TECHNICAL BULLETIN
No. 62, 2023

Physiological Mechanisms of Waterlogging Tolerance in Sesame

Waterlogging severely affects sesame cultivation in Bangladesh. It is a major factor limiting the sesame area coverage and restricting the yield to a meager 0.5-0.6 t/ha in the country. For example, the area under sesame cultivation was 90.82 thousand ha in 1989 which drastically declined to 33.20 thousand ha in 2012. This major abiotic stress leads to a series of morphological, physiological, biochemical and anatomical changes that adversely affect growth and development as well as yield of sesame. Generally, plant adaptations to water logging or oxygen deprivation in the soil include avoidance strategies at the morpho-anatomical and metabolic levels. However, the mechanism of tolerance to waterlogging in sesame is not fully understood. This KGF sponsored project studied the response of sesame to waterlogging with a view to understanding the mechanisms responsible for waterlogging tolerance and identifying waterlogging tolerant sesame genotypes.

Fig. 1. Observing response of different sesame genotypes to various lengths of waterlogging

Methodology

The project was implemented by a team of plant physiologists of BARI, Gazipur. Two screening experiments were conducted with110 sesame genotypes to identify waterlogging tolerant and susceptible genotypes at seedling and reproductive stages both in laboratory and field conditions. Thirty sesame genotypes were found to be relatively tolerant and 2 genotypes susceptible to waterlogging. These 30 genotypes were further evaluated in a pot experiment to screen out the relatively more tolerant and susceptible sesame genotypes under waterlogging conditions where 4 genotypes (BD-10165, GP-03013, BD-6971 and GP-1811) were found to be relatively tolerant to waterlogging for as long as for 48 hours. Later on, two experiments were conducted in the pot house of the Plant Physiology Division, BARI, Gazipur. In the first experiment, five waterlogging tolerant and two sensitive sesame genotypes were used (selected from the 110 sesame genotypes through field and pot experiments earlier) in pot culture and the best waterlogging tolerant sesame genotypes based on physiological parameters (photosynthetic pigments, net photosynthetic rate, stomatal conductance, transpiration rate and intracellular CO2 concentration, etc.) were selected under different durations of waterlogging

(24, 48 and 60 hours) at the flowering stage. In the second experiment, two sesame genotypes tolerant to waterlogging (G7 and G3) and one susceptible genotype (G1) (selected from previous experiments) were grown n pot culture to study the physiological and biochemical mechanisms of waterlogging tolerance in sesame. Seedlings (34 d old) were subjected to three different durations of waterlogging (48, 72 and 120 hours). Physiological and biochemical characteristics such as, 2,3-methylenedioxyamphetamine (MDA) and H2O2 contents, activities of the antioxidants viz., ascorbate peroxidase (APx), glutathione peroxidase (GPx) deoxypodophyllotoxin (POD), glutathione (GSH) and proline, catalase (CAT), argininosuccinic acid (AsA) and glutathione reductase (GR) activities were assessed on the 3rd day after cessation of waterlogging.

Results and Outputs

A significant variation n tolerance to waterlogging was found among the 110 sesame studied, 5 of them (G1; BD 6991, G2; BD 7012, G3; BD 6998, G6; BD 6981 and G7; MR-20) showed a comparatively high survival percentage under a 72-hr waterlogging spell. This tolerance corresponded to comparatively high dry matter production and seed yield.

Physiological evaluation of selected sesame genotypes (5 tolerant and 2 susceptible) revealed that waterlogging stress induced leaf chlorosis in all the genotypes, but serious symptoms occurred earlier in the susceptible genotypes and they did not survive even for 48 hrs in the waterlogged condition. All the tolerant genotypes survived escaped injury with higher Pn, Gs, Tr and photosynthetic pigments than those in the susceptible genotypes. On the basis of gas exchange and photosynthetic pigments, the genotypes G7 (MR-20) and G3 (BD 6998) were selected as relatively tolerant genotypes.

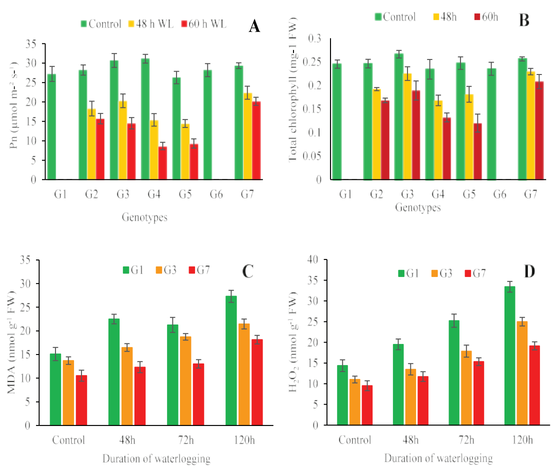

Fig. 2. Effect of waterlogging on the net photosythesis rate (A) and total chlorophyll (B), MDA (C) and H2O2 contents in the leaves of sesame

It was observed that the longer the plant remained waterlogged, the greater was the damage. Waterlogging stress increased the contents of 2,3-methylenedioxyamphetamine (MDA) and H2O2 in all the sesame genotypes, but the magnitude of increase was significantly lower in both tolerant genotypes than in the susceptible genotype. Activities of the antioxidants viz., ascorbate peroxidase (APx), glutathione peroxidase (GPx) deoxypodophyllotoxin (POD), glutathione (GSH) and proline increased with increasing duration of waterlogging in all the genotypes (Fig. 2), but the degree of increase was significantly higher in tolerant genotypes than in the sensitive G1. In contrast, the magnitudes of reduction in catalase (CAT), argininosuccinic acid (AsA) and glutathione reductase (GR) activities were higher in sensitive than in tolerant genotypes, at all waterlog duration.

Anatomical studies revealed that the tolerant genotypes G7; MR-20 had a significant formation of aerenchymatous tissues in roots (Fig.3).

On the basis of the morpho-physiological and biochemical responses to waterlogging for 72 hours, three sesame genotypes (G7; MR-20, G3; BD 6998 and G2; BD 7012) were selected as waterlogging tolerant genotypes.

Expected Impact

i. The project experiments provided important insights into physiological and metabolic changes occurring in sesame due to waterlogging for various periods of time, and that, some sesame genotypes possesses adaptive mechanisms at both physiological and biochemical levels to tolerate waterlogging stress implying that there is scope for investigation at the gene level to discover waterlogging tolerant genes of sesame and develop tolerant varieties.

ii. Relatively tolerant genotypes will have the prospect of enhancing sesame productivity as well as farmers economic benefits.

iii. Identified genotypes and tolerance mechanisms will be useful for plant breeders in future breeding programs.

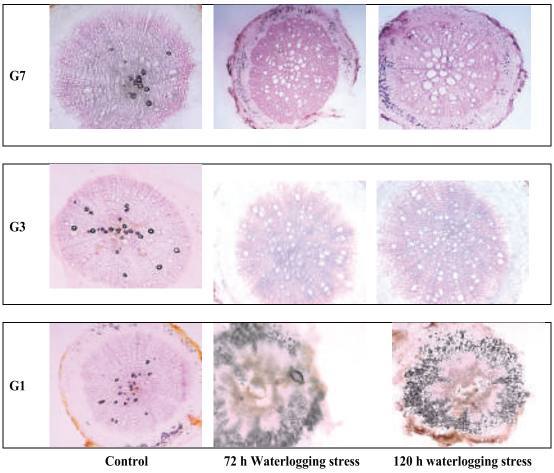

Fig. 3. Transverse root sections of relatively waterlogging tolerant (G3 and G7) and susceptible sesame genotypes

Recommendations

- Further research is needed using for biotechnological and molecular approaches for improving tolerance in sesame of waterlogging stress
- Highly expressed enzymes like POD, CAT, APX and GPX need more research for delineating their role in waterlogging stress tolerance in sesame. Moreover, it remains a challenging task for future basic research to identify the oxygen sensing system(s), to elucidate the corresponding signal-transduction pathway(s) and regulatory components involved in responses to the low internal oxygen concentrations induced by prolonged periods of waterlogging
- The phenomenon of aerenchyma formation in the roots in response to waterlogging stress needs further investigation.

This Technical Bulletin has been prepared on the basis of technical information available from a completed BKGET-KGF Funded Project, the details of which are given below:

Project Code and Title: BR 4-C/17. Physiological Mechanism of Waterlogging Tolerance in Sesame

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Project duration: April 2017 to 2023

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Krishi Gobeshona Foundation (KGF)

Published by:
Krishi Gobeshona Foundation, AIC Building, 3rd Floor, BARC Campus, Farmgate, Dhaka-1215, Bangladesh, Cell: 01729 480988, Website: www.kgf.org.bd, e-mail: kgf-bd@kgf.org.bd