

Table S1. Mean performance of all genotypes under high-N and low- N across two years for studied traits.

Genotypes	NUE (g/g)		NUPE (g/g)		NUTE (g/g)		GPS	
	High-N	Low-N	High-N	Low-N	High-N	Low-N	High-N	Low-N
Parents								
L25	14.16	31.76	16.97	30.77	0.84	1.03	91.29	81.02
L26	16.80	33.64	18.88	36.87	0.89	0.91	87.50	76.85
L27	15.96	32.86	17.63	30.82	0.91	1.07	96.02	89.08
Gem7	13.89	22.99	15.26	22.30	0.92	1.03	67.80	61.94
Gem9	13.77	22.40	13.88	16.97	1.03	1.32	69.52	51.68
Giza168	13.74	24.57	13.38	23.48	1.04	1.06	69.25	58.28
Parents average	14.72	28.04	16.00	26.87	0.94	1.07	80.23	69.81
F₁ crosses								
L25 × L26	16.50	33.68	17.81	30.46	0.93	1.11	90.44	77.21
L25 × L27	13.79	32.80	16.86	28.24	0.82	1.16	96.12	90.69
L25 × Gem7	13.71	30.62	16.52	30.47	0.84	1.01	85.24	71.20
L25 × Gem9	14.32	25.06	16.40	30.37	0.88	0.83	65.59	76.98
L25 × Gz168	14.80	31.84	16.85	34.67	0.88	0.92	73.27	67.08
L26 × L27	17.20	34.39	19.37	39.32	0.89	0.88	77.46	78.62
L26 × Gem7	15.76	28.35	19.47	31.36	0.81	0.91	81.41	72.32
L26 × Gem9	16.47	26.26	16.78	33.92	0.99	0.78	72.40	57.86
L26 × Gz168	17.94	27.59	15.81	30.65	1.14	0.90	86.58	59.36
L27 × Gem7	18.35	30.19	13.84	25.00	1.33	1.22	85.30	83.13
L27 × Gem9	15.89	25.68	12.92	36.03	1.23	0.71	87.72	71.63
L27 × Gz168	16.36	29.65	16.16	24.11	1.02	1.23	85.29	79.29
Gem7 × Gem9	13.31	22.22	15.41	20.92	0.86	1.08	68.73	57.52
Gem7 × Gz168	15.27	23.74	14.59	25.96	1.05	0.92	69.81	70.05
Gem9 × Gz168	13.95	25.91	13.31	19.96	1.05	1.31	73.85	63.47
F ₁ 's average	15.57	28.53	16.14	29.43	0.98	1.00	79.95	71.76
F₂ crosses								
L25 × L26	13.88	31.22	18.17	31.75	0.76	1.03	87.17	66.98
L25 × L27	12.80	32.61	19.38	34.27	0.67	0.90	92.23	77.73
L25 × Gem7	12.47	29.82	20.74	31.18	0.61	0.93	86.88	72.38
L25 × Gem9	12.28	19.95	15.20	32.79	0.81	0.75	65.77	69.50
L25 × Gz168	14.48	27.27	17.09	32.30	0.86	1.07	67.96	66.31
L26 × L27	15.49	25.33	19.89	30.22	0.79	1.03	72.21	72.38
L26 × Gem7	12.82	29.33	22.38	31.48	0.57	0.85	76.69	77.28
L26 × Gem9	13.63	27.49	19.30	37.29	0.72	0.67	65.84	51.14
L26 × Gz168	17.02	30.03	17.92	38.98	0.95	0.90	70.87	55.66
L27 × Gem7	15.90	24.51	16.84	33.54	0.95	0.92	77.33	56.94
L27 × Gem9	12.87	25.02	17.17	25.12	0.75	1.00	83.33	72.06
L27 × Gz168	14.01	29.16	18.40	23.75	0.76	1.18	77.69	60.77
Gem7 × Gem9	13.58	23.93	13.25	21.40	1.03	1.22	61.89	74.07
Gem7 × Gz168	11.74	22.79	11.82	23.28	1.00	1.09	62.25	46.16
Gem9 × Gz168	12.77	25.18	9.37	22.23	1.38	1.22	69.02	52.42
F ₂ 's average	13.72	26.91	17.13	29.97	0.84	0.98	74.48	64.79
LSD 0.05 (G)	1.10	2.60	0.98	3.20	0.09	0.15	2.00	2.10
(N)		3.20		8.15		0.24		4.00
(GN)		2.00		2.50		0.15		2.10

Table S1. (Continued)

Genotypes	100-GW (g)		SPP		GYPP (g)		HI (%)	
	High-N	Low-N	High-N	Low-N	High-N	Low-N	High-N	Low-N
Parents								
L25	5.58	4.57	13.43	10.83	26.48	25.39	39.74	41.06
L26	5.22	4.37	12.43	10.93	31.42	26.91	45.95	44.16
L27	5.17	4.92	12.22	10.85	29.86	26.28	45.61	45.11
Gem7	3.90	3.62	11.75	5.90	25.96	18.37	42.84	42.82
Gem9	3.99	3.40	10.52	7.32	25.76	17.89	40.79	33.49
Giza168	4.10	3.42	10.93	8.85	25.71	19.65	47.12	37.77
Parents average	4.66	4.05	11.88	9.11	27.53	22.42	43.68	40.74
F₁ crosses								
L25 × L26	6.35	4.36	13.58	9.88	30.86	26.94	46.32	43.97
L25 × L27	5.28	5.34	15.12	10.10	25.78	26.23	39.92	45.03
L25 × Gem 7	4.54	3.51	13.13	7.30	25.62	24.50	40.33	55.78
L25 × Gem 9	3.72	3.74	12.53	9.03	26.79	20.06	41.02	42.76
L25 × Gz168	3.67	3.31	11.82	9.83	27.65	25.46	42.11	42.04
L 26 × L 27	5.51	4.76	13.60	12.57	32.16	27.52	44.94	44.23
L26 × Gem 7	3.72	3.37	11.65	9.43	29.49	22.68	40.21	36.93
L 26 × Gem 9	4.25	3.60	11.38	9.03	30.81	21.00	45.27	35.86
L 26 × Gz168	3.81	3.27	12.62	8.23	33.55	22.07	49.39	36.13
L 27 × Gem 7	3.64	3.56	11.55	8.67	34.32	24.16	55.52	43.60
L 27 × Gem 9	4.40	4.42	10.65	9.88	29.74	20.56	45.70	33.64
L27 × Gz168	4.47	4.33	13.22	8.88	30.59	23.74	45.37	38.12
Gem 7 × Gem 9	3.64	3.38	11.65	8.07	24.88	17.78	40.61	35.18
Gem 7 × Gz168	4.41	3.28	10.13	7.37	28.56	18.99	51.73	33.05
Gem 9 × Gz168	3.60	3.40	9.28	8.80	26.09	20.73	48.12	41.39
F ₁ 's average	4.33	3.84	12.13	9.14	29.13	22.83	45.10	40.51
F₂ crosses								
L25 × L26	4.63	3.21	14.72	10.63	25.96	24.97	42.52	42.62
L25 × L27	4.35	3.70	14.27	10.15	23.94	26.09	41.09	48.33
L25 × Gem 7	3.58	2.93	12.92	6.83	23.33	23.88	39.97	53.21
L25 × Gem 9	3.53	3.45	13.88	7.32	22.97	15.97	35.88	36.20
L25 × Gz168	2.35	2.49	13.78	7.57	27.08	21.75	42.14	35.30
L 26 × L 27	4.34	2.60	13.15	11.53	28.97	20.25	44.48	34.09
L26 × Gem 7	2.99	2.00	12.63	6.75	23.95	23.51	36.58	40.19
L 26 × Gem 9	2.92	2.94	12.03	6.27	25.45	22.04	44.14	40.99
L 26 × Gz168	3.45	2.31	13.32	6.52	31.84	24.03	54.07	43.71
L 27 × Gem 7	3.36	2.58	13.30	7.08	29.74	19.62	56.26	37.25
L 27 × Gem 9	3.82	3.24	11.42	5.27	24.07	20.07	40.37	35.27
L27 × Gz168	3.34	1.96	13.62	5.03	26.21	23.39	43.90	44.32
Gem 7 × Gem 9	2.38	1.62	13.32	4.95	25.41	19.18	45.78	46.85
Gem 7 × Gz168	2.46	1.94	11.63	6.13	21.97	18.25	41.39	34.01
Gem 9 × Gz168	3.05	2.22	10.27	7.68	23.88	20.16	43.98	48.25
F ₂ 's average	3.37	2.61	12.95	7.31	25.65	21.54	43.50	41.37
LSD 0.05 (G)	0.49	0.39	0.94	0.87	2.10	2.00	3.80	4.00
(N)		0.80		1.30		2.50		3.00
(GN)		0.45		1.50		2.04		3.90

SPP: spikes/plant, GPS: grains/spike, 100-GW: 100-grain weight, GYPP: grain yield/plant, HI: harvest index, NUE: nitrogen use efficiency, NUPE: nitrogen uptake efficiency, NUTE: nitrogen utilization efficiency.

Table S2. Estimates of general combining ability effects ($\hat{g}_i$) of all traits in F_1 and F_2 diallel crosses under high-N and low-N conditions across two seasons.

Parents	High-N		Low-N		High-N		Low-N	
	F ₁	F ₂	F ₁	F ₂	F ₁	F ₂	F ₁	F ₂
	NUE				NUPE			
L25	-0.74*	-2.97*	2.35**	1.72**	0.71*	-0.47*	2.21*	2.22*
L26	1.27*	1.10	2.35**	2.51**	1.79*	1.05*	5.17**	5.32*
L27	0.77*	1.56*	2.46**	1.46*	0.21	0.62*	2.03**	0.64
Gem 7	-0.39*	0.1	-2.20**	-1.78**	-0.29	-0.47*	-2.47*	-1.94*
Gem 9	-0.73*	-1.64*	-3.60**	-3.03	-1.27**	-0.668*	-4.94**	-3.37**
Giza 168	-0.19	1.86*	-1.36**	-0.88*	-1.15*	-0.063*	-2.00*	-2.87*
SE _{gi}	0.23	0.73	0.5	0.53	0.19	0.23	0.63	0.8
SE _{gi-gj}	0.36	1.13	0.83	0.82	0.3	0.36	0.98	1.24
	NUTE				SPP			
L25	-0.10*	0.86**	-0.14*	-0.04	1.01**	1.20**	0.49*	1.17**
L26	-0.03*	2.22**	-0.23*	-0.09*	0.36*	0.41*	0.89*	1.1**
L27	0.04*	1.16**	-0.11*	0.01	0.73*	0.12	0.98**	0.75*
Gem 7	-0.01	-0.26	-0.13*	0.001	-0.45*	-0.17	-1.41**	-1.41**
Gem 9	0.04*	-1.95*	0.71*	0.05	-1.04*	-0.70**	-0.56*	-1.1**
Giza 168	0.05*	-2.04**	-0.10*	0.07*	-0.61*	-0.85**	-0.39*	-0.52*
SE _{gi}	0.02	0.22	0.04	0.04	0.17	0.19	0.19	0.19
SE _{gi-gj}	0.03	0.35	0.05	0.05	0.27	0.3	0.3	0.28
	GPS				100-GW			
L25	4.13**	6.22*	6.15**	6.43**	0.47**	0.43**	0.26*	0.47**
L26	2.89**	1.87*	1.14**	1.7**	0.39*	0.34**	0.10	0.08
L27	7.97**	7.75**	8.87**	6.81**	0.33*	0.40**	0.62**	0.34*
Gem 7	-4.26**	-4.03**	-1.78**	-1.6*	-0.41**	-0.45**	-0.37*	-0.36*
Gem 9	-6.61**	-5.99**	-7.11**	-5.1**	-0.43**	-0.31**	-0.25*	-0.11
Giza 168	-4.11**	-5.82*	-7.27**	-8.2**	-0.36**	-0.41**	-0.36*	-0.42**
SE _{gi}	0.42	0.41	0.46	0.77	0.12	0.10	0.08	0.10
SE _{gi-gj}	0.66	0.63	0.71	0.71	0.19	0.16	0.13	0.14
	GYPP				HI%			
L25	-1.38*	-0.88*	1.87**	1.36*	-2.96*	-0.09*	3.46**	1.18
L26	2.38*	1.96**	1.88**	2.01*	0.64	-0.06*	0.17	0.20
L27	1.45*	1.17**	1.97**	1.18*	1.22	-0.04**	1.35*	0.14
Gem 7	-0.74*	-0.87*	-1.76*	-1.42*	0.15	-0.01	0.77	1.10
Gem 9	-1.36*	-1.25*	-2.88**	-2.42	1.32	0.084*	-3.53**	-1.72*
Giza 168	-0.35	-0.11	-1.08*	-0.71*	2.26*	0.12**	-2.22*	-0.90
SE _{gi}	0.43	0.43	0.43	0.42	0.84	0.02	0.75	0.92
SE _{gi-gj}	0.67	0.67	0.66	0.65	1.29	0.04	1.16	1.42

*, **: significant at 0.05 and 0.01 probability levels, respectively. SPP: spikes/plant, GPS: grains/spike, 100-GW: 100-grain weight, GYPP: grain yield/plant, HI: harvest index, NUE: nitrogen use efficiency, NUPE: nitrogen uptake efficiency, NUTE: nitrogen utilization efficiency

Table S3. Estimates of specific combining ability effects ($\hat{s}_{ij}$) of all traits in F_1 and F_2 diallel crosses under high-N and low-N conditions across two seasons.

Crosses	High-N		Low-N		High-N		Low-N	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
	NUE				NUPE			
L25 × L26	0.63	-0.70	0.59	-0.24	-0.79	-1.72*	-5.22**	-5.01**
L25 × L27	-1.58*	-1.35*	-0.40	2.19	-0.16	0.55	-4.31**	5.80*
L25 × Gem7	-0.49	-0.59	2.09	2.65*	0.004	3.33**	2.43	3.91*
L25 × Gem9	0.46	-0.58	-2.08	-5.97**	0.85	-0.52	4.81**	0.91
L25 × Gz168	0.39	1.01	2.46*	-0.80	1.19*	1.46*	6.15**	-2.19
L26 × L27	-0.18	-0.18	1.19	-5.87**	1.27*	-0.3	3.80*	-9.09**
L26 × Gem7	-0.44	-1.77*	-0.19	1.37	1.87**	3.61**	0.36	3.32
L26 × Gem9	0.60	-0.75	-0.88	0.78	0.16	2.22**	5.42**	11.02**
L26 × Gz168	1.53*	2.03**	-1.79	1.18	-0.92	0.93	-0.80	3.43
L27 × Gem7	2.64**	1.74*	1.54	-2.40	-2.18**	-0.87	-2.88	1.44
L27 × Gem9	0.52	-1.09	-1.57	-0.64	-2.13**	1.15*	10.63**	0.001
L27 × Gz168	0.44	-0.55	0.16	1.34	1.00*	2.47**	-4.22**	-1.2
Gem7 × Gem9	-0.90	0.78	-0.37	1.51	0.87	-1.34*	0.04	-2.91
Gem7 × Gz168	0.52	-1.74*	-1.09	-1.78	-0.06	-2.69**	2.12	-2.05
Gem9 × Gz168	-0.46	-0.5	-1.09	1.86	-0.37	-3.46**	-1.41	-0.31
SE _{Sij}	0.63	0.63	1.46	1.45	0.54	0.61	1.73	2.2
SE _{Sij-Sik}	0.95	0.95	2.19	2.17	0.80	0.92	1.96	3.28
SE _{Sij-Skl}	0.87	0.87	2.02	2.01	0.74	0.85	2.40	3.04
	NUTE				GPS			
L25 × L26	0.09*	0.04	0.30**	0.19*	3.40*	2.96*	-4.07*	-7.36*
L25 × L27	-0.09*	-0.07	0.24*	-0.09	4.00**	2.15*	-0.61	-1.73
L25 × Gem7	-0.03	-0.16*	0.10	-0.04	5.34**	8.57**	2.06	1.34
L25 × Gem9	-0.03	-0.06	-0.92**	-0.28*	-11.96**	-10.57**	5.88**	1.99
L25 × Gz168	-0.05	-0.04	-0.01	0.04	-6.78**	-8.56**	-2.33*	1.87
L26 × L27	-0.09*	0.03	0.04	0.10	-13.42**	-13.52**	-1.13	-2.35*
L26 × Gem7	-0.12**	-0.22**	0.09	-0.07	2.76*	2.72*	8.03**	10.97**
L26 × Gem9	0.01	-0.17*	-0.88**	-0.30**	-3.90*	-6.15**	-7.99**	-11.66**
L26 × Gz168	0.14**	0.02	0.06	-0.07	7.77**	-1.30	-5.61**	-4.05*
L27 × Gem7	0.33**	0.13*	0.28**	-0.10	1.57	-2.51*	4.77*	-14.49**
L27 × Gem9	0.19**	-0.16*	-1.07**	-0.08	6.34**	5.45**	1.01	4.15*
L27 × Gz168	-0.05	-0.18**	0.27*	0.09	1.41	-0.36	1.22	-10.25**
Gem7 × Gem9	-0.13**	0.09	-0.68**	0.16	-0.43	-4.21**	5.14*	14.57**
Gem7 × Gz168	0.03	0.03	-0.02	0.01	-1.84	4.02**	-3.09*	-10.25**
Gem9 × Gz168	-0.01	0.30*	-0.42**	0.09	4.54**	4.71**	2.55*	-0.47
SE _{Sij}	0.05	0.06	0.10	0.10	1.16	1.13	1.26	1.27
SE _{Sij-Sik}	0.06	0.09	0.14	0.14	1.74	1.68	1.89	1.9
SE _{Sij-Skl}	0.07	0.08	0.13	0.13	1.61	1.55	1.75	1.76

	SPP					100-GW		
L25 × L26	0.18	1.03*	-0.62	0.54	1.07**	0.12	0.10	-0.36
L25 × L27	1.39**	0.53	-0.5	0.40	0.05	-0.21	0.56*	-0.14
L25 × Gem7	0.63	-1.58*	-0.91	-0.76	0.06	-0.14	-0.28	-0.20
L25 × Gem9	0.82	0.55	-0.03	-0.60	-0.75*	-0.33	-0.18	0.07
L25 × Gz168	-0.39	0.32	0.6	-0.91*	-0.87*	-1.40**	-0.49*	-0.58*
L26 × L27	0.87*	0.39	1.56**	1.86**	0.37	-0.13	0.14	0.85*
L26 × Gem7	-0.17	-0.65	0.83	-0.79	-0.69*	-0.63*	-0.26	-0.75*
L26 × Gem9	-0.03	-0.92*	-0.43	-1.57**	-0.14	0.84*	-0.15	-0.05
L26 × Gz168	1.21	-0.15	-1.40*	-1.89**	-0.65*	-0.21	-0.38*	-0.37*
L27 × Gem7	0.12	-0.64	-0.04	-0.08	-0.71*	-0.33	0.59*	-0.43**
L27 × Gem9	-0.0003	-1.29*	0.33	-2.22**	0.07	-0.01	0.15	-0.01
L27 × Gz168	1.59**	-0.003	-0.84	-3.02**	0.06	-0.38	0.18	-0.99**
Gem7 × Gem9	0.18	2.44**	0.91*	-0.39	0.04	0.60*	0.09	0.94**
Gem7 × Gz168	-0.57	-0.81	0.03	0.23	0.74*	-0.41	0.11	-0.30*
Gem9 × Gz168	-0.68	-1.70*	0.62	1.50**	-0.04	0.03	0.11	-0.26*
SE _{Sij}	0.48	0.54	0.52	0.51	0.34	0.29	0.22	0.25
SE _{Sij-Sik}	0.72	0.80	0.79	0.77	0.50	0.43	0.33	0.37
SE _{Sij-Skl}	0.67	0.74	0.73	0.71	0.46	0.40	0.31	0.34

	GYPP					HI		
L25 × L26	1.2	-1.31	0.48	-0.19	3.94*	0.84	-0.24	0.06
L25 × L27	-2.96*	-2.53*	-0.33	1.76	-3.04	-1.05	-0.36	5.82*
L25 × Gem7	-0.93	-1.1	1.68	2.15**	-1.56	-0.71	10.98**	9.74*
L25 × Gem9	0.85	-1.08	-1.65	-4.77*	0.61	-3.05	2.25	-4.45*
L25 × Gz168	0.71	1.9	1.96*	-0.7	-1.88	-0.30	0.23	-6.17*
L26 × L27	-0.34	-0.4	0.95	-4.73**	-1.63	-1.73	2.13	-7.45*
L26 × Gem7	-0.82	-3.32**	-0.15	1.13	-5.28*	-8.17**	4.59*	-2.30
L26 × Gem9	1.12	-1.44	-0.71	0.65	1.25	1.13	1.37	1.32
L26 × Gz168	2.86*	3.80**	-1.44	0.94	1.79	7.56**	-2.4	3.22
L27 × Gem7	4.94*	3.26**	1.24	-1.93*	9.45**	11.05**	0.91	-5.18*
L27 × Gem9	0.97	-2.04*	-1.24	-0.48	1.10	-3.10*	-4.76*	-4.34*
L27 × Gz168	0.82	-1.03	0.14	1.13	-2.81	-3.06*	-1.58	3.89
Gem7 × Gem9	-1.69	1.35	-0.29	1.23	-2.91	3.77*	-2.64	6.28*
Gem7 × Gz168	0.98	-3.23**	-0.87	-1.41	4.62*	-4.12*	-6.07*	-7.39*
Gem9 × Gz168	-0.84	-0.94	1.99*	1.50	2.48	0.21	1.63	9.69*
SE _{Sij}	1.18	1.18	1.17	1.16	2.30	2.01	2.05	2.52
SE _{Sij-Sik}	1.77	1.77	1.75	1.73	3.43	3.00	3.07	3.77
SE _{Sij-Skl}	1.63	1.63	1.61	1.60	3.18	2.78	2.84	3.49

*, **: significant at 0.05 and 0.01 probability levels, respectively. SPP: spikes/plant, GPS: grains/spike, 100-GW: 100-grain weight, GYPP: grain yield/plant, HI: harvest index, NUE: nitrogen use efficiency, NUPE: nitrogen uptake efficiency, NUTE: nitrogen utilization efficiency