



Supplementary Material **S1**. Soil nutrient status at the University of Fort Hare Crop Research Farm at initiation of trial.

Sample	Sample density g/cm <sup>3</sup>	Org. C	N	Clay	P	K	Ca	Mg	Exch. Acidity	Total cations	Acid sat. %	pH (KCl)	Zn	Mn	Cu
		g/kg			mg/kg	cmolc/kg							mg/kg		
NUE 2017	1.33	<5	0.6	120	39	0.99	5.60	2.29	0.07	8.91	1	5.67	2.4	55	7.4

Org. C: Organic carbon, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Exch. Acidity: Exchangeable acidity, Acid sat.: Acid saturation, Zn: Zinc, Mn: Manganese, Cu: Copper.

Supplementary Material S2. Performance of inbred lines for the estimated traits and indices across N levels.

Inbred	REN	PEN	AE	NUE	NUpE	Bio Total N	G Total N	Yield	NUtE	HI
L1	0.001	-35.09	23.83	0.07	0.06	1.60	1.77	4.00	1.19	0.22
L2	0.004	7.76	44.96	0.13	0.06	1.64	1.75	7.34	2.16	0.25
L3	0.001	19.80	30.91	0.12	0.06	1.65	1.75	6.28	1.85	0.21
L4	0.003	7.40	27.47	0.12	0.06	1.66	1.74	6.54	1.92	0.28
L5	0.002	2.96	29.60	0.10	0.06	1.60	1.75	5.41	1.65	0.30
L6	0.002	2.93	-6.45	0.08	0.06	1.56	1.74	4.91	1.52	0.28
L7	0.004	-9.70	-19.71	0.05	0.06	1.60	1.65	3.01	0.96	0.18
L8	-0.002	-7.04	41.04	0.11	0.06	1.60	1.77	6.30	1.86	0.28
L9	0.005	5.55	37.32	0.11	0.06	1.56	1.66	6.57	2.02	0.34
L10	-0.016	1.80	43.90	0.11	0.06	1.82	1.71	5.98	1.73	0.26
L11	-0.001	20.54	59.07	0.11	0.06	1.58	1.68	6.04	1.84	0.28
L12	-0.001	4.44	63.70	0.11	0.06	1.57	1.75	5.73	1.73	0.30
L13	0.001	7.70	72.36	0.11	0.06	1.62	1.77	5.68	1.65	0.29
L14	0.003	13.30	21.51	0.10	0.06	1.55	1.67	6.23	1.92	0.32
L15	0.000	3.54	30.79	0.08	0.06	1.60	1.60	4.05	1.26	0.23
L16	-0.001	-2.99	56.01	0.11	0.05	1.59	1.62	5.77	1.80	0.28
L17	0.003	3.00	62.64	0.11	0.06	1.61	1.76	5.34	1.58	0.26
L18	0.000	29.55	38.77	0.09	0.06	1.63	1.64	5.12	1.57	0.22
L19	-0.003	6.77	46.57	0.10	0.06	1.55	1.83	5.08	1.52	0.27
L20	0.004	2.37	37.01	0.11	0.06	1.62	1.75	6.04	1.81	0.26
L21	0.003	6.24	50.70	0.08	0.06	1.59	1.78	4.97	1.43	0.24
L22	0.002	4.02	33.51	0.11	0.06	1.60	1.70	6.15	1.86	0.21
L23	0.006	1.23	1.52	0.10	0.06	1.55	1.77	6.20	1.88	0.34
L24	-0.001	3.63	23.20	0.10	0.06	1.61	1.65	5.30	1.63	0.25
L25	0.002	2.85	17.84	0.12	0.06	1.65	1.70	6.68	2.00	0.35
L26	0.001	8.81	8.07	0.11	0.06	1.59	1.80	6.10	1.81	0.23
L27	0.001	-16.62	19.53	0.08	0.06	1.58	1.73	4.21	1.31	0.27
L28	0.001	-8.24	20.72	0.12	0.05	1.61	1.77	6.80	2.04	0.28
L29	-0.005	-6.69	22.27	0.12	0.06	1.62	1.78	6.72	2.01	0.32
L30	-0.002	-6.20	62.56	0.11	0.06	1.68	1.81	5.61	1.62	0.35
L31	-0.001	-12.36	-6.45	0.09	0.06	1.66	1.74	5.30	1.58	0.22
L32	0.003	2.99	16.52	0.11	0.06	1.67	1.81	6.38	1.84	0.34

REN: crop recovery efficiency of applied N (kg N-uptake/kg N fertilizer); PEN: physiological efficiency of applied N (kg grain/kg N-uptake); AE: agronomic efficiency (kg grain/kg N-fertilizer); NUE: nitrogen use efficiency (kg grain/kg N-fertilizer); NUpE: total amount of N in the mature plant, divided by the amount of N applied to soil (kg.ha<sup>-1</sup>); NUtE: ratio between grain weight and the total amount of N in the mature plant i.e. kg grain/ total N in dry matter of above ground mature plant; HI: harvest index; Bio Total N: total nitrogen in biomass; G Total N: total nitrogen in grain.

Supplementary Material S3. Yield performance and ranking of QPM genotypes at different levels of nitrogen application.

Inbred	Yield 0 kg N ha <sup>-1</sup> (*)	Yield 30 kg N ha <sup>-1</sup>	Yield 60 kg N ha <sup>-1</sup>	Yield 90 kg N ha <sup>-1</sup>	Yield 120 kg N ha <sup>-1</sup>
L1	2.86 (26)	3.99 (30)	4.39 (29)	5.41 (27)	3.36 (29)
L2	4.85 (11)	6.24 (3)	8.36 (3)	9.09 (1)	8.18 (2)
L3	4.87 (10)	6.47 (1)	6.81 (13)	8.07 (5)	5.19 (22)
L4	5.08 (8)	6.34 (2)	6.48 (16)	7.29 (13)	7.49 (8)
L5	4.14 (17)	5.78 (14)	6.3 (19)	6.51 (19)	4.34 (27)
L6	5.06 (9)	4.17 (29)	5.19 (24)	5.53 (25)	4.62 (25)
L7	4.1 (18)	3.39 (31)	2.43 (32)	3.36 (32)	1.79 (32)
L8	3.97 (19)	4.95 (25)	7.46 (7)	8.96 (2)	6.17 (16)
L9	4.47 (13)	5.65 (18)	7.30 (9)	7.50 (9)	7.92 (4)
L10	3.72 (20)	5.58 (19)	7.37 (8)	5.33 (28)	7.90 (5)
L11	3.07 (24)	5.79 (13)	7.13 (11)	6.93 (16)	7.27 (11)
L12	2.72 (27)	5.80 (12)	7.00 (12)	8.69 (3)	4.44 (26)
L13	2.02 (31)	6.08 (6)	4.3 (30)	7.88 (7)	8.10 (3)
L14	4.74 (12)	4.78 (27)	6.64 (15)	7.38 (11)	7.60 (6)
L15	2.66 (28)	4.21 (28)	5.00 (26)	5.31 (29)	3.05 (30)
L16	3.19 (22)	5.66 (17)	8.47 (2)	7.23 (14)	4.28 (28)
L17	2.46 (30)	5.93 (8)	6.68 (14)	5.46 (26)	6.18 (15)
L18	3.15 (23)	5.02 (24)	5.15 (25)	6.55 (18)	5.72 (18)
L19	3.00 (25)	5.36 (23)	7.25 (10)	4.80 (30)	5.00 (23)
L20	4.39 (15)	6.17 (4)	7.6 (6)	7.36 (12)	4.67 (24)
L21	1.83 (32)	3.05 (32)	4.94 (28)	7.47 (10)	7.54 (7)
L22	4.43 (14)	5.88 (11)	6.16 (20)	8.55 (4)	5.74 (17)
L23	5.84 (1)	5.42 (21)	5.69 (23)	6.77 (17)	7.31 (10)
L24	4.16 (16)	5.48 (20)	4.95 (27)	6.35 (21)	5.54 (20)
L25	5.62 (5)	5.76 (16)	8.27 (4)	6.33 (22)	7.40 (9)
L26	5.66 (4)	5.91 (9)	6.35 (17)	6.35 (20)	6.22 (14)
L27	3.47 (21)	4.89 (26)	4.11 (31)	5.80 (24)	2.75 (31)
L28	5.66 (3)	6.17 (5)	7.84 (5)	7.23 (15)	7.09 (12)
L29	5.59 (6)	6.03 (7)	8.48 (1)	7.95 (6)	5.56 (19)
L30	2.57 (29)	5.89 (10)	5.73 (22)	7.63 (8)	6.24 (13)
L31	5.68 (2)	5.4 (22)	5.81 (21)	4.23 (31)	5.41 (21)
L32	5.32 (7)	5.77 (15)	6.33 (18)	6.27 (23)	8.19 (1)
<b>Mean</b>	4.07	5.41	6.31	6.74	5.88

(\*): rank in brackets



Supplementary Material S4. NUE and NUE indices of inbred lines at 90 kg N ha<sup>-1</sup> and 120 kg N ha<sup>-1</sup>.

Inbred line	REN 120 kg N ha <sup>-1</sup>	PEN 120 kg N ha <sup>-1</sup>	AE 120 kg N ha <sup>-1</sup>	NUE 120 kg N ha <sup>-1</sup>	NUPE 120 kg N ha <sup>-1</sup>	REN 90 kg N ha <sup>-1</sup>	PEN 90 kg N ha <sup>-1</sup>	AE 90 kg N ha <sup>-1</sup>	NUE 90 kg N ha <sup>-1</sup>	NUPE 90 kg N ha <sup>-1</sup>
L1	0.003	-130.79	4.16	0.03	0.03	0.002	-5.65	28.29	0.06	0.04
L10	-0.006	1.79	34.83	0.07	0.03	-0.010	2.12	17.94	0.06	0.04
L11	0.002	58.05	34.96	0.06	0.03	0.001	21.60	42.90	0.08	0.04
L12	0.002	5.26	14.38	0.04	0.03	0.002	42.66	66.38	0.10	0.04
L13	0.003	13.25	50.68	0.07	0.03	0.002	17.91	65.17	0.09	0.04
L14	0.005	3.56	23.87	0.06	0.03	0.003	4.62	29.31	0.08	0.04
L15	0.001	4.63	3.24	0.03	0.03	0.004	4.84	29.38	0.06	0.04
L16	0.002	4.51	9.07	0.04	0.03	0.001	20.10	44.89	0.08	0.04
L17	0.004	4.30	31.03	0.05	0.03	0.002	14.01	33.33	0.06	0.04
L18	0.003	35.57	21.44	0.05	0.03	0.001	26.71	37.80	0.07	0.04
L19	0.002	6.20	16.71	0.04	0.03	0.000	27.47	20.00	0.05	0.04
L2	0.004	4.40	27.73	0.07	0.03	0.004	7.22	47.08	0.10	0.04
L20	0.006	0.42	2.27	0.04	0.03	0.004	5.55	32.91	0.08	0.04
L21	0.004	9.49	47.58	0.06	0.03	0.004	10.67	62.71	0.08	0.04
L22	0.004	2.36	10.96	0.05	0.03	0.004	6.39	45.78	0.09	0.04
L23	0.005	1.79	12.24	0.06	0.03	0.003	1.70	10.32	0.08	0.04
L24	0.001	7.06	11.45	0.05	0.03	0.003	4.96	24.33	0.07	0.04
L25	0.002	5.33	14.85	0.06	0.03	0.003	2.88	7.85	0.07	0.04
L26	0.002	1.72	4.64	0.05	0.03	0.004	1.60	7.66	0.07	0.04
L27	0.002	-2.88	-5.94	0.02	0.03	0.003	-23.81	25.93	0.06	0.04
L28	0.007	1.31	11.90	0.06	0.04	0.004	4.15	17.42	0.08	0.04
L29	0.001	1.99	-0.23	0.05	0.03	-0.002	-8.60	26.23	0.09	0.04
L3	0.002	2.95	2.61	0.04	0.03	0.003	8.13	35.54	0.09	0.04
L30	0.002	10.65	30.58	0.05	0.03	-0.002	2.53	56.23	0.08	0.04



<b>L31</b>	0.000	-0.73	-2.25	0.05	0.03	0.001	-24.88	-16.17	0.05	0.04
<b>L32</b>	0.004	4.35	23.90	0.07	0.03	0.002	3.02	10.54	0.07	0.04
<b>L4</b>	0.004	4.65	20.07	0.06	0.03	0.005	4.31	24.58	0.08	0.04
<b>L5</b>	0.005	0.13	1.63	0.04	0.03	0.004	6.61	26.28	0.07	0.04
<b>L6</b>	0.003	-0.37	-3.65	0.04	0.03	0.000	10.62	5.33	0.06	0.03
<b>L7</b>	0.005	-2.33	-19.25	0.01	0.03	0.004	-0.44	-8.16	0.04	0.04
<b>L8</b>	0.001	11.97	18.26	0.05	0.03	0.000	-15.70	55.39	0.10	0.04
<b>L9</b>	0.006	3.39	28.81	0.07	0.03	0.003	10.55	33.73	0.08	0.03

Supplementary Material S5. NUE and NUE indices of inbred lines at 30 kg N ha<sup>-1</sup> and 60 kg N ha<sup>-1</sup>.

<b>Inbred line</b>	<b>REN 60 kg N ha<sup>-1</sup></b>	<b>PEN 60 kg N ha<sup>-1</sup></b>	<b>AE 60 kg N ha<sup>-1</sup></b>	<b>NUE 60 kg N ha<sup>-1</sup></b>	<b>NUpe 60 kg N ha<sup>-1</sup></b>	<b>REN 30 kg N ha<sup>-1</sup></b>	<b>PEN 30 kg N ha<sup>-1</sup></b>	<b>AE 30 kg N ha<sup>-1</sup></b>	<b>NUE 30 kg N ha<sup>-1</sup></b>	<b>NUpe 30 kg N ha<sup>-1</sup></b>
<b>L1</b>	0.003	2.29	25.38	0.07	0.06	-0.004	-6.20	37	0.13	0.10
<b>L10</b>	-0.016	1.03	60.89	0.12	0.06	-0.032	2.24	62	0.19	0.11
<b>L11</b>	-0.003	-0.93	67.68	0.12	0.05	-0.004	3.46	91	0.19	0.10
<b>L12</b>	-0.002	-3.38	71.38	0.12	0.05	-0.004	-26.76	103	0.19	0.10
<b>L13</b>	-0.003	-0.38	38.11	0.07	0.05	0.001	0.03	135	0.20	0.11
<b>L14</b>	0.006	3.31	31.61	0.11	0.06	-0.001	41.73	1	0.16	0.10
<b>L15</b>	0.002	5.76	38.89	0.08	0.05	-0.006	-1.08	52	0.14	0.10
<b>L16</b>	-0.001	-25.80	87.91	0.14	0.05	-0.008	-10.76	82	0.19	0.09
<b>L17</b>	0.001	36.88	70.43	0.11	0.05	0.003	-43.18	116	0.20	0.11
<b>L18</b>	-0.002	14.36	33.40	0.09	0.05	-0.002	41.54	62	0.17	0.10
<b>L19</b>	-0.003	4.02	70.86	0.12	0.05	-0.012	-10.61	79	0.18	0.10
<b>L2</b>	0.004	12.15	58.60	0.14	0.05	0.006	7.28	46	0.21	0.11



<b>L20</b>	0.007	6.00	53.52	0.13	0.06	-0.001	-2.48	59	0.21	0.10
<b>L21</b>	0.003	12.32	51.86	0.08	0.06	0.002	-7.52	41	0.10	0.11
<b>L22</b>	0.004	6.25	28.86	0.10	0.06	-0.002	1.09	48	0.20	0.10
<b>L23</b>	0.007	-0.78	-2.52	0.09	0.06	0.009	2.20	-14	0.18	0.11
<b>L24</b>	0.004	5.86	13.18	0.08	0.06	-0.010	-3.35	44	0.18	0.10
<b>L25</b>	0.006	8.52	44.07	0.14	0.06	-0.003	-5.33	5	0.19	0.10
<b>L26</b>	0.001	32.92	11.53	0.11	0.06	-0.004	-1.01	8	0.20	0.10
<b>L27</b>	0.004	8.23	10.79	0.07	0.06	-0.005	-48.04	47	0.16	0.09
<b>L28</b>	0.000	-36.50	36.44	0.13	0.05	-0.005	-1.91	17	0.21	0.09
<b>L29</b>	-0.004	-19.46	48.29	0.14	0.06	-0.015	-0.69	15	0.20	0.09
<b>L3</b>	0.000	75.71	32.30	0.11	0.05	-0.001	-7.61	53	0.22	0.11
<b>L30</b>	-0.002	-29.52	52.70	0.10	0.06	-0.008	-8.47	111	0.20	0.10
<b>L31</b>	0.000	-29.47	2.14	0.10	0.06	-0.007	5.63	-10	0.18	0.10
<b>L32</b>	0.006	1.94	16.75	0.11	0.06	0.000	2.65	15	0.19	0.10
<b>L4</b>	0.002	10.52	23.24	0.11	0.05	0.004	10.12	42	0.21	0.11
<b>L5</b>	0.003	12.29	35.92	0.10	0.05	-0.003	-7.19	55	0.19	0.10
<b>L6</b>	0.003	0.50	2.17	0.09	0.06	0.001	0.97	-30	0.14	0.10
<b>L7</b>	0.006	-3.08	-27.82	0.04	0.06	0.002	-32.95	-24	0.11	0.10
<b>L8</b>	0.000	-16.69	58.15	0.12	0.06	-0.008	-7.75	32	0.16	0.10
<b>L9</b>	0.006	4.24	47.23	0.12	0.06	0.006	4.02	39	0.19	0.10