**SUPPLEMENTARY MATERIAL**

**Growth and yield responses of sunflower to drainage in waterlogged saline soil are caused by changes in plant-water relations and ion concentrations in leaves**

Mohammad Nazrul Islam1,2\*, Richard W. Bell1, Edward G. Barrett-Lennard1,3,4, Mohammad Maniruzzaman5

1 Centre for Sustainable Farming Systems, Future Food Institute, Murdoch University, WA-6150, Australia

2 Soil Science Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh

3 Department of Primary Industries and Regional Development, South Perth, WA-6151, Australia

4 School of Agriculture and Environment, The University of Western Australia, Nedlands, WA-6009, Australia

5 Irrigation and Water Management Division, Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh

\*Corresponding author: nazrulag@gmail.com, Soil Science Division, Bangladesh Rice Research Institute, Gazipur.

Journal name: Plant and Soil



**Fig. S1** Effect of drains on the concentration of Na and K ions in younger leaves and its ratio (Na+/K+) in 2018–19 and 2019–20. Abbreviations: SSD = subsoil drain, SD = surface drain, DASI = days after second inundation, FL = flowering, YL = younger leaves.

**Table S1.** Effects of drains on leaf chlorophyll content at different times in 2018–19 and 2019–20.\*

|  |  |
| --- | --- |
| Treatment | Chlorophyll content (CCI) |
| 2018–19 | 2019–20 |
| 3 DASI | 10 DASI | 17 DASI | FL | 3 DASI | 10 DASI | 17 DASI | FL |
| SSD+SD | 17.2 a | 16.1 a | 14.2 a | 12.0 a | 23.1 a | 17.5 a | 14.7 a | 13.7 a |
| SSD | 16.2 b | 14.7 b | 13.4 b | 11.1 b | 21.0 b | 16.4 b | 13.3 b | 12.1 b |
| SD | 16.2 b | 14.8 b | 13.3 b | 11.0 b | 21.4 b | 16.1 b | 13.1 b | 12.2 b |
| Undrained | 14.8 c | 13.7 c | 12.5 c | 9.0 c | 19.2 c | 15.1 c | 12.2 c | 11.3 b |
| *P-*value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.01 |

\*The leaf chlorophyll content was measured with a chlorophyll content meter (CCM-200 plus, OPTI-SCIENCE, USA). This instrument reports values of chlorophyll content index (CCI). Means with the same letter are not significantly different at 5% level of significance. Abbreviations: SSD = subsoil drain, SD = surface drain, DASI = days after second inundation, FL = flowering.

**Table S2.** Significance of effects of *g*s, Ψleaf and LCC at different times during the growing season on achene yield in 2018–19 and 2019–20.

|  |  |
| --- | --- |
| Times | Significance level with r2 values and direction of the slope (in brackets)  |
| 2018–19 | 2019–20 |
| LCC (CCI) | *g*s (mmol m–2 s–1) | Ψleaf (MPa) | LCC (CCI) | *g*s (mmol m–2 s–1) | Ψleaf (MPa) |
| 3 DASI | (+) 0.61\*\*\*  | (+) 0.68\*\*\*  | (-) 0.65\*\*\*  | (+) 0.69\*\*\* | - | (-) 0.67\*\*\*  |
| 10 DASI | (+) 0.66\*\*\*  | (+) 0.17\*  | - | (+) 0.66\*\*\* | - | (-) 0.49\*\*\*  |
| 17 DASI | (+) 0.66\*\*\*  | (+) 0.25\*  | - | (+) 0.56\*\*\* | - | (-) 0.45\*\*\*  |
| FL | (+) 0.47\*\*\*  | - | (-) 0.57\*\*\*  | (+) 0.60\*\*\* | - | (-) 0.64\*\*\*  |

Abbreviations: *g*s = stomatal conductance, Ψleaf = leaf water potential, SEW30 = sum of excess water above 30 cm, LCC = leaf chlorophyll content, DASI = days after second inundation, FL = flowering. For all relationships *n* = 24.

**Table S3.** Relationships among different factors (Ψs and EC1:5 at 0–15 cm soil depth, SEW30, *g*s, LCC and Ψleaf at different times during the crop growing season in 2018–19 and 2019–20.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variates | 3 DASI | 10 DASI | 17 DASI | FL |
| Significance level with r2 values and direction of the slope (in brackets) |
| **Year 2018–19** |
| SEW30 × *g*s  | (-) 0.80\*\*\* | NS | (-) 0.19\* | - |
| EC1:5 × *g*s | - | NS | (-) 0.34\*\* | - |
| Ψs × *g*s | - | NS | (+) 0.45\*\*\* | - |
| SEW30 × LCC  | (-) 0.85\*\*\* | (-) 0.69\*\*\* | (-) 0.73\*\*\* | (-) 0.78\*\*\* |
| EC1:5 × LCC | - | (-) 0.65\*\*\* | (-) 0.65\*\*\* | (-) 0.59\*\*\* |
| Ψs × LCC | - | (+) 0.35\*\* | (+) 0.33\*\* | (+) 0.49\*\*\* |
| SEW30 × Ψleaf | (+) 0.68\*\*\* | - | - | (+) 0.66\*\*\* |
| EC1:5 × Ψleaf | - | - | - | (+) 0.63\*\*\* |
| Ψs × Ψleaf | - | - | - | (-) 0.63\*\*\* |
| *g*s × LCC | (+) 0.63\*\*\* | NS | NS | - |
| *g*s × Ψleaf | (-) 0.72\*\*\* | - | - | - |
| **Year 2019–20** |  |  |  |  |
| SEW30 × LCC  | (-) 0.90\*\*\* | (-) 0.80\*\*\* | (-) 0.72\*\*\* | (-) 0.57\*\*\* |
| EC1:5 × LCC | - | (-) 0.68\*\*\* | (-) 0.74\*\*\* | (-) 0.74\*\*\* |
| Ψs × LCC | - | (+) 0.52\*\*\* | (+) 0.60\*\*\* | (+) 0.67\*\*\* |
| SEW30 × Ψleaf | (+) 0.55\*\*\* | (+) 0.35\*\* | (+) 0.25\* | (+) 0.53\*\*\* |
| EC1:5 × Ψleaf | - | (+) 0.52\*\*\* | (+) 0.42\*\*\* | (+) 0.50\*\*\* |
| Ψs × Ψleaf | - | (-) 0.44\*\*\* | (-) 0.51\*\*\* | (-) 0.58\*\*\* |

Abbreviations: Ψs = solute potential, *g*s = stomatal conductance, LCC = leaf chlorophyll content, Ψleaf = leaf water potential, SEW30 = sum of excess water within 30 cm, DASI = days after second inundation, FL = flowering, NS = non-significant. For all relationships *n* = 24.



**Fig. S2** Correlation between plant height and leaf water potential at 3 DASI (a) and FL (b) in 2018–19 and at 3 DASI (c) and FL (d) in 2019–20. Abbreviations: DASI = days after second inundation, FL = flowering. We selected nine plants randomly from each position to measure plant height (with a ruler).

****

**Fig. S3** Correlation between leaf area and leaf water potential at 3 DASI (a) and FL (b) in 2018–19 and at 3 DASI (c) and FL (d) in 2019–20. Abbreviations: DASI = days after second inundation, FL = flowering. Leaf area (LA) was estimated from measurement of lamina length and width according to Islam et al. (2021).

**Table S4.** Effect of drains on shoot dry weight at different times during the cropping season in 2018–19 and 2019–20.

|  |  |
| --- | --- |
| Treatment | Shoot dry weight (g plant–1) |
|  | 7 DAFI | 14 DAFI | 10 DASI | 17 DASI | FL |
| Year 2018–19 |
| SSD+SD | 0.09 a | 0.29 a | 4.4 a | 11.7 a | 31.1 a |
| SSD | 0.07 b | 0.20 b | 3.6 b | 8.0 b | 23.4 b |
| SD | 0.07 b | 0.18 b | 3.6 b | 7.8 b | 24.5 b |
| Undrained | 0.05 c | 0.12 c | 2.2 c | 5.1 c | 15.8 c |
| *P*-values | <0.01 | <0.001 | <0.001 | <0.001 | <0.001 |
| LSD0.05 | 0.012 | 0.046 | 0.46 | 0.64 | 3.24 |
| Year 2019–20 |
| SSD+SD | 0.19 a | 0.66 a | 5.9 a | 13.6 a | 41.8 a |
| SSD | 0.17 a | 0.48 b | 4.4 b | 9.7 b | 32.2 b |
| SD | 0.18 a | 0.53 b | 4.5 b | 9.9 b | 33.0 b |
| Undrained | 0.12 b | 0.26 c | 2.5 c | 5.2 c | 20.7 c |
| *P*-values | <0.01 | <0.001 | <0.001 | <0.001 | <0.001 |
| LSD0.05 | 0.028 | 0.091 | 0.495 | 1.345 | 2.899 |

Abbreviations: SSD = subsoil drain, SD = surface drain, DAFI = days after first inundation, DASI = days after second inundation, FL = flowering.

****

**Fig. S4** Correlation between shoot dry weight and SEW30 at different times in 2018–19 and 2019–20. Abbreviations: SEW30 = sum of excess water within 30 cm, DAFI = days after first inundation, DASI = days after second inundation, FL = flowering.



**Fig. S5** Correlation between shoot dry weight and soil EC1:5 at 0–15 cm at different times in 2018–19 and 2019–20. Abbreviations: DAFI = days after first inundation, DASI = days after second inundation, FL = flowering.

****

**Fig. S6** Correlation between shoot dry weight and solute potential of soil at 0–15 cm at different times in 2018–19 and 2019–20. Abbreviations: DAFI = days after first inundation, DASI = days after second inundation, FL = flowering.



**Fig. S7** Correlation between shoot dry weight and Na+ or K+ or Na+/K+ in leaves at different times in 2018–19. Abbreviations: DAFI = days after first inundation, DASI = days after second inundation, FL = flowering, AL = all leaves, YL = younger leaves, OL = older leaves.



**Fig. S8** Correlation between shoot dry weight and Na+ or K+ or Na+/K+ in leaves at different times in 2019–20. Abbreviations: DAFI = days after first inundation, DASI = days after second inundation, FL = flowering, AL = all leaves, YL = younger leaves, OL = older leaves.

****

**Fig. S9** Correlation between shoot dry weight and leaf chlorophyll content at different times during the growing season in 2018–19 (a–c) and 2019–20 (d–f). Abbreviations: DASI = days after second inundation, FL = flowering.