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WATERLOGGED TOLERANCE OF SESAME GENOTYPES ON THE BASIS OF MORPHO-ANATOMICAL FEATURES AND YIELD

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Abstract

Waterlogging is an environmental factor that reduces gas exchange between plant tissues and the atmosphere and limits plant growth and yield and damages root and shoot structures. A pot experiment was conducted with four sesame genotypes *viz*. Rajshahi Khoyeri, KistotilChapai, KathtilChapai and Binatil-2 during March to June 2019. Four waterlogged treatments *viz*. Control, 24, 48 and 72 hours were imposed at flowering stage of the sesame genotypes. Plant height, shoot and root dry weight, total dry matter plant^{-1}, capsules plant^{-1}, number of seeds capsule^{-1}, number of seeds plant^{-1}, 1000-seed weight and seed yield plant^{-1} were significantly decreased with increasing water logging periods. Rajshahi Khoyeri produced the highest seed yield followed by KathtilChapai. Total dry matter reduction was less in Rajshahi Khoyeri and yield reduction was less in KathtilChapaiunder different water logging treatments. Root and stem anatomy of all the genotypes was investigated under control and 72 hours water logging and found that water logging at 72 hours partially damaged its epidermis, hypodermis and vascular bundle and adventitious roots were formed to help storage and exchange of gases within stressed plants to maintain a hypoxia tolerance pathway for survival.

Key words: Sesame, water logging, root anatomy, stem anatomy, yield

Introduction

Water logging reduces gas exchange between plant tissues and the atmosphere, resulting in an imbalance between slow diffusion and rapid consumption of oxygen in the rhizosphere that drastically reduces the oxygen supply and induces anoxia in plants (Sachs *et al*. 1980). Short-term water logging often firstly causes oxygen deficiency (hypoxiaor anoxia) in plants and leads to root damage (Grassini*et al*. 2007). Water logging causes a shortfall in oxygen availability to plants which is felt directly by the root system, and indirectly by the shoots (Capon *et al*. 2009). In tissue suffering hypoxia (and specially anoxia), oxygen-depending processes are suppressed, both carbon assimilation and photosynthate utilization are inhibited, and functional relationships (especially the internal transport of oxygen) between roots and shoots are disrupted (Chugh*et al*. 2012). The response of a plant to hypoxia can be conceptually divided into three stages. Initially, the plant rapidly induces a set of signal transduction components, which then activates the second stage, a metabolic adaptation involving fermentation pathways. Finally, the third stage involves morphological changes such as the formation of gas filled air spaces (aerenchima) and/or adventitious root,

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depending on the tolerance of the plant (Jackson and Colmer, 2005; Evans 2003; Justin and Armstrong, 1987).

Sesame (*Sesamumindicum*), a crop with high oil content, has the potential capacity to combat nutritional deficiencies in developing regions and countries. Most current cultivars contain 50–60% oil and 18–24% protein in their seeds (Mondal*et al*. 2010). In particular, greater than 80% of its oil is in the form of unsaturated fatty acids, which are more beneficial for human health than are saturated fatty acids. In addition, the antioxidant properties of sesame lignans, primarily sesamin and sesamolin, are used for therapeutic and cosmetic applications (Nakano *et al*. 2006). Sesame is typically considered drought-tolerant but susceptible to water logging, a property that can be ascribed to its suspected origin in Africa or India and its subsequent dispersal to tropical or semitropical regions (Ram *et al*. 1990 and Bedigian 2004).

To understand the effects of abiotic stress in an effort to maintain a stable food supply, a number of studies have investigated the responses of model plants and crops to stresses (Rasmussen *et al*. 2013). These studies have revealed that plant responses to different stresses are coordinated by complex and often interconnected signaling pathways that regulate numerous metabolic networks (Miro and Ismail,2013). At the protein level, low oxygen selectively induces the synthesis of anaerobic proteins, especially enzymes involved in sugar metabolism, glycolysis and fermentation (Komatsu *et al*. 2009). The vast majority of these proteins have been investigated in water logging-susceptible or tolerant strains of Arabidopsis or rice (Nakashima *et al*. 2009; Atkinson *et al*. 2013). Sesame mutants/varieties/land races show some tolerance to water logging (Islam and Khatoon, 2018). In this study, morphological attributes and yield of some selected sesame genotypes were investigated under water logging along with root and shoot structures of the tolerant genotype.

Material and Methods

A pot experiment was conducted with four sesame genotypes *viz*. Rajshahi Khoyeri, KistotilChapai, KathtilChapai and Binatil-2 at BINA farm, Mymensingh during March to June 2019. The sesame land races were collected from different agro-ecological zones of Bangladesh. The objective of the study was to find out the waterlogged tolerant genotypes. Each pot contained 8 kg soil collected from BINA farm. Urea, TSP, MP and Gypsum were applied 1.25, 1.5, 0.5 and 1.1 g pot^{-1} corresponding 125, 150, 50 and 110 kg ha^{-1}, respectively. Half of urea and all other fertilizers were mixed with pot soils and remaining urea was applied at 30 days after sowing. Seeds were sown on 3 March 2019. After seedling establishment one seedling was allowed to grow in each pot. The experiment was laid out in completely randomized design with three replications. Four water logging treatments *viz.* control and waterlogged periods of 24, 48 and 72 hours were imposed at flowering stage of the sesame genotypes.Anatomical features of both root and stem of all the genotypes under

72 hours water logging and controlled condition were efficiently observed by sectioning and finally by using Stereo Microscope having fixed slide. Data on plant height, root and shoot dry weight, total dry matter plant^{-1}, number of capsule plant^{-1}, number of seeds capsule^{-1}, number of seeds plant^{-1}, 1000-seed weight and seed yield plant^{-1} of all the genotypes under the treatments were collected at maturity. Data were analyzed statistically and DMRT was done to compare the means.

Results and Discussion

Results revealed that plant height, shoot and root dry weight, total dry matter plant^{-1}, capsules plant^{-1}, number of seeds capsule^{-1}, number of seeds plant^{-1}, 1000-seed weight and seed yield plant^{-1} were significantly decreased with increasing water logging periods (Table 1). Similar results were observed by many researchers (Wei *et al*. 2013; Islam *et al*. 2018, 2017). Rajshahi Khoyeri produced higher seed yield (3.73g) followed by KathtilChapai (3.22g) and KistotilChapai (2.74g) under the treatments.Rajshahi Khoyeriproduced the longest plants (57.67cm) and Kristotil produced the shortest (41.67cm) (Table 2). Higher shoot dry weight was observed in KistotilChapai (4.01g) and Rajshahi Khoyery (4.01g) whereas higher root dry weight was found in KathtilChapai (1.03g) and Rajshahi Khoyery (0.82g). The highest seed was observed in Rajshahi Khoyeri (8.43g) under control condition and the lowest in KistotilChapai (0.32g) at 72 hours water logging (Table 3). Rajshahi Khoyery reduced less reduction of total dry matter and KathtilChapaireduced less seed yield under different water logging conditions. So, Rajshahi Khoyery and KathtilChapaishowed better performance under water logging compared to others.

Table 1. Effect of water logging period on morphological, physiological, seed yield and yield components of sesame genotypes

Treatments	Plant height (cm)	Shoot dry wt. plant^{-1} (g)	Root dry wt. plant^{-1} (g)	Total dry matter plant^{-1} (g)	Capsules plant^{-1} (no.)	Seeds capsule^{-1} (no.)	Seeds plant^{-1} (no.)	1000 seed wt. (g)	Seed yield plant^{-1} (g)
Control	60.1a	5.25a	1.12a	6.05a	32.67a	53.67a	1080a	3.74a	5.44a
24 hrs	51.3b	4.12b	0.97b	5.01b	25.32b	41.21b	745.2b	2.99b	4.01b
48 hrs	40.7 c	2.57c	0.84bc	3.21c	19.29c	30.62c	603.7c	2.82c	1.52c
72 hrs	40.1 d	1.51d	0.76c	2.24d	10.52d	22.19d	265.2d	1.27d	0.34d

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT

Table 2. Plant height, biomass production, yield and yield components of sesame genotypes under waterlogged condition

Genotype	Plant height (cm)	Shoot dry wt. plant^{-1} (g)	Root dry wt. plant^{-1} (g)	Total dry matter plant^{-1} (g)	Capsules plant^{-1} (no.)	Seeds capsule^{-1} (no.)	Seeds plant^{-1} (no.)	1000 seed wt. (g)	Seed yield plant^{-1} (g)
Rajshahi Khoyeri	57.67a	4.00a	0.82a	4.33a	21.23d	48.8a	1283ab	2.34a	3.73a
KistotilChapai	41.67d	4.01a	0.76b	4.77a	21.57cd	46.9ab	1219ab	2.21bc	2.74ab
KathtilChapai	48.00bc	3.23b	1.03a	4.15ab	29.53a	45.7bc	1301a	2.32ab	3.22a
Binatil-2	52.92b	3.24b	0.77b	4.0b	28.25a	35.8c	1143ab	2.03c	2.66b

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT

Anatomy of root and shoot of all the sesame genotypes under control and 72 hours water logging are shown (Figs. 1-16). In control both root and stem, the orientation of epidermis, hypodermis and vascular bundle looks normal (Figs. 1, 3, 5, 7, 9, 11, 13 & 15). Water logging at 72 hours almost damaged epidermis, hypodermis and vascular bundle of most of the varieties (Figs. 6, 8, 10, 12, 14 & 16). But water logging at 72 hours partially damaged epidermis, hypodermis and vascular bundle of Rajshahi Khoyeriand adventitious roots were formed to help storage and exchange of gases within stressed plants to maintain a hypoxia tolerance pathway for survival (Figs. 2 & 4). The results are in conformity of Wei *et al.* (2013) who found less damaged tissue, adventitious root and aerenchyma in tolerant type of sesame. Water uptake, nutrient and oxygen supply hamper due to damage of vascular bundle and plants show wilting and may die. In oxygen-deprived condition the plant rapidly induces a set of signal transduction components, activates a metabolic adaptation involving fermentation pathways and involves morphological changes such as the formation of gas filled air spaces (aerenchyma) and/or adventitious root, depending on the tolerance of the plant (Jackson and Colmer, 2005; Evans 2003; Justin and Armstrong, 1987). So, better yield and less damaged tissue under waterlogged condition of Rajshahi Khoyeri showed its tolerance to water logging.

Table 3. Interaction effect of waterlogged condition on plant height, biomass production, yield and yield components of sesame genotypes

Interaction	Plant height (cm)	Shoot dry wt. plant^{-1} (g)	Root dry wt. plant^{-1} (g)	Total dry matter plant^{-1} (g)	Capsules plant^{-1} (no.)	Seeds capsule^{-1} (no.)	Seeds plant^{-1} (no.)	1000 seed wt. (g)	Seed yield plant^{-1} (g)
V1T1	57.3b-d	6.63ab	1.12b-e	7.81a	39.0a-d	75.3a	2833a	3.01ab	8.43a
V1T2	46.1g-j	4.21e-g	0.65c-e	4.85c-e	21.0hi	58.7a-d	1236ef	2.50c-e	3.05d
V1T3	45.1g-j	3.13h-k	0.95b-e	4.11e-h	15.3ij	43.3b-j	658.7gh	2.57cd	1.69e-g
V1T4	34.3kl	2.16j-m	0.95b-e	3.05h-j	7.0k	30.7g-m	215.3i	1.70lm	0.36h-j
V2T1	56.6c-e	6.82a	1.04b-e	7.87a	37.0b-e	75.3a	2679ab	2.43c-g	6.40b
V2T2	41.2i-k	4.86c-f	0.92b-e	5.77b-d	23.7gh	56.6a-f	1342ef	2.64b-d	3.56d
V2T3	39.6i-k	2.87i-k	1.03b-e	3.91e-h	18.0hi	34.7f-m	628gh	2.43c-g	1.53f-i
V2T4	29.02l	1.44 lm	0.85b-e	2.33i-k	9.01k	22.0j-m	197.3i	1.6m	0.32ij
V3T1	67.0ab	5.62cd	1.40ab	7.04ab	42.61a	51.6b-g	2213cd	3.08a	6.79b
V3T2	43.3g-k	3.47g-i	1.02b-e	4.78c-f	32.7d-f	41.0b-k	1342ef	2.53c-e	3.37d
V3T3	38.7jk	2.31j-l	1.27a-c	3.48f-i	28.3fg	35.7e-l	1003fg	2.36c-i	2.36d-f
V3T4	43.0h-k	1.25m	0.83b-e	2.12jk	15.7ij	54.3a-f	697gh	1.73k-m	1.16f-j
V4T1	67.0ab	5.50cd	1.2bcd	6.71ab	41.31ab	58.0a-e	2399bc	2.74a-c	6.57b
V4T2	50.01d-i	3.68g-i	1.0bc-e	4.55d-g	32.3d-f	39.6c-k	1288ef	2.13e-k	2.75de
V4T3	52.01c-h	2.54jk	0.65c-e	3.3g-j	23.7gh	26.7i-m	628.7gh	2.00h-m	1.25f-j
V4T4	42.6h-k	1.24m	0.62de	1.89jk	15.61-j	18.6k-m	295.3hi	1.68lm	0.48g-j

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT; Where, T_1= Control, T_2= 24 hours water logging, T_3= 48 hours water logging, T_4= 72 hours water logging, V_1=Rajshahi Khoyeri, V_2= KistotilChapai, V_3= KathtilChapai, V4= Binatil-2

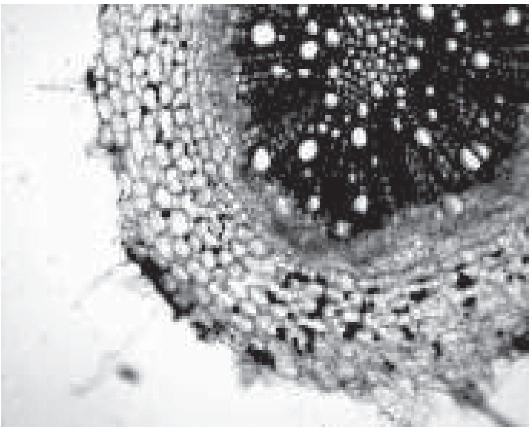

Fig. 1. Anatomy of root of a sesame cultivar, RajshahiKhoyeri (Control)

Fig. 2. Anatomy of root of a sesame cultivar, Rajshahi Khoyeri under 72 hours water logging

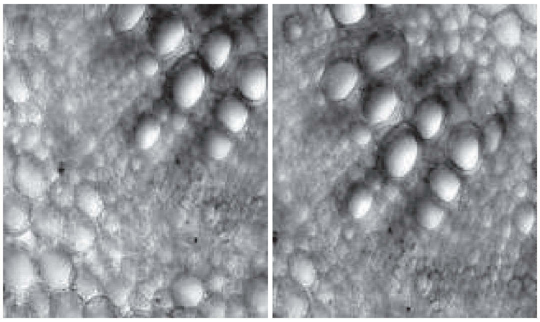

Fig. 3. Anatomy of stem of a sesame cultivar, Rajshahi Khoyeri (Control)

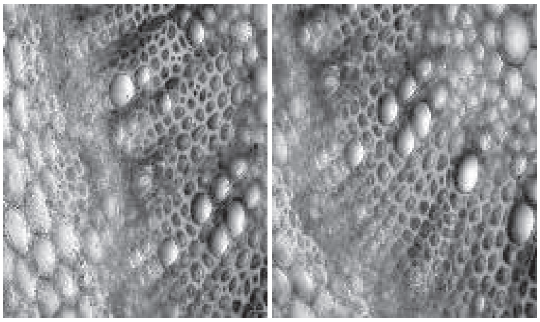

Fig. 4. Anatomy of stem of a sesame cultivar, Rajshahi Khoyeri under 72 hours water logging

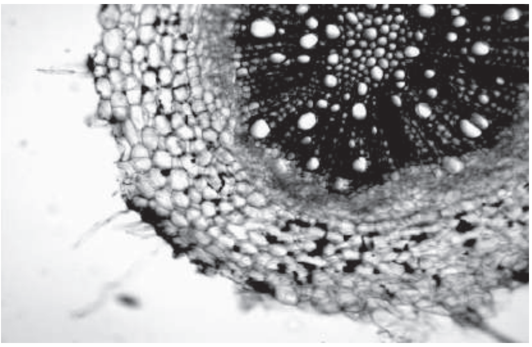

Fig. 5. Anatomy of root of a sesame cultivar, KistotilChapai (Control)

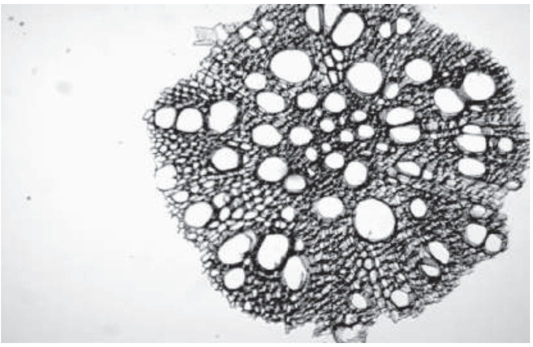

Fig. 6. Anatomy of root of a sesame cultivar, Kistotil Chapai under 72 hours water logging

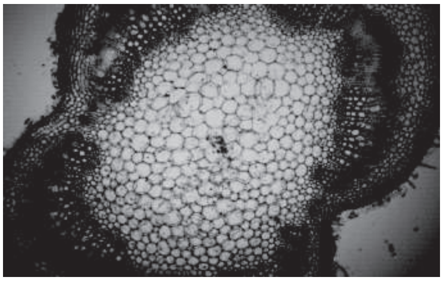

Fig. 7. Anatomy of shoot of a sesame cultivar, KistotilChapai (Control)

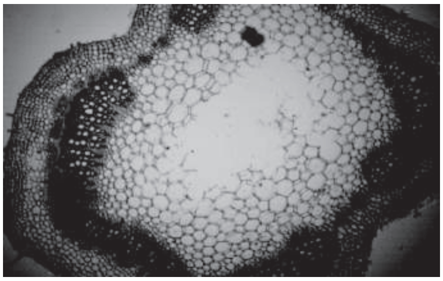

Fig. 8. Anatomy of shoot of a sesame cultivar, Kistotil Chapaiunder 72 hours water logging

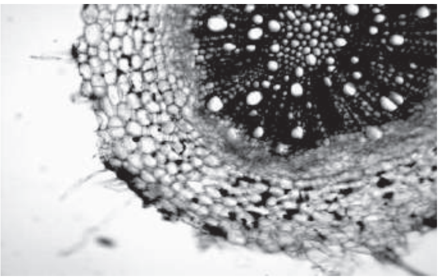

Fig. 9. Anatomy of root of a sesame cultivar, KathtilChapai (Control)

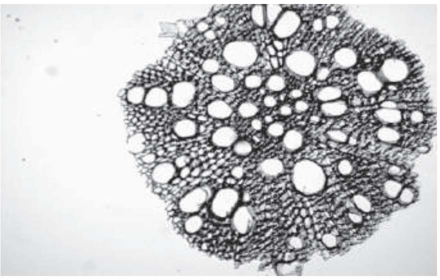

Fig. 10. Anatomy of root of a sesame cultivar, Kathtil Chapai under 72 hours water logging

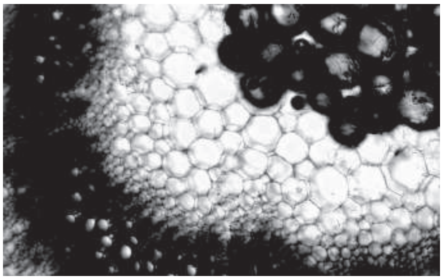

Fig. 11. Anatomy of shoot of a sesame cultivar, KathtilChapai (Control)

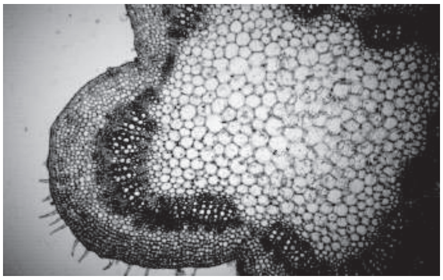

Fig. 12. Anatomy of shoot of a sesame cultivar, Kathtil Chapai under 72-hours water logging

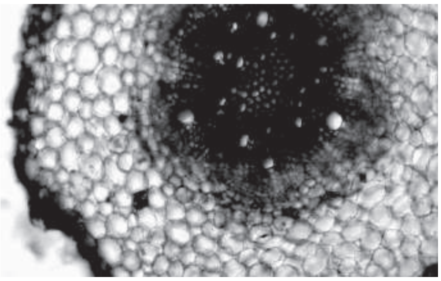

Fig. 13. Anatomy of root of a sesame cultivar, Binatil-2 (Control)

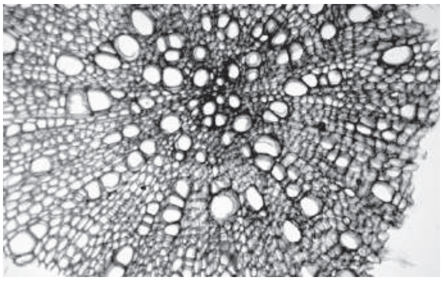

Fig. 14. Anatomy of root of a sesame cultivar, Binatil-2 under 72 hours water logging

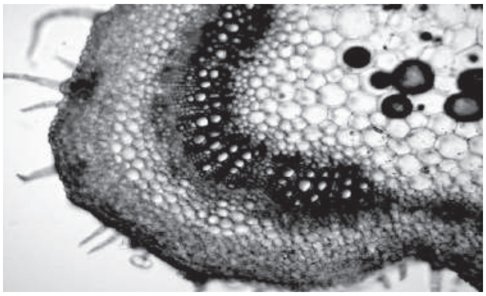

Fig. 15. Anatomy of shoot of a sesame cultivar, Binatil-2 (Control)

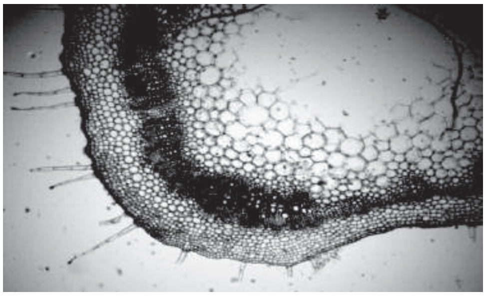

Fig. 16. Anatomy of shoot of a sesame cultivar, Binatil-2 under 72 hours water logging

Conclusion

Plant height, shoot and root dry weight, total dry matter plant^{-1}, capsules plant^{-1}, number of seeds capsule^{-1}, number of seeds plant^{-1}, 1000-seed weight and seed yield plant^{-1} were significantly decreased with increasing water logging periods. Among the genotypes, Rajshahi Khoyeri produced higher seed yield under the treatments followed by KathtilChapai. Rajshahi Khoyerihad less damaged epidermis, hypodermis and vascular bundle and adventitious roots under water logging at 72 hours. So, Rajshahi Khoyeri and KathtilChapaishowed moderately tolerance to waterlogged condition.

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