

Supplementary Material

Analysis of chlorophyll fluorescence parameters as predictors of biomass accumulation and tolerance to heat and drought stress of wheat (*Triticum aestivum*) plants

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Table S1. Values of morphometric parameters of 3-week-old wheat plants

Data are means \pm SEM. Different small letters following the data within the same column indicate significant differences (ANOVA followed by Tukey's test, $p < 0.05$). Values with the same letters are not significantly different. Values without letters within the same column are not significantly different

Cultivar	Shoot			Root		Plant (shoot+root)	
	Length (mm)	FW (mg)	DW (mg)	FW (mg)	DW (mg)	FW (mg)	DW (mg)
Astrid (1)	318.5 \pm 7.2 ^{abc}	250.5 \pm 20.4	21.2 \pm 2	62.2 \pm 5.1	8.2 \pm 2.1	312.7 \pm 23.6	29.4 \pm 3.9
Daria (2)	311.1 \pm 6.6 ^{ab}	257.3 \pm 26.4	20.7 \pm 2.5	65.5 \pm 6.0	7.9 \pm 2.2	322.9 \pm 31.8	28.6 \pm 4.6
Zauralskaya Volna (3)	355.3 \pm 7.4 ^c	269.3 \pm 9.6	24.2 \pm 0.8	66.3 \pm 4.7	8.7 \pm 1.9	335.6 \pm 13.6	32.9 \pm 2.4
Zauralskiy Yantar (4)	306.3 \pm 5.5 ^a	244.6 \pm 16.9	19.7 \pm 1.9	64.4 \pm 4.5	8.1 \pm 2.0	309.0 \pm 18.0	27.8 \pm 3.5
Zlata (5)	343 \pm 5.8 ^{cde}	285.8 \pm 17.4	24.2 \pm 1.9	67.0 \pm 5.7	7.7 \pm 1.9	352.7 \pm 21.3	31.9 \pm 3.7
Iren 2(6)	337.1 \pm 7.4 ^{bde}	268.4 \pm 23.4	22.0 \pm 2.2	58.6 \pm 7.9	9.1 \pm 3.0	327.0 \pm 30.3	31.1 \pm 5.0
Novosibirskaya 16 (7)	306.4 \pm 5.8 ^a	251.8 \pm 23.7	20.4 \pm 2.3	60.6 \pm 8.6	8.0 \pm 2.7	312.4 \pm 31.5	28.4 \pm 4.7
Sudarynya (8)	311.1 \pm 6.0 ^{ab}	253.3 \pm 18	20.6 \pm 1.7	56.6 \pm 6.8	7.8 \pm 2.1	309.8 \pm 25.5	28.3 \pm 3.6
Ulyanovskaya 105 (9)	336.1 \pm 4.3 ^{bde}	295.5 \pm 19.1	24.4 \pm 2.2	73.2 \pm 7.7	9.0 \pm 2.4	368.7 \pm 24.9	33.4 \pm 4.3
Happy (10)	319 \pm 4.8 ^{abd}	309.7 \pm 19.1	26.8 \pm 2.1	68.6 \pm 6.1	8.7 \pm 2.7	378.3 \pm 24.4	35.5 \pm 4.5

Table S2. Values of morphometric parameters of 6-week-old wheat plants

Data are means \pm SEM. Different small letters following the data within the same column indicate significant differences (ANOVA followed by Tukey's test, $p < 0.05$). Values with the same letters are not significantly different. Values without letters within the same column are not significantly different

Cultivar	Shoot			Root		Plant (shoot+root)	
	Length (mm)	FW (mg)	DW (mg)	FW (mg)	DW (mg)	FW (mg)	DW (mg)
Astrid (1)	408.8 \pm 9.0 ^{acf}	353.1 \pm 24	49.0 \pm 11.8	29.8 \pm 3.8	6.7 \pm 0.4	382.9 \pm 22	55.7 \pm 11.8
Daria (2)	370 \pm 14.7 ^a	332.8 \pm 39.7	41.0 \pm 9.8	43.6 \pm 3.7	7.7 \pm 0.1	376.4 \pm 40.4	48.7 \pm 9.9
Zauralskaya Volna (3)	433.1 \pm 13.9 ^{bdf}	404.1 \pm 32.2	65.3 \pm 15.6	48.8 \pm 7.2	10.3 \pm 1.0	452.9 \pm 27.3	75.6 \pm 14.6
Zauralskiy Yantar (4)	425 \pm 10.0 ^{bdf}	379.3 \pm 21.5	56.9 \pm 11.9	41.9 \pm 9.1	9.3 \pm 1.1	421.2 \pm 23	66.2 \pm 10.9
Zlata (5)	452.8 \pm 6.7 ^f	460.3 \pm 31	66.7 \pm 16.8	41.1 \pm 1.1	9.2 \pm 1.0	501.4 \pm 30.6	75.9 \pm 17.5
Iren 2(6)	437.4 \pm 10.7 ^{def}	386.1 \pm 61.5	49.7 \pm 4.2	31.9 \pm 6	7.2 \pm 0.5	418.1 \pm 67.3	56.8 \pm 3.8
Novosibirskaya 16 (7)	398.8 \pm 8.2 ^{abcde}	390.0 \pm 41.5	57.8 \pm 14.4	29.7 \pm 4.2	6.1 \pm 0.9	419.7 \pm 39.2	63.9 \pm 13.8
Sudarynya (8)	408.6 \pm 10.7 ^{acf}	336.0 \pm 15.2	54.5 \pm 10.1	30.6 \pm 2.7	8.3 \pm 1.3	366.6 \pm 16.8	62.8 \pm 11.3
Ulyanovskaya 105 (9)	388.6 \pm 8.1 ^{abc}	410.2 \pm 19.3	58.5 \pm 11.4	31.3 \pm 1.1	7.7 \pm 0.9	441.5 \pm 18.9	66.2 \pm 12.1
Happy (10)	423.1 \pm 8.5 ^{cf}	453.0 \pm 57	64.2 \pm 8.5	26.9 \pm 0.6	7.4 \pm 0.7	479.9 \pm 56.7	71.6 \pm 9.0

Table S3. Values of chlorophyll fluorescence parameters in 2-week-old wheat plants

Data are means \pm SEM. Different small letters following the data within the same column indicate significant differences (ANOVA followed by Tukey's test, $p < 0.05$). Values with the same letters are not significantly different

Cultivar	F_v/F_m	Φ_{PSIIef}	Φ_{PSIID}	$t_{1/2}(\Phi_{PSIIef})$	NPQ_{max}	NPQ_s	NPQ_d
Astrid (1)	0.770 \pm 0.002 ^{ac}	0.444 \pm 0.010 ^{ab}	0.719 \pm 0.003 ^{ac}	159.0 \pm 6.6 ^b	1.38 \pm 0.03 ^{abc}	0.84 \pm 0.03 ^{ac}	0.28 \pm 0.02 ^{ac}
Daria (2)	0.775 \pm 0.002 ^{ce}	0.465 \pm 0.009 ^{ab}	0.725 \pm 0.004 ^c	164.0 \pm 6.3 ^b	1.31 \pm 0.04 ^{ab}	0.76 \pm 0.03 ^{ab}	0.28 \pm 0.02 ^{ac}
Zauralskaya Volna (3)	0.774 \pm 0.001 ^{ce}	0.456 \pm 0.011 ^{ab}	0.724 \pm 0.002 ^{ac}	109.5 \pm 4.5 ^a	1.38 \pm 0.04 ^{abc}	0.89 \pm 0.05 ^{ac}	0.27 \pm 0.01 ^{ac}
Zauralskiy Yantar (4)	0.774 \pm 0.001 ^{ce}	0.452 \pm 0.009 ^{ab}	0.727 \pm 0.003 ^c	161.1 \pm 7.9 ^b	1.43 \pm 0.03 ^{bcd}	0.86 \pm 0.03 ^{ac}	0.27 \pm 0.02 ^{ac}
Zlata (5)	0.776 \pm 0.001 ^{de}	0.457 \pm 0.011 ^{ab}	0.724 \pm 0.003 ^{ac}	159.1 \pm 7.3 ^b	1.53 \pm 0.04 ^{cd}	0.91 \pm 0.05 ^{bc}	0.30 \pm 0.01 ^{bc}
Iren 2(6)	0.778 \pm 0.002 ^e	0.442 \pm 0.009 ^{ab}	0.742 \pm 0.002 ^c	174.9 \pm 9.4 ^b	1.57 \pm 0.03 ^d	0.96 \pm 0.03 ^c	0.23 \pm 0.02 ^a
Novosibirskaya 16 (7)	0.765 \pm 0.002 ^a	0.431 \pm 0.010 ^a	0.715 \pm 0.003 ^{ac}	155.9 \pm 6.9 ^b	1.42 \pm 0.04 ^{abcd}	0.90 \pm 0.04 ^{ac}	0.25 \pm 0.01 ^{ab}
Sudarynya (8)	0.774 \pm 0.001 ^{cef}	0.440 \pm 0.011 ^{ab}	0.726 \pm 0.002 ^c	158.8 \pm 7.6 ^b	1.39 \pm 0.04 ^{abc}	0.92 \pm 0.04 ^{bc}	0.27 \pm 0.01 ^{ac}
Ulyanovskaya 105 (9)	0.771 \pm 0.001 ^{acd}	0.453 \pm 0.010 ^{ab}	0.725 \pm 0.003 ^{cd}	131.9 \pm 6.9 ^{ab}	1.35 \pm 0.04 ^{ab}	0.91 \pm 0.05 ^{bc}	0.26 \pm 0.01 ^{ac}
Happy (10)	0.766 \pm 0.001 ^{ab}	0.475 \pm 0.007 ^b	0.712 \pm 0.002 ^{ab}	111.1 \pm 5.2 ^a	1.26 \pm 0.04 ^a	0.73 \pm 0.02 ^a	0.32 \pm 0.01 ^c

Table S4. Tolerance of wheat plants (expressed in % of dry weight of experimental plants in comparison with control ones) to heat and drought stress

Data are means \pm SEM. Different small letters following the data within the same column indicate significant differences (ANOVA followed by Tukey's test, $p < 0.05$). Values with the same letters are not significantly different. Values without letters within the same column are not significantly different

Cultivar	Tolerance index (30 min of heat stress, %)	Tolerance index (60 min of heat stress, %)	Tolerance index (1 week of drought, %)	Tolerance index (2 weeks of drought, %)
Astrid (1)	96.0 \pm 6.6	94.3 \pm 13.4	112.4 \pm 5.8	73.8 \pm 2.2 ^{abc}
Daria (2)	97.7 \pm 6.9	92.1 \pm 5.9	126.8 \pm 16.6	81.2 \pm 2.1 ^c
Zauralskaya Volna (3)	105.9 \pm 9.4	99.5 \pm 8.4	140.9 \pm 8.4	80.9 \pm 1.6 ^{bc}
Zauralskiy Yantar (4)	102.2 \pm 9.0	89.6 \pm 5.3	113.4 \pm 8.0	76.0 \pm 2.4 ^{abc}
Zlata (5)	107.5 \pm 7.0	95.9 \pm 11.4	116.0 \pm 5.1	69.7 \pm 3.9 ^{ab}
Iren 2(6)	105.9 \pm 4.6	104.0 \pm 9.5	107.6 \pm 5.0	67.0 \pm 1.7 ^a
Novosibirskaya 16 (7)	86.5 \pm 14.2	89.9 \pm 11.3	99.3 \pm 4.3	76.4 \pm 3.0 ^{abc}
Sudarynya (8)	93.0 \pm 11.1	95.6 \pm 11.4	111.2 \pm 9.1	76.8 \pm 1.3 ^{abc}
Ulyanovskaya 105 (9)	98.0 \pm 5.2	93.7 \pm 3.0	89.9 \pm 18.1	80.9 \pm 3.1 ^{bc}
Happy (10)	87.7 \pm 8.0	91.3 \pm 4.4	105.1 \pm 22.4	82.6 \pm 2.3 ^c

Table S5. Residual values of ChlF parameters (expressed in % of control) after heat treatment for 30 minutes

Data are means \pm SEM. Different small letters following the data within the same column indicate significant differences (ANOVA followed by Tukey's test, $p < 0.05$). Values with the same letters are not significantly different

Cultivar	F_v/F_m (%)	Φ_{PSIIef} (%)	Φ_{PSIIId} (%)	NPQ_{max} (%)	NPQ_s (%)	NPQ_d (%)
Astrid (1)	87.1 \pm 3.2 ^{ab}	82.0 \pm 4.5 ^{ab}	86.8 \pm 3.9 ^{ac}	74.1 \pm 5.0 ^{ab}	69.1 \pm 4.1 ^{ab}	83.9 \pm 7.3 ^{ab}
Daria (2)	76.8 \pm 4.9 ^a	70.2 \pm 6.7 ^a	73.1 \pm 5.3 ^a	50.8 \pm 4.9 ^a	51.4 \pm 4.3 ^a	63.9 \pm 5.8 ^{ab}
Zauralskaya Volna (3)	85.4 \pm 4.9 ^{ab}	82.7 \pm 6.8 ^{ab}	83.4 \pm 5.5 ^{ac}	68.1 \pm 6.4 ^{ab}	64.6 \pm 7.9 ^{ab}	95.4 \pm 12.3 ^{ab}
Zauralskiy Yantar (4)	95.7 \pm 0.8 ^b	95.3 \pm 1.8 ^b	94.4 \pm 0.9 ^{bc}	80.5 \pm 2.3 ^{ab}	72.6 \pm 3.4 ^{ab}	87.2 \pm 6.7 ^{ab}
Zlata (5)	85.5 \pm 4.2 ^{ab}	77.1 \pm 5.8 ^{ab}	83.2 \pm 4.7 ^{ac}	73.6 \pm 5.9 ^{ab}	79.8 \pm 4.0 ^{ab}	95.9 \pm 5.3 ^{ab}
Iren 2(6)	94.6 \pm 1.6 ^{ab}	89.0 \pm 2.9 ^{ab}	94.9 \pm 1.8 ^c	85.0 \pm 3.6 ^b	71.2 \pm 5.0 ^{ab}	53.8 \pm 3.6 ^a
Novosibirskaya 16 (7)	88.3 \pm 2.1 ^{ab}	84.1 \pm 3.4 ^{ab}	86.5 \pm 2.7 ^{ac}	66.7 \pm 3.0 ^{ab}	56.7 \pm 4.1 ^a	47.8 \pm 1.8 ^a
Sudarynya (8)	80.2 \pm 3.6 ^{ab}	68.1 \pm 4.4 ^a	78.1 \pm 4.1 ^{ac}	83.5 \pm 16.1 ^b	103.4 \pm 27.4 ^b	110.7 \pm 34.7 ^{ab}
Ulyanovskaya 105 (9)	77.7 \pm 4.8 ^{ab}	68.7 \pm 6.2 ^a	74.4 \pm 5.2 ^{ab}	71.3 \pm 7.1 ^{ab}	82.7 \pm 7.6 ^{ab}	121.3 \pm 17.6 ^b
Happy (10)	78.6 \pm 7.0 ^{ab}	73.0 \pm 8.4 ^{ab}	77.8 \pm 7.3 ^{ac}	78.8 \pm 7.3 ^{ab}	66.0 \pm 4.5 ^{ab}	91.9 \pm 15.5 ^{ab}

Table S6. Residual values of ChlF parameters (expressed in % of control) after 1-week drought treatment

Data are means \pm SEM. Different small letters following the data within the same column indicate significant differences (ANOVA followed by Tukey's test, $p < 0.05$). Values with the same letters are not significantly different. Values without letters within the same column are not significantly different

Cultivar	F_v/F_m (%)	Φ_{PSIIef} (%)	Φ_{PSIIId} (%)	NPQ_{max} (%)	NPQ_s (%)	NPQ_d (%)
Astrid (1)	100.7 \pm 0.5 ^{abc}	101.4 \pm 1.2 ^b	100.3 \pm 0.2 ^b	86.6 \pm 4.7 ^{abc}	111.7 \pm 6.7	104.7 \pm 10.0 ^{ac}
Daria (2)	99.8 \pm 0.4 ^a	99.5 \pm 1.5 ^{ab}	99.80.3 ^{ab}	124.0 \pm 14.3 ^{bc}	108.2 \pm 4.9	92.1 \pm 7.2 ^a
Zauralskaya Volna (3)	100.4 \pm 0.4 ^{ab}	101.8 \pm 1.6 ^b	100.5 \pm 0.2 ^b	139.1 \pm 39.7 ^c	101.2 \pm 4.9	100.8 \pm 11.2 ^{ac}
Zauralskiy Yantar (4)	99.9 \pm 0.4 ^a	100.5 \pm 1.1 ^{ab}	100.1 \pm 0.2 ^b	105.4 \pm 16.3 ^{abc}	107.8 \pm 5.4	123.3 \pm 13.9 ^{ac}
Zlata (5)	102.7 \pm 0.4 ^c	98.7 \pm 2.0 ^{ab}	100.1 \pm 0.3 ^b	54.1 \pm 2.1 ^{ab}	123.0 \pm 5.5	147.9 \pm 14.0 ^{bc}
Iren 2(6)	99.7 \pm 0.8 ^a	92.4 \pm 3.7 ^a	98.0 \pm 0.9 ^a	68.4 \pm 2.1 ^{abc}	123.0 \pm 5.6	150.4 \pm 13.5 ^c
Novosibirskaya 16 (7)	100.0 \pm 0.5 ^{ab}	101.5 \pm 1.7 ^b	99.9 \pm 0.4 ^b	124.4 \pm 23.8 ^{bc}	110.1 \pm 5.9	95.9 \pm 8.1 ^{ab}
Sudarynya (8)	100.6 \pm 0.3 ^{ab}	102.0 \pm 1.9 ^b	100.3 \pm 0.3 ^b	71.8 \pm 3.2 ^{abc}	102.9 \pm 5.2	122.6 \pm 10.7 ^{ac}
Ulyanovskaya 105 (9)	102.1 \pm 0.4 ^{bc}	106.0 \pm 1.1 ^b	100.6 \pm 0.3 ^b	41.6 \pm 1.4 ^a	107.0 \pm 3.8	126.0 \pm 14.1 ^{ac}
Happy (10)	100.2 \pm 0.4 ^{ab}	102.7 \pm 1.7 ^b	99.9 \pm 0.5 ^b	95.4 \pm 5.5 ^{abc}	105.7 \pm 5.3	110.6 \pm 9.8 ^{ac}

Table S7. Residual values of ChlF parameters (expressed in % of control) after heat treatment for 60 minutes

Data are means \pm SEM. Different small letters following the data within the same column indicate significant differences (ANOVA followed by Tukey's test, $p < 0.05$). Values with the same letters are not significantly different

Cultivar	F_v/F_m (%)	Φ_{PSIIef} (%)	Φ_{PSIIId} (%)	NPQ_{max} (%)	NPQ_s (%)	NPQ_d (%)
Astrid (1)	74.4 \pm 6.4 ^{ab}	69.3 \pm 7.8 ^{ab}	73.0 \pm 6.8 ^{ab}	62.5 \pm 8.1 ^{ab}	69.8 \pm 13.2 ^{ab}	96.0 \pm 20.8 ^{ab}
Daria (2)	59.3 \pm 3.7 ^a	44.9 \pm 4.4 ^a	54.3 \pm 4.1 ^a	32.8 \pm 3.8 ^a	43.2 \pm 5.0 ^a	52.4 \pm 6.5 ^a
Zauralskaya Volna (3)	79.2 \pm 5.3 ^{ab}	74.3 \pm 7.1 ^{ab}	76.8 \pm 5.4 ^{ab}	76.9 \pm 10.8 ^b	93.7 \pm 15.5 ^b	170.7 \pm 35.7 ^b
Zauralskiy Yantar (4)	83.8 \pm 4.1 ^b	80.4 \pm 5.1 ^b	82.3 \pm 4.2 ^b	69.8 \pm 5.2 ^b	60.9 \pm 3.7 ^{ab}	71.6 \pm 3.2 ^a
Zlata (5)	81.0 \pm 4.6 ^{ab}	71.5 \pm 5.3 ^{ab}	78.2 \pm 4.6 ^{ab}	66.9 \pm 5.9 ^{ab}	75.6 \pm 5.0 ^{ab}	88.4 \pm 5.0 ^a
Iren 2(6)	90.5 \pm 3.1 ^b	85.0 \pm 4.4 ^b	89.4 \pm 3.5 ^b	80.2 \pm 4.7 ^b	67.9 \pm 3.2 ^{ab}	63.8 \pm 2.5 ^a
Novosibirskaya 16 (7)	82.2 \pm 4.8 ^{ab}	84.6 \pm 7.2 ^b	81.1 \pm 5.1 ^b	61.7 \pm 6.6 ^{ab}	46.3 \pm 3.5 ^a	60.4 \pm 12.5 ^a
Sudarynya (8)	68.9 \pm 6.9 ^{ab}	59.2 \pm 8.0 ^{ab}	68.0 \pm 7.1 ^{ab}	62.6 \pm 13.8 ^{ab}	72.9 \pm 21.7 ^{ab}	68.6 \pm 27.0 ^a
Ulyanovskaya 105 (9)	74.8 \pm 6.7 ^{ab}	69.8 \pm 7.9 ^{ab}	73.0 \pm 6.8 ^{ab}	69.0 \pm 7.6 ^b	72.2 \pm 6.6 ^{ab}	102.7 \pm 13.1 ^{ab}
Happy (10)	71.3 \pm 6.1 ^{ab}	67.6 \pm 7.9 ^{ab}	69.0 \pm 6.4 ^{ab}	53.6 \pm 7.5 ^{ab}	44.9 \pm 4.2 ^a	71.4 \pm 5.5 ^a

Table S8. Residual values of ChlF parameters (expressed in % of control) after 2-week drought treatment

Data are means \pm SEM. Different small letters following the data within the same column indicate significant differences (ANOVA followed by Tukey's test, $p < 0.05$). Values with the same letters are not significantly different. Values without letters within the same column are not significantly different

Cultivar	F_v/F_m (%)	Φ_{PSIIef} (%)	Φ_{PSIIId} (%)	NPQ_{max} (%)	NPQ_s (%)	NPQ_d (%)
Astrid (1)	69.0 \pm 6.0 ^{ab}	41.5 \pm 5.1 ^{ab}	67.1 \pm 6.3 ^{ab}	91.1 \pm 10.2 ^b	127.8 \pm 15.1 ^{ab}	71.1 \pm 4.8
Daria (2)	82.3 \pm 4.4 ^b	52.8 \pm 5.3 ^b	80.6 \pm 4.8 ^b	102.8 \pm 9.5 ^b	144.7 \pm 11.8 ^b	76.4 \pm 6.3
Zauralskaya Volna (3)	75.0 \pm 5.3 ^b	46.1 \pm 5.2 ^b	73.1 \pm 5.5 ^b	90.9 \pm 7.7 ^b	135.0 \pm 11.3 ^b	88.5 \pm 6.9
Zauralskiy Yantar (4)	72.3 \pm 5.0 ^b	42.0 \pm 4.4 ^{ab}	70.8 \pm 5.4 ^b	79.5 \pm 8.6 ^{ab}	120.6 \pm 12.9 ^{ab}	72.0 \pm 4.2
Zlata (5)	84.3 \pm 4.5 ^b	50.7 \pm 4.5 ^b	84.1 \pm 4.7 ^b	94.5 \pm 7.3 ^b	152.1 \pm 11.9 ^b	78.3 \pm 5.4
Iren 2(6)	51.9 \pm 6.6 ^a	25.9 \pm 3.1 ^a	43.6 \pm 6.5 ^a	49.1 \pm 8.1 ^a	75.9 \pm 13.2 ^a	70.3 \pm 6.7
Novosibirskaya 16 (7)	66.2 \pm 6.6 ^{ab}	38.8 \pm 4.9 ^{ab}	64.5 \pm 6.7 ^{ab}	77.0 \pm 8.8 ^{ab}	118.9 \pm 14.3 ^{ab}	82.2 \pm 5.0
Sudarynya (8)	77.5 \pm 5.3 ^b	50.2 \pm 5.1 ^b	76.3 \pm 5.6 ^b	92.2 \pm 7.4 ^b	124.0 \pm 10.1 ^{ab}	78.9 \pm 4.7
Ulyanovskaya 105 (9)	79.7 \pm 4.9 ^b	47.7 \pm 4.9 ^b	78.7 \pm 5.2 ^b	107.9 \pm 8.6 ^b	145.0 \pm 12.1 ^b	68.9 \pm 5.7
Happy (10)	76.6 \pm 5.4 ^b	50.0 \pm 5.3 ^b	75.2 \pm 5.7 ^b	96.6 \pm 8.1 ^b	138.0 \pm 13.0 ^b	65.8 \pm 3.4