Stay-Green Trait: A Prospective Approach in Crop Improvement

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OPEN ACCESS

Keywords

Stay-Green, Drought Stress, Heat Stress, Quantitative Trait Loci, Yield

How to cite this article:

Goswami, I., Rana, V., Prikshit. and Kapoor, A. 2025. Stay-Green Trait: A Prospective Approach in Crop Improvement. *Vigyan Varta* 6 (5): 127-129.

ABSTRACT

The growth and yield of many crops that are crucial to agriculture have been negatively impacted by the challenges that arise from a number of known and unknown abiotic and biotic stresses imposed on by population growth, global warming, and other possible climatic causes. Stay-green (SG) is a secondary characteristic that helps crop plants, particularly in drought and heat stress situations, to retain their green leaves and ability to perform photosynthesis for a longer period of time after anthesis. As a result, SG plants yield more than non-SG plants due to their prolonged grain-filling period. Crop yields have increased as a result of functional SG breeding, especially when paired with other beneficial features. To overcome the production stagnation linked to environmental stress adaptation, it may be necessary to understand the molecular and physiological mechanisms underlying the SG characteristic.

INTRODUCTION

Rapid worldwide population growth and significant climate change are threatening global food security. Heat and drought are the two most significant environmental stresses that have a significant impact on crop development, growth, grain production and biomass productivity. In order to secure food availability and meet future demands for agricultural production, it is essential to accelerate plant breeding and the

discovery of novel traits for increased yield potential and better adaptation to abiotic stresses, given the growing expectations of crop yield losses due to global climate change and exponential population growth. In this situation, stay-green (SG) genotype selection may be an essential approach for raising agricultural yields in order to satisfy the demands of an anticipated population growth, especially in situations when heat and water are scarce. Delay of leaf senescence, also known as stay-green character, has been identified as an important component in the genetic improvement of several crops to promote stress tolerance and yield.

What is stay green?

Stay-green is the term given to a variant in which senescence is delayed in comparison to a standard reference genotype. The stay-green character is characterized by a longer green state of the plant in the late period of grain filling, establishing a senescence pattern in which leaves and stem are the last parts to loose photosynthetic ability, providing greater production of sugars from photosynthesis. "STAY-GREEN" is one of the most significant traits, which allows plants to keep their leaves in the active photosynthetic state under high temperature to maintain assimilation process and increase crop yield.

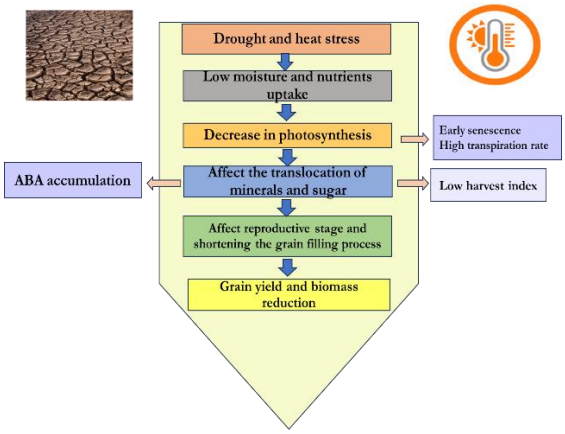

Fig 1: Impacts of heat/drought stress on crop biomass and yield

Types of stay-greens

- **Functional stay-green:** Alteration of genetic processes determining the initiation of senescence and results in a phenotype which photosynthesize for longer than normal (Type A, B & E).
- **Non-functional stay-green:** Leaves remain green due to retention of chlorophyll resulting from lesions in its catabolism, but lack photosynthetic competence (Type C & D)

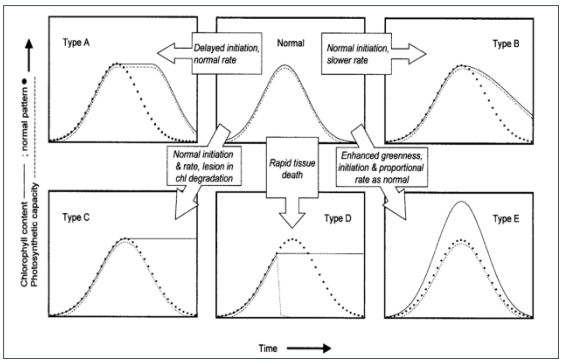

Fig 2: Classes of stay-greens

How useful stay green can be to provide tolerance against heat stress?

Stay green is a beneficial characteristic that could greatly increase the efficiency of radiation use by extending the life of plants' photosynthetic machinery. Being environmental friendly encourages the growth of economic products, particularly in crops where grain is the end product. It gives the plants an extra 20% of their production. Chlorophyll loss during grain filling results in a major fall in yield because the plant's active photosynthetic component, the leaves, does not participate to photosynthesis, which prevents food synthesis and food transfer from leaves to grains. The protection of the photosynthetic apparatus of chloroplasts, such as the maintenance of photosystem II (PSII) and control of content of reactive oxygen species, was also indicated as a major contribution in slowing the degeneration of

tissues in genotypes wheat with functional stay-green character. The cosmetic stay-green mutant of Arabidopsis exhibited improved preservation of photosynthetic structures and increased control over the redox potential, even demonstrating a decrease in some photosynthetic characteristics including the capacity to absorb CO_2.

Use of molecular markers

Due to importance of this trait in heat stress tolerance, more emphasis has been given in last two decades to dissect the mechanism of stay green at molecular level. The mechanism of senescence may get affected by number of candidate genes which are expected to have differential expression in stay green and non-stay green genotypes. Using linked SSR markers to generate information about the presence of stay green genes/QTLs in the potential genotypes is projected to significantly increase stay green efficiency. The functional stay-green trait is a useful trait for increasing crop stress tolerance in cereals, according to quantitative trait loci research. Two QTLs i.e., *Gwm1037* (*QSg.bhu-3B*) and *Gwm691* (*QSg.bhu-1A*) for stay green trait has been reported in wheat. Four QTLs in rice (*TCS4, Csfl6, Csfl9/Tcs9* and *Csfl12*) were found. Moreover, the stay-green QTLs *Csfl6* and *Tcs9* were identified in the same position that two QTL for grain yield (*Yld6 and Yld9*), thus strengthening the link between high productivity and presence of stay-green character (Fu *et al.*, 2011). In barley, nine QTLs associated with stay-green were identified (Emebiri, 2013), and four QTLs (*SZtgb, STG1, Stg3* and *Stg4*) were identified in sorghum (Kassahun *et al.*, 2010). Furthermore, there are markers for additional heat tolerance traits that can be used in marker-assisted breeding and selection. These markers could be helpful in identifying promising wheat lines from the gene pool of National Gene Bank as well as other genetic stocks, such as land races and wild types.

CONCLUSION

Incorporating stay-green genes into commercially significant crops that are linked to traits like high yield, industrial quality, disease resistance, and abiotic stress tolerance would aid in addressing numerous serious problems, such as drought and heat stress. Breeding and growing plants with the ability to preserve leaf function and delay senescence in the presence of terminal heat stress offers a viable path. Solutions to significant environmental problems, like drought and heat, may be possible if this trait is combined with other favorable traits.

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