

Supplementary material

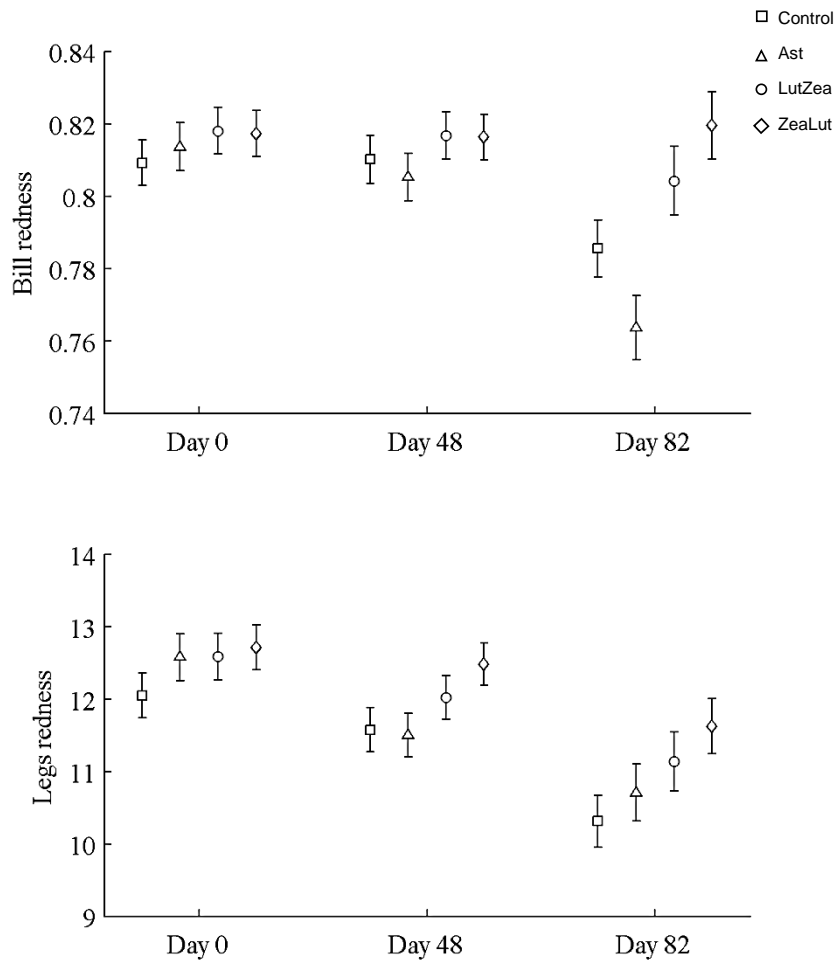


Figure 1SM: Changes in ornament coloration during the experiment depending on the carotenoid treatment. Least squared means \pm se were obtained from the models (see Methods and table 1).

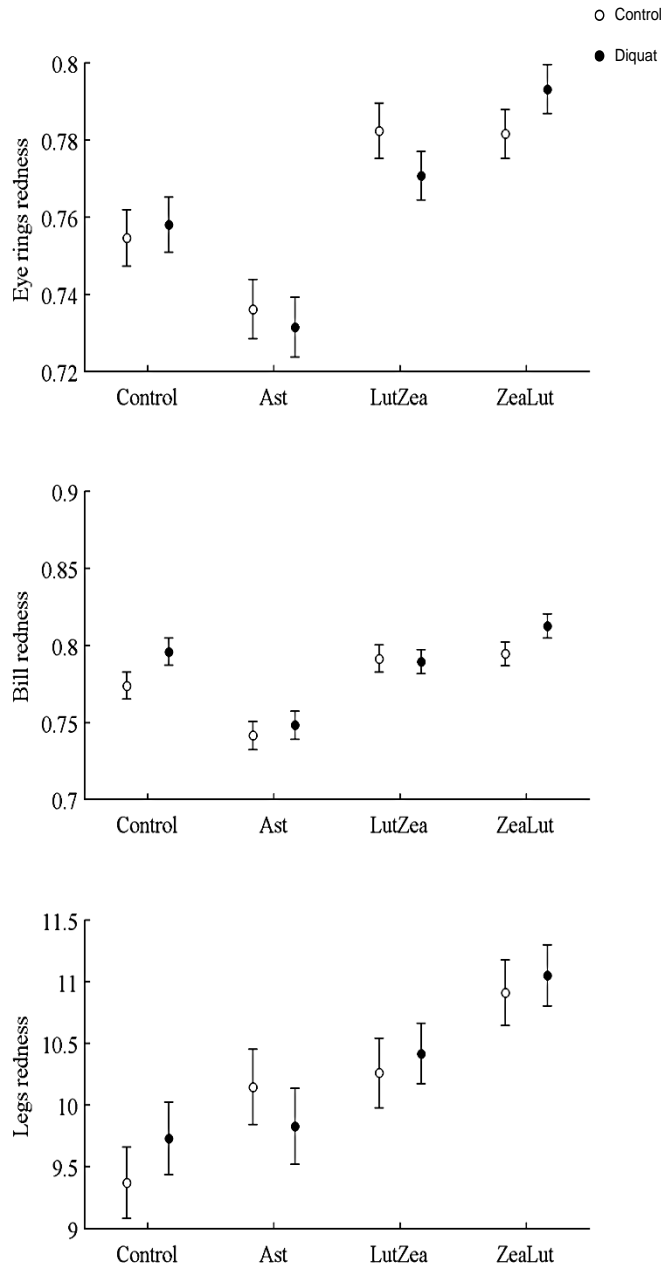


Figure 2SM: Changes in ornament coloration after diquat exposure depending on the carotenoid treatment. Least squared means \pm se from the models (see Methods and table 3).

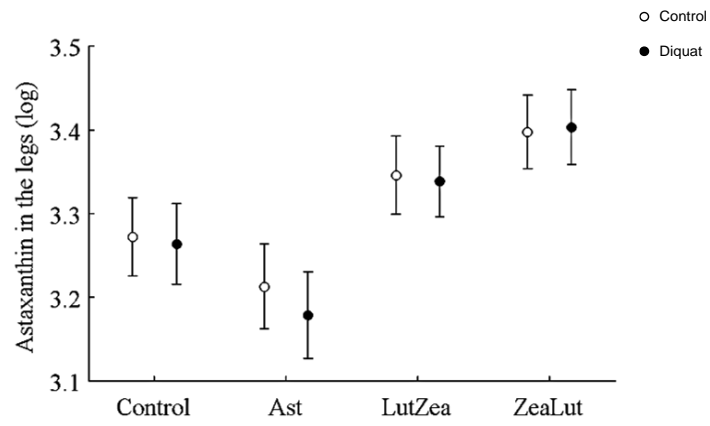


Figure 3SM: Levels of astaxanthin in the legs after diquat exposure depending on the carotenoid treatment. Least squared means \pm se from the models (see Methods and table 3).

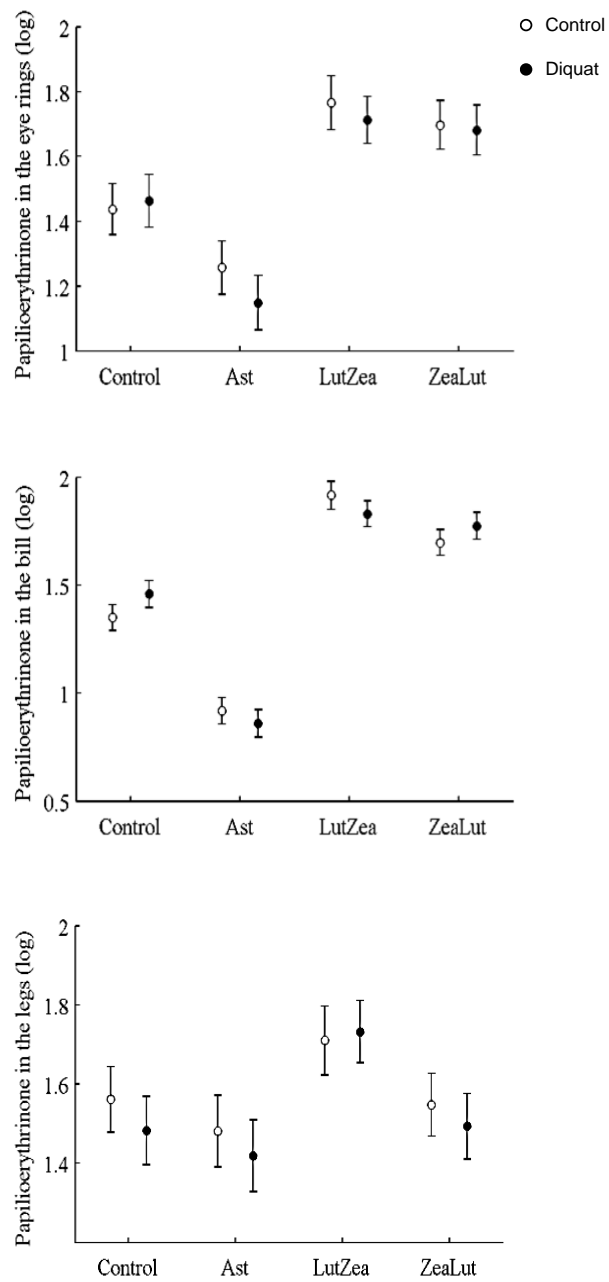


Figure 4SM: Levels of papilioerythrinone in the three ornaments after diquat exposure depending on the carotenoid treatment. Least squared means \pm se from the models (see Methods and table 3).

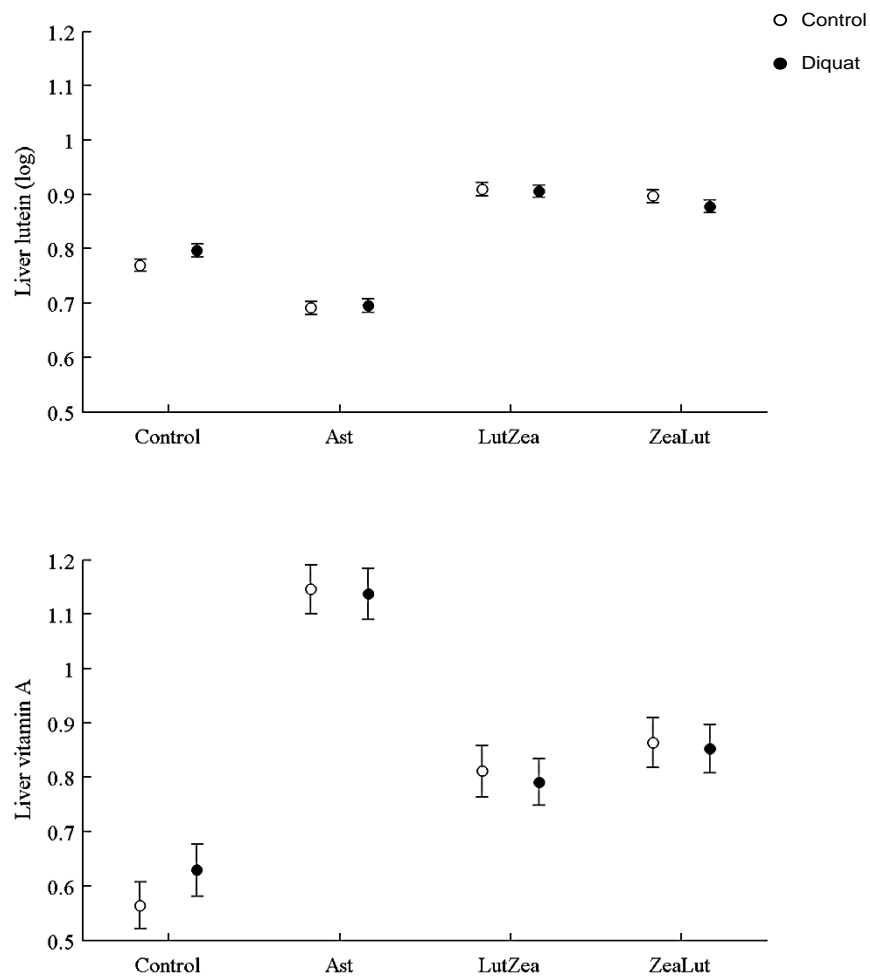


Figure 5SM: Levels of lutein and total vitamin A (free and esterified retinol) in liver after diquat exposure depending on the carotenoid treatment. Least squared means \pm se from the models (Methods and table 3).

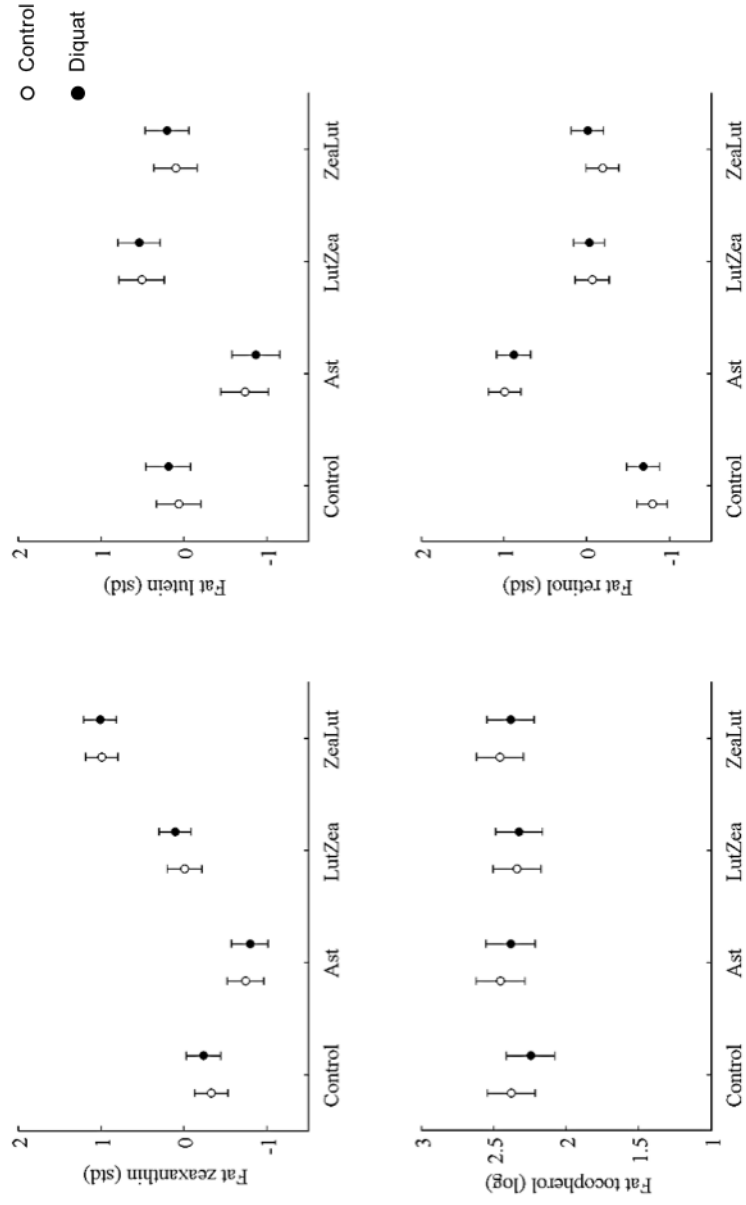


Figure 6SM: Levels of carotenoids and vitamins in subcutaneous fat after diquat exposure depending on the carotenoid treatment. Least squared means \pm se from the models (see Methods and table 3).

Table 15M: Raw data for carotenoids and vitamins (nmol/ml) in plasma throughout the study. The effects were provided by the models (see table 2). TxC: Time x carotenoid interaction; ns: No significant differences ($p > 0.10$). Sample size: time 0: N= 173; time 48: N= 173; and time 82: N= 86 (in time 82, diquat birds were discarded, see methods).

	Time	Control (mean \pm sd)	Ast (mean \pm sd)	LutZea (mean \pm sd)	Zealut (mean \pm sd)	Effect
Lutein	0	22.57 \pm 5.45	21.52 \pm 5.54	20.34 \pm 6.42	20.16 \pm 6.38	
	48	10.68 \pm 2.87	6.56 \pm 1.48	16.09 \pm 6.10	12.65 \pm 3.98	TxC
	82	9.48 \pm 1.69	6.52 \pm 0.75	16.86 \pm 3.55	13.74 \pm 2.45	
Zeaxanthin	0	10.96 \pm 2.32	10.64 \pm 1.74	10.33 \pm 2.46	10.06 \pm 2.30	
	48	7.64 \pm 1.99	6.25 \pm 1.58	13.37 \pm 5.13	24.37 \pm 9.20	TxC
	82	6.74 \pm 1.07	6.59 \pm 0.93	13.56 \pm 3.28	25.88 \pm 5.07	
Tocopherol	0	22.35 \pm 9.67	22.73 \pm 6.66	21.18 \pm 8.15	21.37 \pm 9.49	
	48	9.08 \pm 3.29	9.30 \pm 3.24	10.50 \pm 4.65	11.83 \pm 4.70	TxC
	82	11.02 \pm 2.68	11.02 \pm 2.56	12.60 \pm 3.63	14.91 \pm 3.99	
Retinol	0	23.89 \pm 3.22	24.05 \pm 4.21	24.08 \pm 4.45	22.92 \pm 3.57	
	48	22.11 \pm 3.42	23.32 \pm 3.62	23.78 \pm 4.56	23.80 \pm 4.49	ns
	82	25.74 \pm 4.71	27.59 \pm 4.44	27.01 \pm 3.94	27.42 \pm 4.38	

Table 2SM: Raw data for carotenoids and vitamins (nmol/g) in ornaments after the diquat exposure. The effects were provided by the models (see tables 3 and 4). C: Group of carotenoid supplement; DxC: Diquat x carotenoid interaction; D: Diquat treatment; S: Sex

		Control (mean ± sd)	Ast (mean ± sd)	LutZea (mean ± sd)	ZeaLut (mean ± sd)	Effect	
Eye rings	<i>Astaxanthin</i>	Control	66.68 ± 38.04	69.64 ± 28.80	113.57 ± 63.17	168.45 ± 74.50	
		Diquat	61.52 ± 32.93	44.31 ± 20.24	103.46 ± 53.79	225.62 ± 141.05	DxC
	<i>Papilioerythrinone</i>	Control	7.63 ± 4.31	3.73 ± 2.42	16.59 ± 8.45	12.91 ± 5.26	C, S
		Diquat	6.30 ± 3.77	2.69 ± 2.01	16.65 ± 10.20	16.60 ± 10.55	
	<i>Tocopherol</i>	Control	63.91 ± 69.12	62.12 ± 23.49	45.10 ± 18.32	54.61 ± 20.44	DxC
		Diquat	39.21 ± 15.31	50.25 ± 16.65	45.48 ± 14.22	58.56 ± 19.50	
Bill	<i>Astaxanthin</i>	Control	156.80 ± 76.32	100.93 ± 36.08	373.51 ± 148.63	444.05 ± 287.12	DxC
		Diquat	148.61 ± 75.94	102.73 ± 50.98	224.45 ± 106.71	517.99 ± 276.06	
	<i>Papilioerythrinone</i>	Control	15.10 ± 9.85	6.02 ± 3.87	52.31 ± 31.08	26.06 ± 14.90	C, S
		Diquat	13.08 ± 6.36	4.72 ± 2.84	35.03 ± 24.01	32.67 ± 15.41	
	<i>Tocopherol</i>	Control	84.42 ± 20.90	88.06 ± 23.40	91.98 ± 26.96	82.22 ± 26.64	DxC
		Diquat	65.46 ± 25.05	87.06 ± 28.84	71.20 ± 30.59	89.90 ± 28.68	
Legs	<i>Astaxanthin</i>	Control	49.07 ± 41.32	41.68 ± 25.82	71.45 ± 22.61	106.47 ± 70.17	C, S
		Diquat	36.64 ± 24.77	40.88 ± 49.75	60.27 ± 41.63	107.89 ± 70.37	
	<i>Papilioerythrinone</i>	Control	6.07 ± 3.75	4.41 ± 2.77	10.25 ± 2.55	8.29 ± 4.32	C, S
		Diquat	5.12 ± 2.47	3.51 ± 4.48	9.71 ± 5.74	8.97 ± 7.54	
	<i>Tocopherol</i>	Control	53.78 ± 15.96	54.68 ± 11.53	46.26 ± 12.59	54.69 ± 16.50	C, S
		Diquat	47.31 ± 12.84	48.53 ± 16.14	48.85 ± 16.19	55.73 ± 19.75	

Table 3SM: Raw data for carotenoids and vitamins in plasma (nmol/mL), liver and fat (nmol/g) after the diquat exposure. The effects were provided by the models (see tables 3 and 4). C: Group of carotenoid supplement; Dx: Diquat x carotenoid interaction; S: Sex; ns: No significant differences.

		Control (mean ± sd)	Ast (mean ± sd)	LutZea (mean ± sd)	Zealut (mean ± sd)	Effect
Plasma	Lutein	Control	9.48 ± 1.69	6.52 ± 0.75	16.86 ± 3.55	13.74 ± 2.45
		Diquat	9.45 ± 1.66	6.55 ± 0.77	15.03 ± 4.23	12.80 ± 2.67
	Zeaxanthin	Control	6.74 ± 1.07	6.59 ± 0.93	13.56 ± 3.28	25.88 ± 5.07
		Diquat	6.79 ± 1.09	6.82 ± 1.31	12.66 ± 4.46	24.52 ± 6.12
	Retinol	Control	25.74 ± 4.71	27.59 ± 4.44	27.01 ± 3.94	27.42 ± 4.38
		Diquat	24.71 ± 4.41	26.07 ± 3.94	26.86 ± 3.02	27.45 ± 4.19
	Tocopherol	Control	11.02 ± 2.68	11.02 ± 2.56	12.60 ± 3.63	14.91 ± 3.99
		Diquat	9.46 ± 3.65	11.14 ± 4.04	11.97 ± 3.95	13.71 ± 3.89
	Lutein	Control	5.75 ± 0.49	4.86 ± 0.36	8.31 ± 1.54	8.82 ± 1.99
		Diquat	5.70 ± 0.63	4.83 ± 0.39	8.14 ± 1.80	8.20 ± 2.22
	Zeaxanthin	Control	4.16 ± 0.34	4.11 ± 0.48	6.52 ± 1.23	14.21 ± 3.80
		Diquat	4.11 ± 0.38	4.12 ± 0.53	6.29 ± 1.35	12.84 ± 4.45
Total vitamin A	Control	389.28 ± 245.49	1392.40 ± 490.99	679.07 ± 237.45	814.33 ± 325.32	
	Diquat	449.32 ± 297.65	1374.66 ± 682.11	618.66 ± 269.50	765.81 ± 399.72	
Tocopherol	Control	6.02 ± 1.69	6.67 ± 2.67	6.75 ± 2.66	9.03 ± 2.52	
	Diquat	4.71 ± 1.05	6.45 ± 2.68	6.65 ± 2.63	8.10 ± 3.76	
Lutein	Control	17.74 ± 12.92	21.78 ± 13.77	25.31 ± 12.53	18.54 ± 13.63	
	Diquat	18.19 ± 11.16	19.95 ± 9.77	20.79 ± 16.24	21.46 ± 13.70	
Zeaxanthin	Control	11.56 ± 8.25	15.37 ± 9.46	16.30 ± 7.63	16.07 ± 11.12	
	Diquat	11.98 ± 7.17	14.43 ± 6.98	13.89 ± 10.51	18.75 ± 11.71	
Retinol	Control	87.09 ± 64.70	196.73 ± 108.90	149.17 ± 79.36	108.26 ± 86.98	
	Diquat	98.36 ± 65.76	179.52 ± 99.98	116.00 ± 99.21	131.30 ± 90.95	
Tocopherol	Control	381.21 ± 392.46	489.32 ± 599.44	328.65 ± 297.64	319.61 ± 260.11	
	Diquat	267.97 ± 283.51	396.92 ± 341.49	318.61 ± 378.15	373.70 ± 384.49	

Table 4SM: Raw data for oxidative stress biomarkers in blood and other tissues at the end of the study after diquat treatment. The effects were provided by the models (see tables 3 and 4). C: Group of carotenoid supplement; D: Diquat treatment; DXcXS; Diquat x carotenoid x sex interaction; DxS: Diquat x Sex interaction.

	Sex	Control (mean ± sd)	Ast (mean ± sd)	LutZea (mean ± sd)	Zealut (mean ± sd)	Effect
Resistance to oxidative stress in erythrocytes (min)	Control	101.38 ± 10.4	106.25 ± 11.89	103.67 ± 12.093	103.13 ± 11.64	D
	Diquat	100.2 ± 11.7	97.211 ± 10.04	100 ± 8.56	99.3 ± 9.739	
Plasma TRG-MDA-corrected (µM)	Male	Control	3.387 ± 0.687	2.954 ± 0.573	3.311 ± 0.490	3.458 ± 0.965
		Diquat	3.879 ± 0.521	3.840 ± 0.475	4.057 ± 0.503	4.102 ± 0.824
	Female	Control	3.660 ± 2.374	3.012 ± 0.514	3.114 ± 0.543	3.408 ± 0.615
		Diquat	4.619 ± 1.894	4.330 ± 1.550	4.159 ± 1.337	4.517 ± 2.523
UA-ALB-corrected PLAOX (mmol/L)	Male	Control	0.008 ± 0.089	0.079 ± 0.125	-0.038 ± 0.103	-0.026 ± 0.102
		Diquat	0.020 ± 0.072	0.104 ± 0.114	0.007 ± 0.080	-0.036 ± 0.097
	Female	Control	0.001 ± 0.160	-0.008 ± 0.091	-0.047 ± 0.078	-0.011 ± 0.176
		Diquat	-0.004 ± 0.076	0.060 ± 0.224	-0.043 ± 0.042	-0.043 ± 0.067
Liver MDA (µmol/g)	Male	Control	0.026 ± 0.007	0.023 ± 0.006	0.026 ± 0.005	0.024 ± 0.005
		Diquat	0.023 ± 0.006	0.023 ± 0.007	0.025 ± 0.007	0.026 ± 0.007
	Female	Control	0.025 ± 0.007	0.034 ± 0.010	0.033 ± 0.014	0.028 ± 0.004
		Diquat	0.032 ± 0.006	0.030 ± 0.012	0.024 ± 0.007	0.028 ± 0.010
Heart MDA (µmol/g)	Control	0.025 ± 0.005	0.023 ± 0.007	0.027 ± 0.01	0.026 ± 0.011	
	Diquat	0.024 ± 0.005	0.027 ± 0.005	0.023 ± 0.006	0.024 ± 0.005	