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Water logging Stress: Its nature, impact and integrated breeding strategies to improve Water logging tolerance in sesame

Waterlogging is a condition of land in which temporarily or permanently soil profile is saturated with water. In agricultural waterlogging can reduce economic value of land and causing yield reductions or total crop failures. Waterlogging in agricultural lands can be of various types categorized according to causes, permanence, source of water and location. Waterlogging is caused via two means: (i) natural causes and (ii) human-induced. Natural causes of waterlogging are physiography of a watershed, geology, the weather, soil type, seepage inflows and human induced causes of waterlogging are two type irrigation and rainfed system. In irrigation include over irrigation, seepage from canals, inadequate drainage, poor irrigation management, obstruction of natural drainage and land locked parches having no outlet and in rainfed system include excessive rainfall, flat topography, occasional spills by floods, closed/contour water conservation structures.

Waterlogging have both beneficial and harmfull effects. Beneficial effects include being a habitat for certain plants and animals e.g. mudfish and harmfull effects of waterlogging in agriculture include effect on the soil, crops and farm operations. Effects on soil include lack of aeration, reduced soil temperature, salinization, inhibit activity of soil bacteria, denitrification, and retards cultivation. Effects on crop include delayed cultivation operations, aquatic weeds, diseased crops, loss of cash crops, low yields and oxygen depletion.

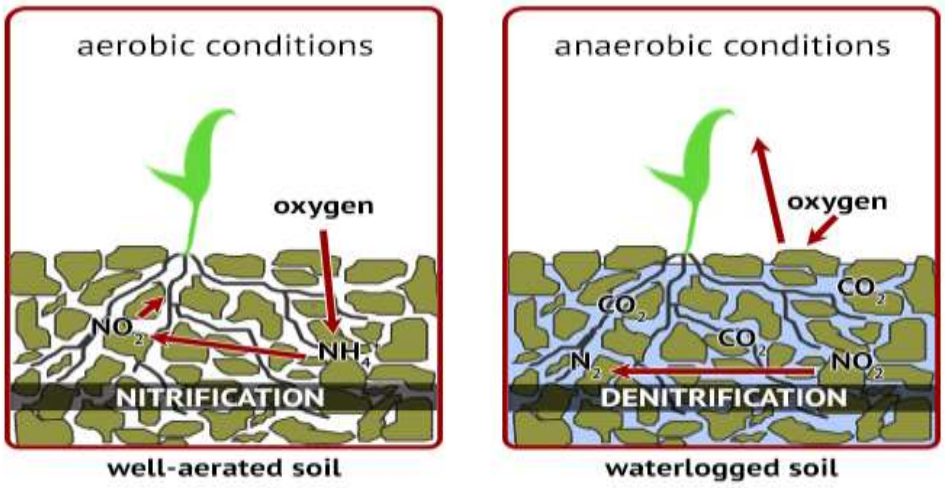

Fig. 1: Well aerated v/s waterlogged soils

Sesamum (*Sesamum indicum* L.) is an important ancient oil seed crop cultivated extensively in India after groundnut, rape seed and mustard. It is "Queen of oilseeds" due to its resistance to oxidation and rancidity. It is a self-pollinated diploid crop with 2n=2x=26 chromosomes. Seeds of sesamum contains 40 to 63 % oil (rich in antioxidants and significant amount of oleic and linoleic acids) (Abate and Mekbib, 2015). It is very drought tolerant, in part due to its extensive root system but very sensitive to excess moisture and crop losses due to waterlogging are considerably high. Yield of sesame is decreases day by day due to climate change and irregular rainfall, higher rainfall for 3-4 day causes waterlogging in field of sesame and reduced yield and sometimes whole crop in India and especially in Gujarat. Developing resistant varieties is the most ideal and economic approach, to manage the stress as agronomic measures and engineering structures of plant are costly and have their own limitations.

An overview: Plant adaptations to flooding stress:

Plant adaptations to submergence have been classified into two main strategies (Bailey-Serres and Voesenek 2008):

- Low Oxygen Quiescence Syndrome (LOQS)
- Low Oxygen Escape Syndrome (LOES)

1) Low Oxygen Quiescence Syndrome (LOQS):

Plants with the LOQS are characterised by traits that enable them to:
(i) Use ATP economically,
(ii)Increase the abundance of enzymes necessary to make some ATP without molecular O_2.
(iii)Increase the production of components that counteract harmful cellular changes associated with flooding.

2) Low Oxygen Escape Syndrome (LOES):

Plants with the LOES are characterised by traits that enable them to:

(i) Re-orientate the growth direction and increase the rate of growth of shoot organs, such as stems and petioles, so plant emerge above flood waters.

(ii) Develop anatomical structures that facilitate internal gas diffusion or pressurized through-flow.

(iii) Develop structures that facilitate gas exchange between plants and their submerged environment.

- The LOES has been studied in detail in *Rumex palustris* and deepwater rice.

Gene expressed during waterlogging in sesame:

Genes of two family MYB and WRKY are reported to express in sesame during waterlogging. In MYB gene family five genes are upregulated namely SIMYB107, SIMYB108, SIMYB195, SIMYB216 and SIMYB231 and three are downregulated namely SIMYB155, SIMYB166 and SIMYB174 reported by Dossa *et al*., 2017. In WRKY gene family 18 genes are upregulated namely SiWRKY8, SiWRKY13, SiWRKY16, SiWRKY19, SiWRKY30, SiWRKY35, SiWRKY41, SiWRKY43, SiWRKY 46, SiWRKY49, SiWRKY51, SiWRKY54, SiWRKY55, SiWRKY56, SiWRKY64, SiWRKY66, SiWRKY68 and SiWRKY71 and 15 genes are downregulated namely SiWRKY1, SiWRKY6, SiWRKY7, SiWRKY12, SiWRKY17, SiWRKY27, SiWRKY39, SiWRKY42, SiWRKY47, SiWRKY57, SiWRKY59, SiWRKY60, SiWRKY62, SiWRKY63 and SiWRKY70 reported by Li *et al*. (2017) in *Wuhan,* China.

Breeding methods used for sesame breeding for waterlogging

Two types of breeding method conventional breeding methods and innovative breeding methods are used for improvement of waterlogging related traits in sesame. In conventional breeding methods, pure line and mass selection, hybridization and mutation are generally used and incase of innovative breeding methods In Vitro culture and screening, somatic hybridization, genetic manipulation, marker assisted selection and QTL mapping are used for improvement of waterlogging related traits in sesame.

Sesame genotypes tolerant waterloging based on physiological and biochemical changes

Saha *et al*. in 2016 at Bangladesh conduct the experiment on physiological and biochemical changes in waterlog tolerant sesame genotypes. An experiment was conducted under pot culture to investigate physiological responses as well as antioxidative enzymes activities that may lead to select sesame genotype (s) which were more waterlogging tolerant at vegetative stage. Four sesame genotypes viz. BD-6980, BD-6985, BD-6992 and BD-7012 were grown under waterlogged (at vegetative stage) and control (no waterlogged) conditions. Plant height, root length, root volume, root dry weight and leaf area per plant in all the four sesame genotypes significantly decreased due to waterlogging at vegetative stage in comparison to controlled condition. Higher SPAD value (Soil and Plant Analyzer Development) and

specific leaf mass were recorded in waterlogged plant than controlled plant during waterlogging period but reverse was the case during recovery period. All the genotypes showed positive indices of waterlogging tolerance in terms of better performance of root, stem, leaf and petiole. Among the genotypes, BD 6980 showed higher waterlogging tolerance in all the components followed by BD 6985. Malondialdehyde (MDA) content was found higher in waterlogged plant of all the four sesame genotypes in both waterlogging period and recovery period than the controlled plant. Antioxidant enzyme activities like Peroxidase (POD), Catalase (CAT), Ascorbate peroxidase (APX), Glutathione peroxidase (GPX) and Superoxide dismutase (SOD) were inconsistent in the present study but most of the antioxidant enzyme activities showed an increasing trend in waterlogged plant than that of control plant in all the genotypes. Comparatively low amount of MDA content and high antioxidant activities of sesame genotype BD 6980 is considered as highly tolerant to waterlogging and other three genotypes are moderately tolerant under water logging condition.

Screening of waterlogging tolerance genotypes of sesame in India

Athul *et al*. in 2017 at Kerala, India, conduct the experiment on evaluation of sesame genotypes for tolerance to waterlogging. In this experiment thirty genotypes were screened at seedling stage (20 days after sowing) by pot culture experiment to identify tolerant types for excess soil moisture by imposing flooding for 24 hrs, 48 hrs and 72 hrs duration. All the genotypes survived 24 h and 48 h of waterlogging while 17 genotypes alone survived 72 h of waterlogging. Observations of the genotypes which survived 72 h of flooding were recorded and the results showed that the genotypes significantly differe for the characters under study. Ten genotypes viz. Ayali, *Sesamum malabaricum*, TKG 22, OSC 207, Thilak, Thilarani, GT 10, SV 2, TKG 308 and Rama which recorded the highest survival percentage were selected for field experiment. In the field experiment flooding was imposed for 72 h duration and biometrical characters were recorded and statistically analysed. All the characters significant difference showed among the genotypes. Among the ten genotypes highest yield per plant was recorded by the local variety, Ayali (7.46g) and lowest by *Sesamum malabaricum* (2.92g). Oil content was highest for Thilak (48.6 %) and lowest for wild species *Sesamum malabaricum* (32.5%).

Conclusion:

- Waterlogging affect growth and yield of sesame genotypes.
- Physiological traits *viz.,* root system, stomatal activity, chlorophyll content, relative water content, antioxidant activity and proline content should be given emphasis while breeding sesame for waterlogging tolerance.
- Wild species *Sesamum malabaricum,* local varieties BD6980, Zhongzhi No.13, Ayali and Binatil-2 and mutant genotypes SM1, SM8 and SM58 are tolerant to waterlogging which may be utilized for sesame improvement for introgression of waterlogging tolerance.
- Being a self-pollinated crop, pedigree and back cross method are suitable for breeding of sesame against waterlogging.
- As waterlogging is a complex trait, simultaneous improvement of related traits is breeder's choice.

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