



Drought and salinity stress as major threat for sustainable Mung bean production: Emerging challenges and future perspectives

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Abstract: Climate change is a serious concern in the present scenario for the sustainable production of food crops. Insufficient food availability, increasing population, poverty, malnutrition, and depletion of natural resources may lead to a global food crisis. Stable and greater production of nutritious food crops may be an alternative to overcome these difficulties. Mung bean (*Vigna radiata*) is an important food legume with an excellent source of easily digestible protein. It is also recommended for health benefits due to the presence of bioactive compounds. Short life cycle and nitrogen fixing ability makes it suitable for major cropping system. Mung bean is highly sensitive towards various abiotic and biotic stress factors prevailing in the environment. The present review focuses on drought and salinity stress as major abiotic stresses limiting mung bean production. It includes adverse effects, mung bean response, management strategies, and significant efforts made towards these challenges. In this review, the need of addressing the current demand on modern agriculture and food production activities impaired by global climate change has been focused.

Keywords: Drought; Salinity stress; Mung bean; Management strategies.

Introduction

Mung bean (*Vigna radiata* (L.) Wilczek) is an important edible food grain legume in Asia. Commonly it is known as green gram or moong bean (Lambrides and Godwin, 2007). It is fast growing, self-pollinating and warm season annual crop with wide adaptability. The domestication of this crop was initially in India from where it increased its dimensions in other tropical and subtropical regions (Fuller, 2007). It has small genome size (579 Mb) with diploid chromosome number ($2n=2x=22$) and narrow genetic base (Kang *et al.*, 2014). Mung bean belongs to the genus *Vigna*, subgenus *Ceratotropis* and family Fabaceae (Tomooka *et al.*, 2002; Aitawade *et al.*, 2012).

India is the leading producer, consumer and exporter of mung bean (Ali and Gupta, 2012). The production of mung bean was 2.01 Mt over

an area of 4.26 Mha during 2017-2018 in India (Nair *et al.*, 2019).

Mung bean is an excellent source of easily digestible protein for humans. It is generally consumed as Dhal or dal, a traditional food included in Indian diet pattern (Nair *et al.*, 2013). It is also used in the form of germinated seeds, sprouts, flour, soup, porridges and cooked mung bean seeds either whole or split seed in Asian countries. Mung bean seeds are rich in nutrients including essential amino acids, fatty acids, fibers, minerals and vitamins (Nair *et al.*, 2013; FAO, 2016; Fuller *et al.*, 2016). In addition, presences of secondary metabolites (phenols and flavonoids) in various parts i.e. seeds, seed coat and sprouts of mung bean are gaining more interest due to their health promoting benefits (Ganesan and Xu, 2018).

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Symbiotic association of mung bean roots and *Rhizobium* bacterium helps in nitrogen fixation which increases soil fertility and crop productivity (Allito *et al.*, 2015; Fuskhah *et al.*, 2019). Hence this is independent of use of fertilizers. Short life duration, low input requirements and nitrogen fixing ability of mung bean makes it an ideal crop for various cropping systems either as catch, cash, relay, intercrop or green manure crop (Allito *et al.*, 2015). Despite of nutritional, medicinal, economic and agricultural importance of mung bean, overall production of this crop is still limiting. This is due to susceptibility of this valuable crop towards various abiotic and biotic stresses existing in the environment and continuous increasing climate variability (Alderfasi *et al.*, 2017; Singh, 2018; Sehrawat *et al.*, 2019).

Almost abiotic stress (high temperature stress, cold, salinity, drought, heavy metals), salinity stress and drought are most atrocious factors limiting plant growth and development throughout their lifecycle in arid and semi-arid regions (Gong *et al.*, 2013; Bangar *et al.*, 2019; Nair *et al.*, 2019; Sehrawat *et al.*, 2019). Exposure to these stresses cause abnormal changes in physiological processes and metabolism of plants. This may results in alterations at biochemical and molecular level including expression, suppression or over-expression of normal genes along with stress responsive genes, transcription factors, osmolytes, proteins, peptides and enzymes of different mechanisms or signaling pathways responsible for stress tolerance (Nair *et al.*, 2019). Plant response towards any stress generally depends upon various factors including: a) genotype, b) developmental stage of plant, c) duration and intensity of imposed stress, d) simultaneous occurrence of any other stress and d) plant defense system. Inability of plant to regulate the stress at any stage finally leads to plant death due to growth arrest and

metabolism failure (Yadav *et al.*, 2011; Sehrawat *et al.*, 2019).

Drought: Effects and Plant response

Drought is an emerging threat for agriculture plant production of majority of the crops including mung bean. It is continuously expanding its dimensions at global level due to rapid and drastic changes in climatic conditions, limited water sources and uneven rainfall (Fahad *et al.*, 2017). This abiotic stress is very complex due to its prevalence in different geographical areas having climate variability. Drought may arise due to low rainfall, high temperature and increase in salinity. Plant growing in a particular area get influenced by drought stress in two ways: i) natural drought (less availability of water) and ii) physiological drought (plants fail to absorb sufficient water instead of availability in its surroundings) (Bangar *et al.*, 2019). Drought exerts its adverse effects on plant growth and development by affecting various process at morphological, biochemical, physiological and molecular level (Basu *et al.*, 2016 Fahad *et al.*, 2017; Bharadwaj *et al.*, 2018).

Mung bean is generally grown in rainfed conditions having high temperatures (27-30° C), low humidity and moderate rainfall (60-80 cm). It is generally considered as drought tolerant crop because it can easily survive on soil having limited moisture or water content. But greater decrease in soil moisture imposes negative impacts on its growth, survival and productivity (Fathy *et al.*, 2018; Nadeem *et al.*, 2019a). The decrease in total plant dry weight, reduced photosynthesis and harvest index were the main reasons for reduced seed yield due to drought stress in mung bean (Thomas *et al.*, 2004). Drought stress limits mung bean production, productivity and quality by affecting different developmental stages of this crop (Dutta and Bera, 2008; Ahmad *et al.*, 2015; Bangar *et al.*, 2019). Roots play an important

role in water stress tolerance by reduction in leaf expansion and promotion of root growth. Root length at seedling stage provides a fair estimate about the root growth in field (Kumar *et al.*, 2015). It has been reported that mung bean crop is more sensitive towards water deficit/ drought during flowering stage which seriously affect mung bean productivity. But the response of different mung bean towards drought stress specifically depends upon the plant genotype, growth stage, stress intensity and duration and simultaneous occurrence of any other abiotic or biotic stress (Ranawake *et al.*, 2012; Uddin *et al.*, 2013).

Drought induced water deficit in plant cells cause loss of normal turgidity which inhibits cell elongation and enlargement. This is responsible for growth retardation and changes in growth pattern of plants (Prakash *et al.*, 2017; Bangar *et al.*, 2019). Drought also causes increase in leaf cell thickness due to excessive deposition of lignin and cutin inside the cells. Earlier studies reported significant variability in morphological and physiological traits of mung bean genotypes for drought tolerance (Naresh *et al.*, 2013; Raina *et al.*, 2016). In addition, drought induces production of harmful superoxide radicals during photosynthesis which are responsible for cellular damage. Hence drought induces oxidative stress in plants. Scavenging or alleviation of these free radicals may improve the crop yield and quality of seeds produced (Anjum *et al.*, 2015). Drought tolerance in mung bean varieties can be assessed by measuring relative water content, leaf area index, proline accumulation, antioxidant enzymatic activities, PEG mediation and yield components. Drought tolerant genotypes shows less reduction in these traits with respect to the non-stressed plants as compared to the drought sensitive ones (Swathi *et al.*, 2017; Sadeghipour, 2019).

Management strategies for drought tolerance

Drought stress is considered as a severe threat to sustainable agriculture and food security. Plants follow several strategies for their acclimation under drought conditions. It includes : i) alteration of morphological and physiological events to adjust drought induced water crisis and ii) physiological adaptation as accumulation of osmolytes for osmotic adjustments which protect the plant cells from dehydration (Omprakash *et al.*, 2017; Bharadwaj *et al.*, 2018; Nazran *et al.*, 2019). Drought resistance is a complex quantitative trait, involving interactions of many metabolic pathways related to stress-resistant genes. One strategy to reduce the effect of water stress on crop yield is to use drought tolerant genotypes and is a good management of irrigation water supplies (Fahad *et al.*, 2017; Fathy *et al.*, 2018). Development of drought tolerant varieties is the best option. Screening and identification of drought tolerant genotypes provide promising genetic resources for breeding program to develop drought tolerant cultivars or lines of mung bean (Fahad *et al.*, 2017; Prakash *et al.*, 2017). Conventional plant breeding over the time has shifted from morphological to physiological selection criteria since they are time consuming and rely on present genetic variability (Raina *et al.*, 2019).

Salinity stress: Effects and Plant response

Salinity problems mostly occur in arid and semi-arid regions. But it is also a major problem of irrigated lands and dry areas (Fuskhah *et al.*, 2019). Almost 20% of the irrigated land is salt affected worldwide and is continuously increasing at a rate of 1% to 3% per year (Qadir *et al.*, 2014). In India, the area under salt-affected soils is about 6.73 million ha. Increase in salinization is a result of disruption of ecological balance of the soil due to various anthropogenic activities such as a) development of industrial and agriculture sector, b) nonstop use of irrigated water

c) transportation, d) mining, e) construction, f) deforestation and g) habitations (Sharma *et al.*, 2014; Singh, 2018). Salinity generally affects the crop plants by inducing osmotic stress and ion toxicity. Salinity induced osmotic stress causes reduction of water absorption capacity of roots, acceleration of evaporation from leaf surface, impairment of nutrient balance, ionic distribution, denaturation of structural and functional proteins and metabolic damage of the growing plants. Accumulation of toxic ions in plant tissues seriously affect the normal ionic distribution, opening and closing of stomata, photosynthesis and plant productivity (Ahmad and Umar, 2011; Hasanuzzaman *et al.*, 2013b).

Salinity stress influences all stages of mung bean growth, physiology and development throughout its life cycle (Sehrawat *et al.*, 2019). Initially, it either inhibits or delay seed germination by restricting the inherent potential of seeds to germinate (Sehrawat *et al.*, 2014a). In early stages of plant growth, seed germination and early seedling survival are most affected stages due to salinity. During seedling growth stage, the primary sensor of salinity stress i.e. radical length or root growth is more affected as compared to the plumule length or shoots growth (Sehrawat *et al.*, 2014a). Later on during plant life cycle, salinity stress affects various characteristics of mungbean as; a) growth and survival of seedlings, b) vegetative growth (plant height, no. of trifoliates open, leaf area, membrane thickness, no. of secondary branches), c) reproductive development (flowering time, no. of flowers, flower shedding), and d) yield characteristics (first pod formation, no. of pods/ plant, pod length, no. of seeds/plant) (Sehrawat *et al.*, 2013a; 2014b; 2014c). Earlier studies reported that the vegetative growth stage is more sensitive towards salinity which finally determines the occurrence or absence of reproductive phase in life cycle of the plant. Hence reproductive stage of mung bean is less

affected in comparison to vegetative growth phase (Sehrawat *et al.*, 2013a; 2014b; 2014c).

Besides this, salinity also affects the morphological features (leaf color, membrane rupturing, time to open first trifoliolate, seed color and type), biomass characteristics (fresh and dry weight of seedlings, shoot, root and leaves, 100 seed weight, grain yield/plant, harvest index) and biochemical parameters (ionic distribution in various plant parts, photosynthetic pigments, stomatal conductance, accumulation of osmoprotectants, enzyme activities, free radical generation and their scavenging) of mung bean as compared to the non-stressed plants (Sehrawat *et al.*, 2013b; Sehrawat *et al.*, 2015). Overproduction of reactive oxygen species (ROS) under salinity stress damages the intracellular plant machinery resulting in oxidative stress. This may cause activation of programmed cell death in stressed cells (Hasanuzzaman *et al.*, 2012; Nair *et al.*, 2019). Salinity stress also affects the root-rhizobia symbiotic association and prevent effective nodulation phenomenon. This may affect the nutrition, growth, stability and survival of plants under stresses environment. Therefore, salinity stress affects the quality of mung bean seeds and causes severe yield loss. But these above said characteristics shows variation according to the plant genotype, seasonal variations and plant adaptability under stress (Sehrawat *et al.*, 2015; 2019).

Management strategies for salinity tolerance

Salt tolerance is a complex and polygenic trait which is related to the plant genotype and development. Plant responses towards salinity stress include an array of changes at the molecular, biochemical and physiological levels. These adverse effects are responsible for activation of cell signaling pathways involved in stress tolerance, defense or adaptability in plants to different extent (Nadeem *et al.*, 2019b). Earlier reports suggested several strategies to overcome the

salinity problem and sustainable plant production. The management strategies are basically of two types: i) Soil based and ii) Crop based management. Soil based solutions for salinity includes; a) reclamation of salinity affected soil, b) leaching out of excess salts, c) alternative for limited natural resources. The plant based management of salinity includes: i) synthesis and accumulation of osmolytes for osmotic homeostasis, ii) exclusion or sequestration of toxic sodium ion for ionic homeostasis, iii) improved free radical scavenging system to reduce oxidative stress, iv) alleviation of salinity stress by pretreatments of seeds by various chemicals or hormones, v) identification and use of stress resistant genotypes and vi) development of stress resistance/tolerance in cultivated crop plants either by transgenic approach or breeding (Hasanuzzaman *et al.*, 2013; Sehrawat *et al.*, 2014f; Nair *et al.*, 2019; Sehrawat *et al.*, 2019). Among all these strategies, the plant-based management of salinity is more promising and cost-effective as compared to the previous one. Out of the plant-based techniques, development of genetically improved varieties against abiotic stresses may give significant outcomes. Breeding is most vital option to introduce stress resistance in plants for polygenic traits as salt tolerance (Sehrawat *et al.*, 2016). But the efforts made in this direction are not so fruitful due to narrow genetic base of mung bean, lack of reliable and fast method of screening. Successful breeding program requires suitable resources having genetic variations and stable resistance for the targeted trait. Therefore, available crop germplasm or wild relatives in genus *Vigna* need to explore to greater extent by the researchers or breeders using molecular based advanced biotechnological approaches as marker assisted selection, molecular breeding etc. (Sehrawat *et al.*, 2013c; 2014e; Kim *et al.*, 2015; Sehrawat *et al.*, 2016; Nair *et al.*, 2019).

Conclusion

Mung bean is an economically important food crop with excellent health benefits and low input requirements. Drought and increasing Salinity are the most detrimental environmental problems affecting mung bean productivity worldwide. Increasing climate variability, rising population and limited natural resources may lead to serious food crisis due to non-availability of nutritious food particularly for the poor vegetarians. Therefore, it is necessary to identify and develop genetically improved mung bean varieties with stable resistance against these harmful environmental stresses. Researchers or scientific community should take more interest in this area for sufficient food supply and balanced nutrition for humans in near future.

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