drought resistance need to be investigated carefully to establish the relationship. The use of suitable techniques for its measurement are developed, then germplasm is screened to assess the genetic variability for the trait, correlations between such traits and yield may indication for drought resistance or tolerance. Drought tolerance is the ability to withstand water-deficit with low tissue water potential. To improve drought tolerance trait, breeding requires fundamental changes in the set of relevant attributes, finally emerging as something named drought tolerance (Maleki *et al.*, 2013).

Drought tolerance depends on the plant developmental stage at the onset of the stress syndrome. In particular, post-flowering drought stress can result in significant reductions in crop yield (Rosenow *et al.*, 1996). Drought escape is the ability of a plant to complete its life cycle before serious soil and plant water deficits develop. This mechanism involves rapid phenological development (early flowering and early maturity), developmental plasticity (variation in duration of growth period depending on the extent of water-deficit) and remobilization of parenthesis assimilates to grain. Drought avoidance is the ability of plants to maintain relatively high tissue water potential despite a shortage of soil-moisture. Mechanisms for improving water uptake, storing in plant cell and reducing water loss confer drought avoidance. Drought avoidance is performed by maintenance of turgor through increased rooting depth, efficient root system and by reduction of water loss through reduced epidermal (stomatal and lenticular) conductance, reduced absorption of radiation by leaf rolling or folding, and reduced evaporation surface (leaf area). The mechanisms that confer drought resistance by reducing water loss (such as stomatal closure and reduced leaf area) usually result in reduced assimilation of carbon dioxide. Consequently, crop adaptation must reflect a balance among escape, avoidance and tolerance while maintaining adequate productivity.

The use of improved cultivars, particularly hybrids, was found to be the major component of the integrated approach of mitigating the drastic effect of drought. Several factors such as low soil fertility, poor pest and disease control and low yielding potential of local varieties contributed to low yield, much of the reduction in yield is thought to be due to severe drought stress (Zhang, J *et al.*, 1999). Efforts have been underway to mitigate the effect of recurrent drought through soil and moisture conservation and tillage practices and development of varieties adapted to the dry land condition. Previous reports indicated that significant morphological and genetic variability attributes to drought tolerance were detected among Africans crops (Blum, A., 2004). Drought resistance is of enormous importance in crop production. The identification of genetic factors involved in plant response to drought stress provides a strong foundation for improving drought tolerance. There is different morphological and physiological mechanisms contribute to overcome the effect of drought in crop plants (Mitra, 2001). Plants have evolved a series of mechanisms at the morphological, physiological, biochemical, cellular, and molecular levels to overcome water deficit or drought stress conditions. Various drought-related traits, including root traits, leaf traits, osmotic adjustment capabilities, water potential, ABA content, and stability of the cell membrane, have been used as indicators to evaluate the drought resistance of plants.

3.5. Breeding for Maturity Duration or Earliness

Earliness is the most desirable character which has several advantages. It requires less crop management period, less insecticidal sprays, permits new crop rotations and often extends the crop area. Thus breeding for early maturing crop varieties or varieties suitable for different dates of planting may be an important objective. Maturity has been reduced from 270 days to 170 days in cotton, from 270 days to 120 days in pigeonpea, from 360 days to 270 days in sugarcane. This can help minimize the effect of climate change on farming activities affected by shortened rainfall patterns, erratic rainfalls or drought. Crops maturing early can ensure quick economic return on the harvest resistance to cracking of fruit harvest has the same size as a standard variety, good aesthetics and safety during transportation. Escape from drought is attained by the shortening of life cycle or growing season, allowing plants to reproduce only in the favorable environment conditions.

Shortening of flowering time, days to 50 % flowering can lead to drought escape. Crop duration \times genotype \times environment determine the ability of plant to escape from drought. Drought escape occur

when plant complete developmental stages with favorable soil moisture and optimum environmental conditions (Araus *et al.*, 2002).

3.6. Breeding for Agronomic Characteristics

Modification of agronomic characteristics, such as grain yield, plant height, maturity, lodging resistance, branching, tillering capacity, growth habit, better fertilizer response and other agronomic traits are very important in increasing crop production and productivity. For example, grain yield is a complex characteristic with several components that include genetic and environmental factors. The objective of the breeding program is to continue increasing yield without deteriorating quality. Plant height is a major agronomic characteristic which has association with lodging. Plant height is controlled by growing environment and by many genes having both major and minor effects. Hence, dwarfness in cereals is generally associated with lodging resistance and better fertilizer response whereas, tallness, high tillering and profuse branching are desirable characters in fodder crops. Grain yield generally is greater with late-maturing than with early maturing lines. However, late-maturing lines can be adversely affected by drought and frost before harvest. Therefore, the objective of the breeding program is to release early and medium-maturing cultivars. The early and medium maturing-cultivars have high yield and mature before drought and frost.

3.7. Breeding for Synchronous Maturity and Non-Shattering Characteristics

In agriculture, shattering is the dispersal of a crop's seeds upon their becoming maturity. From an agricultural perspective this is generally an undesirable process, and in the history of crop domestication several important advances have involved a mutation in a crop plant that reduced shattering instead of the seeds being dispersed as soon as they were mature. Non-shattering phenotype is one of the prerequisites for plant breeding especially when introgressing valuable traits from wild varieties of domesticated crops (Tang, H *et al.*, 2013). The selection was at first unconscious as the early human gatherers collected grains retained on the plants for food or seed in preference to those dispersed on the ground. Conscious selection for the non-shattering trait in wheat, barley and rice 6000–10000 years ago was probably the first major human “improvement” in plants (Diamond, 2002).

Seed shattering or pod shed after maturity is a major problem in crop production worldwide, and shattering can cause up to 50% yield loss if harvesting is delayed due to adverse conditions (Grant, W.F, 1996). The early and heavy shattering of seeds as they mature in the inflorescence is an important mechanism for their dispersal and distribution. It increases the probability that a substantial portion of the seeds produced by a plant are scattered to the surface of the soil where they can be spread further by wind and water before being consumed by animals, harvested with the grain, or eventually falling to the ground in a clump along with the plant. Shattering is the naturally selected trait of plants but, as mentioned above, it was a very inconvenient trait in plants that produced food grains desired by early humans in the gathering stage of human development. Thus, since the dawn of crop husbandry, non-shattering has been a prized trait in the selection and improvement of varieties of crops. The non-shattering trait has not been disadvantageous to the crops cultivated because their survival is dependent on human activities and not nature.

3.8. Breeding for Elimination of Toxic Substances

Brassica oils have erucic acid which is harmful to human health. Removal of such toxic substances would be increase to nutritional value of the crops. It is essential to develop varieties free from toxic compounds in some crops to make them safe for human consumption. For example, removal of neurotoxin in Khesari (*Lathyrus sativus*) which leads to paralysis of lower limbs, erucic acid from Brassica which is harmful for human health and Gossypol from the seed of cotton is necessary to make them fit for human consumption. Removal of such toxic substances would increase the nutritional value of these crops.

3.9. Application of the Right Fertilizers and Its Rates with the Right Time

Many agricultural soils of the world are deficient in one or more of the essential nutrients needed to support healthy plants. Acidity, alkalinity, salinity, anthropogenic processes, nature of farming, and erosion can lead to soil degradation and lowering of fertility across different agro-ecosystems.

Additions of fertilizers and amendments are essential for a proper nutrient supply and maximum yields. Developing resistant or tolerant varieties against acidity and salinity problem is very important where acidity and salinity are becoming a serious challenge for crop production and productivity. There is good potential for directly breeding for adaptation to low nitrogen while retaining an ability to respond to high nitrogen conditions.

Breeding for salinity tolerance have proven to be difficult, and the complex mechanisms of tolerance. As crops grow and are harvested, they gradually remove the existing nutrients from the soil and over time will require additional nutrients to maintain or increase crop yield. When nutrients are added in excess of the plants' ability to utilize them, there is an increased risk that the nutrients will enter the surrounding environment (water or air) and create environmental problems. In the 21st century, nutrient efficient plants will play a major role in increasing crop yields compared to the 20th century, mainly due to limited land and water resources available for crop production, higher cost of inorganic fertilizer inputs, declining trends in crop yields globally, and increasing environmental concerns. Furthermore, at least 60% of the world's arable lands have mineral deficiencies or elemental toxicity problems, and on such soils fertilizers and lime amendments are essential for achieving improved crop yields. Fertilizer inputs are increasing cost of production of farmers, and there is a major concern for environmental pollution due to excess fertilizer inputs (Borlaug and Dowsell, 1997).

4. CONCLUSION AND RECOMMENDATION

Agriculture and climate change are internally correlated with each other in various aspects, as climate change is the main cause of biotic and abiotic stresses, which have adverse effects on the agriculture of a world. The land and its agriculture are being affected by climate changes in different ways, example, variations in annual rainfall, average temperature, heat waves, modifications in weeds, pests or microbes, global change of atmospheric CO₂ or ozone level, and fluctuations in sea level. The threat of varying global climate has greatly driven the attention of scientists, as these variations are imparting negative impact on global crop production and compromising food security worldwide. According to some predicted reports, agriculture is considered the most endangered activity adversely affected by climate changes. To date, food security and ecosystem resilience are the most concerning subjects worldwide. Climate-smart agriculture is the only way to lower the negative impact of climate variations on crop adaptation, before it might affect global crop production drastically.

The potential impact of using breeding for low-input conditions for a more sustainable agriculture is great, and indeed its feasibility has been demonstrated for many crops, both autogamous and allogamous. However, the use of local crop breeding initiatives for low-input systems requires mobilization of most immediate stakeholders, who unfortunately are often demobilized, decapitalized small farmers and peasants. Nonetheless, it is imperative and urgent that now, as world resources are becoming scarce, not only small farmers but also commercial agriculture embraces a more rational use of resources to produce enough food and raw materials for all. Government intervention will certainly be required to allow small farmers to continue cultivating the land, whereas also commercial farmers will need to face a paradigm shift towards sustainability to guarantee the future of the next generation in a super populated world. The production constraints to the yield gaps embrace shortages of nutrients, water, damage due to pests, weeds and diseases, insufficient or improper application of labour or machines, and lack of knowledge. These constraints are interrelated, but in the approach it is not possible to identify or account for all possible interactions.

Eventually, Global food security threatened by climate change is one of the most important challenges in the 21st century to supply sufficient food for the increasing population while sustaining the already stressed environment. The use of well adapted, high-yielding varieties with resistance to biotic and abiotic stresses and improved nutritional quality and judicious use of organic and inorganic fertilizers are critically important to reach maximum yield potential as long as possible through minimizing the risk of climate change. Plant breeding is an evolutionary processes that guided by human and playing substantial role through addressing food demand for a growing world population, adapting plants to environmental stresses, adapting crops to specific production systems, satisfying industrial and other end-use requirements. To cope up all these stresses, plant develops certain efficient strategies to avoid or tolerate the stresses which allow them to adapt and defense themselves from stress situations. Analysis of yield gaps is very relevant to identify the major constraints that contribute to yield

reduction directly and/ or indirectly and to come up with the most promising research solution over the next decades. Global population on the rise and also the food demand is rising which indicates the farmers must increase the yield on existing land and minimize the losses due to both biotic and abiotic stresses by using different breeding and protection strategies.

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