Phenotypic characterization of elite quality protein maize (QPM) inbred lines adapted to tropical-highlands and the association studies using SSR markers

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Supplemental Table 1. List of phenotypic traits, abbreviations used and their description.

No	Abbreviation	Trait	Units	Trait description
1	GY	Grain yield	Tonnes per hectare (t ha^{-1})	The total grain yield from all the ears of each experimental unit; moisture level was adjusted to 12.5% and 80% shelling percentage to estimate grain yield per hectare
2	AD	Days to anthesis	Days (D)	The number of days from planting to 50% of the plants in a plot shed pollen
3	ASI	Anthesis-silking interval	D	Number of days between anthesis and silking dates
4	PH	Plant height	Centimeters (cm)	The height from the soil surface to the base of the tassel branching; the measurement was made two weeks after pollen shedding has ceased
5	EH	Ear height	(cm)	The height from the ground level to the upper most ear bearing node, it was also measured two weeks after pollen shedding ceased
6	EA	Ear aspect	1-5	Overall phenotypic appearance of the ear; where 1= excellent and 5= poor
7	PA	Plant aspect	1-5	Overall phenotypic appearance of the plant; where 1= excellent and 5= poor
8	ED	Ear diameter	cm	Measured at the mid-way along ear length, as the average diameter of 10 randomly taken ears
9	EL	Ear length	cm	Length of the ear from the base to tip; it was measured as the average length of ten randomly sampled ears from each experimental unit
10	TKW	Thousand kernel weight	Grams (g)	After shelling, random kernels from the bulk of each experimental unit was counted and weighed in grams after the moisture was adjusted to 12.5%
11	RPE	Number of rows per ear	Number (No.)	This was recorded as the average number of kernel rows per ear from the 10 randomly sampled ears
12	KPR	Number of kernels per row	No.	Recorded as the average number of kernels per row from the 10 randomly taken ears
13	LL	Leaf length	cm	Length of the leaf from ligule to apex; the measurement was taken after flowering from the leaf that subtends the uppermost ear
14	LW	Leaf width	cm	Measurement was taken from the same leaf as leaf length at mid-way along its length
15	LA	Leaf area	Square cm (cm^2)	Area of the upper most ear leaf computed as maximum width x length x 0.75
16	TS	Tassel size	Tassel size 3, 5 or 7	Recorded after milk stage as 3 (small), 5 (medium) and 7 (large)
17	LN	Number of leaves above the ear	No.	Counted after flowering; observation was made on 10 randomly selected plants in a plot
18	FR	Foliage rating	Foliage rating 3, 5, or 7	Rating of total leaf surface after milk stage as 3 (small), 5 (intermediate) and 7 (large); and the observation was made on 10 randomly selected plants/plot

Supplemental Table 2. Mean squares from combined analyses of variance for 14 phenotypic traits.

Trait	Location (df=1)	Line (df=35)	Location x Line (df=35)	Error (df=62)
Grain yield (t ha^{-1})	4.0	1.5**	0.6**	0.195
Ear aspect (1-5 scores)	0.0	1.4**	0.4**	0.078
Plant aspect (1-5 scores)	0.02	1.9**	0.5**	0.178
Ear height (cm)	36.4	617.1**	42.8**	18.85
Leaf length (cm)	67.5*	178.2**	12.6	14.78
Leaf width (cm)	0.06	6.6**	0.80	0.462
Leaf area (cm^2)	4311.8	29479.1**	3058.0	3058.0
Tasselsize(3, 5 or 7 scores)	1.3	6.8**	0.7	0.515
Number of Leaves (No.)	3.5*	1.8**	0.2*	0.087
Foliage rating (3, 5 or 7 scores)	1.8	3.2**	0.6**	0.262
Ear length (cm)	19.3**	9.3**	1.2**	0.366
Number of rows/ear (No.)	4.3	6.5**	0.8*	0.471
Number of kernels per row (No.)	400.8**	54.3**	10.0**	3.38
Thousand kernel weight (gram)	88.1	12309.8**	1491.7**	587.3

* Significant at $P \le 0.05$ level; ** Significant at $P \le 0.01$ level; df= Degrees of freedom.

Supplemental Table 3. Mean performances from combined analysis of 14 phenotypic traits for the 36 inbred lines evaluated at Ambo and Kulumsa in Ethiopia in 2013.

No.	Lines	Traits[§]													
		GY	EA	PA	EH	LL	LW	LA	TS	LN	FR	EL	RPE	KPR	TKW
1	KIT31	1.9	3.8	3.0	53.3	67.0	10.3	514.2	4.1	5.1	6.0	9.7	13.0	20.3	212.1
2	KIT29	2.7	2.2	2.3	74.0	72.4	9.8	535.3	5.0	5.3	5.0	12.5	12.3	23.5	387.2
3	FS112	2.1	4.1	3.8	51.3	72.5	9.2	500.6	6.5	5.3	6.0	12.4	15.0	22.6	199.1
4	FS211-1SR	2.9	3.0	3.9	53.5	55.4	8.3	343.2	3.6	4.9	3.0	12.3	11.2	24.4	218.0
5	FS45	2.3	2.9	3.9	73.3	70.7	9.9	523.2	5.9	4.7	5.5	9.2	12.2	17.1	335.9
6	KIT32Q	4.1	2.0	2.0	61.0	70.2	10.1	529.1	4.9	5.1	5.5	12.1	11.8	21.8	260.0
7	FS111	3.0	2.5	2.4	53.8	72.7	10.5	571.6	5.0	6.7	5.5	12.5	12.4	22.1	224.5
8	FS2-3SR	4.0	1.9	2.1	76.3	66.8	9.1	458.8	2.9	4.5	4.9	13.6	11.2	30.2	241.0
9	KIT12	2.9	3.2	2.6	81.5	78.1	9.4	550.1	4.9	5.6	5.0	11.9	11.8	21.9	237.7
10	FS4-3SR	2.9	3.3	3.5	54.3	54.9	9.9	408.9	5.1	5.3	3.5	12.4	10.8	28.1	200.2
11	SRSYN20Q	3.1	2.6	1.9	88.3	77.7	11.0	644.2	4.5	6.2	5.0	11.4	13.5	22.3	287.0
12	SRSYN48	2.4	3.0	2.0	59.3	57.7	9.4	406.5	5.0	5.1	5.0	14.1	12.0	27.6	197.3
13	KIT34	2.6	3.1	2.1	52.8	68.8	9.6	497.9	5.6	6.0	6.0	12.9	13.4	23.3	215.8
14	FS48	3.6	2.2	3.8	69.0	68.0	6.5	328.9	6.9	4.4	3.0	14.5	12.3	28.1	238.3
15	FS67(BC2)	3.6	3.1	2.6	83.3	60.5	8.7	394.8	3.0	4.6	4.5	12.2	12.2	24.9	253.9
16	FS59-2	3.0	3.6	2.3	55.5	60.7	9.9	451.5	2.9	4.9	5.0	13.5	9.8	22.3	276.1
17	FS68(BC1)	2.2	3.5	3.3	48.8	60.6	9.7	445.5	4.4	5.5	5.0	9.8	10.7	20.5	243.5
18	FS48-1SR	3.3	2.3	2.5	72.0	66.9	8.6	429.3	4.9	4.9	5.0	13.3	13.8	25.4	245.5
19	FS59-4Q	2.9	2.5	3.1	79.3	62.0	7.4	342.8	6.5	4.6	5.0	12.4	13.3	23.7	229.5
20	FS60	3.4	2.3	2.4	65.8	58.5	13.1	574.5	7.0	4.9	7.0	14.4	13.9	29.0	239.0
21	FS151-3SR	3.1	2.9	2.5	76.0	75.5	10.0	567.5	6.6	5.6	6.1	13.8	13.0	22.7	237.6
22	FS170Q	3.1	3.5	3.0	70.8	66.6	11.2	556.3	4.6	5.4	5.0	12.0	12.8	24.3	212.3
23	FS232Q	2.8	3.4	2.9	57.3	70.2	7.7	407.7	5.5	5.6	4.5	13.3	10.4	23.5	239.7
24	FS68(BC2)	2.8	2.4	1.9	88.0	60.4	9.7	438.6	5.4	5.6	5.0	10.4	9.8	18.0	375.3
25	FS67(BC1)	3.5	3.3	3.5	59.5	62.7	9.2	432.1	3.1	6.0	5.0	12.4	10.0	23.5	298.8
26	CML491	3.0	2.1	2.5	75.0	75.5	9.8	562.6	7.0	7.3	7.0	12.2	13.3	24.2	227.6
27	F7215Q	3.3	3.3	2.5	83.5	81.0	9.0	546.1	4.9	4.7	5.0	12.7	13.1	24.5	277.3
28	142-1-eQ	4.4	2.5	2.8	86.0	71.3	11.2	593.5	6.5	5.2	5.0	15.5	12.2	33.3	257.6
29	CML144	2.8	3.0	2.6	68.5	76.2	10.5	606.7	6.6	6.3	7.0	11.4	14.7	23.9	154.1
30	CML176	2.1	3.3	4.6	55.8	69.6	8.7	449.8	5.0	6.2	4.5	9.6	13.0	23.5	171.8
31	FS67-N	4.5	1.8	1.4	77.8	67.6	12.2	620.6	6.1	4.7	5.5	14.1	10.3	28.4	373.6
32	FS59-4N	3.9	2.0	2.1	87.3	57.4	8.4	361.0	4.6	5.2	4.5	13.4	12.0	23.8	348.9
33	FS232N	3.3	2.5	2.9	73.5	62.6	10.7	506.8	4.6	5.5	5.0	12.2	11.9	22.0	316.7
34	KIT32N	3.4	2.3	1.8	80.3	71.1	10.1	540.3	7.0	5.2	5.0	13.3	12.4	29.9	243.2
35	SRSYN20N	2.4	2.9	2.8	86.8	62.4	8.9	417.3	4.4	5.9	4.5	8.4	12.6	13.7	320.7
36	FS170N	3.2	2.5	2.6	73.8	67.8	10.1	514.3	6.0	4.9	5.0	12.4	12.3	26.9	218.6
	Mean	3.1	2.8	2.7	69.6	67.2	9.7	488.1	5.2	5.4	5.1	12.3	12.2	24.0	256.0
	Min	1.9	1.8	1.4	48.8	54.9	6.5	328.9	2.9	4.4	3.0	8.4	9.8	13.7	154.1
	Max	4.5	4.1	4.6	88.3	81.0	13.1	644.2	7.0	7.3	7.0	15.5	15.0	33.3	387.2

| lsd$_{(0.05)}$ | 0.63 | 0.40 | 0.60 | 6.12 | 5.50 | 1.01 | 77.97 | 1.02 | 0.47 | 0.74 | 0.88 | 0.99 | 2.70 | 35.71 |
| CV (%) | 14.2 | 10.0 | 15.6 | 6.2 | 5.7 | 7.0 | 11.3 | 13.9 | 5.5 | 10.0 | 4.9 | 5.6 | 7.7 | 9.5 |

CV(%)= Coefficient of variation; lsd=Least Significant Difference; Min= minimum; Max= maximum; GY= Grain yield; EA= Ear aspect; PA= Plant aspect; EH= Ear height; LL= Leaf length; LW= Leaf width; LA= Leaf area; TS=Tassel size; LN=Leaf No.; FR= Foliage rating; EL= Ear length; RPE= Number of rows/ear; KPR= Number of kernels/row; TKW=Thousand kernel weight.

Supplemental Table 4. Summary of model-based population structure analysis.

# K	Reps	Mean LnP(K)	StdevLnP(K)	Ln'(K)	|Ln''(K)|	Delta K
1	5	-860.58	0.51	NA	-	-
2	5	-864.76	8.53	-4.18	6.74	0.79
3	5	-875.68	16.65	-10.92	14.66	0.88
4	5	-871.94	7.10	3.74	20.22	2.85
5	5	-888.42	36.00	-16.48	31.78	0.88
6	5	-873.12	16.88	15.30	5.22	0.31
7	5	-863.04	6.44	10.08	19.94	3.10
8	5	-872.90	22.23	-9.86	17.30	0.78
9	5	-865.46	10.45	7.44	9.46	0.91
10	5	-867.48	10.14	-2.02	-	-