

SUPPLEMENTARY MATERIALS

to the article Yu.V. Kruchinina, E.G. Komyshev, M.A. Genaev, V.S. Koval, D.A. Afonnikov, N.P. Goncharov
 "Genetic analysis of wheat ear architecture in F₂ hybrid of tetraploid wheats
Triticum aethiopicum and *T. carthlicum* and its computer phenotyping"

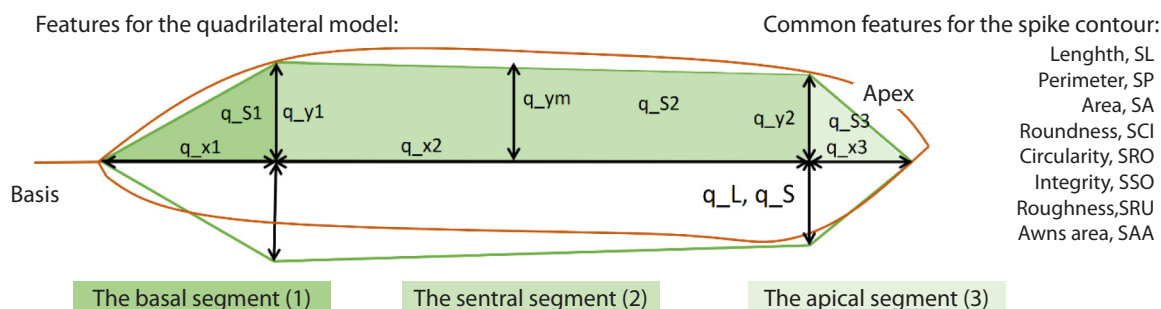


Fig. S1. Description of the shape and size of the spike (Komyshev et al., 2024). In the central part of the figure, the brown line schematically shows the outline of the spike (the central line is horizontal, with the base on the left and the tip on the right). The green outline shows a model of quadrilaterals that are symmetrical about the spike axis. The characteristics of the spike outline are provided on the right.

References

Komyshev E.G., Genaev M.A., Kruchinina Yu.V., Koval V.S., Goncharov N.P., Afonnikov D.A. Evaluation of the spike diversity of seven hexaploid wheat species and an artificial amphidiploid using a quadrangle model obtained from 2D images. *Plants*. 2024;13(19):2736. doi 10.3390/plants13192736

Table S1. Species-specific traits of the spike in plants of the F₂ hybrid population from crossing ♀*T. aethiopicum* (k–19301/2) × ♂*T. carthlicum* (k–32496)

Seed number	Tetraaristatum (+ yes; – no; al awnless)	Colored spike (+ black; +f funeral; – normal; g green)	Character (type) of awnness (A <i>T. aeth.</i> ; C <i>T. carthl.</i> ; al awnless)	Teeth of awn (+ yes; +f furca; – no)	Hairy glume (+ yes; – no)	Baldness in the trichomes on the spike glume (+ yes; – no)
114/1	–	+	A	+	+	+
114/2	–	+	A	–	+	+
114/3	–	+	A	+	+	+
114/4	–	+f	A	–	–	–
114/5	–	+f	C	–	–	–
114/6	–	+	C	+	+	+
114/7	+	+	C	+	+	–
114/8	–	+	A	+f	+	–
114/9	–	+f	A	+	–	–
114/10	–	+	A	+	+	+
114/11	–	+f	C	+	+	+
114/12	–	+f	C	+f	+	+
114/13	–	+f	A	+	+	+
114/14	–	+	C	+	+	+
114/15	+	+f	C	+	+	+
114/16	+	+	C	+	+	–
114/17	+	–	A	+	–	–
114/18	al	–	al	+f	–	–
114/19	+	–	C	+	–	–
114/20	–	+	A	+	+	–
114/31	+	+f	A	+	+	+
114/32	+	+f	C	+	+	+
114/33	–	–	C	+	–	–
114/34	+	+	A	+	+	+
114/35	+	+f	C	+	+	–
114/36	–	–	C	+	–	–
114/37	+	+	C	+	+	+
114/38	+	+f	A	+	+	+
114/39	+	+	C	+	+	+
114/40	+	+	A	+	+	+
114/21	–	+f	C	+	+	+
114/22	–	+	C	+f	+	+
114/23	–	+	A	+	+	+
114/24	+	+f	A	+	+	–
114/25	+	+f	C	+	–	–
114/26	–	+f	A	+	–	–
114/27	–	+f	A	+	+	–
114/28	+	+	C	+	–	–
114/29	–	+f	C	+	–	–
114/30	+	+	A	+	+	–
114/41	–	+f	C	+	+	+
114/42	–	+f	C	+	+	+
114/43	+	+f	C	+	–	–
114/44	–	+f	A	+	–	–
114/45	+	+f	A	+	+	–
114/46	–	+f	C	+	+	–
114/47	–	–	C	+	–	–
114/48	–	+f	C	+	+	–
114/49	+	+f	A	+	+	+
114/50	–	+	C	+	–	–
114/51	–	+f	C	+	–	–
114/52	–	–	C	+	–	–

Table S1 (continued)

Seed number	Tetraaristatum (+ yes; – no; al awnless)	Colored spike (+ black; +f funeral; – normal; g green)	Character (type) of awnness (A <i>T. aeth.</i> ; C <i>T. carthl.</i> ; al awnless)	Teeth of awn (+ yes; +f furca; – no)	Hairy glume (+ yes; – no)	Baldness in the trichomes on the spike glume (+ yes; – no)
114/53	–	+	C	+	+	–
114/54	–	+	C	+	+	+
114/55	–	–	C	+	–	–
114/56	–	+f	C	+	–	–
114/57	+	+f	C	+	–	–
114/58	–	+f	C	+f	–	–
114/59	–	+	C	+	–	–
114/60	–	+f	C	+	+	–
114/61	–	–	C	+	–	–
114/62	–	+	C	+f	–	–
114/63	–	+	C	+	–	–
114/64	–	+	C	+	+	+
114/65	–	+f	C	+f	+	–
114/66	–	g	C	+	–	–
114/67	–	+	C	+	–	–
114/68	+	g	C	+	–	–
114/69	+	+	C	+	+	+
114/70	+	g	C	+	–	–
114/71	+	+	C	+	+	+
114/72	–	+	C	+f	+	+
114/73	–	g	C	+	–	–
114/74	+	+	C	+	–	–
114/75	–	g	A	+	+	+
113/1	–	+	C	+	+	–
113/2	–	–	C	+	–	–
113/3	+	+	C	+	+	–
113/4	–	+f	C	+	+	+
113/5	–	+f	C	+	+	–
113/6	–	+f	C	+	+	+
113/7	–	+	C	+	+	+
113/8	+	+f	C	+	+	–
113/9	al	+f	al	–	+	–
113/10	–	+f	C	+f	+	–
113/11	–	+f	C	–	+	–
113/12	–	–	C	+	+	+
113/13	–	+	C	–	–	–
113/14	+	+	C	+	+	–
113/15	al	+	al	–	+	–
113/16	–	+	C	+	+	–
113/17	–	+	C	+	+	+
113/18	–	+	A	–	–	–
113/19	+	+	C	+	+	+
113/20	–	+f	A	+	+	–
113/21	–	+	C	+	+	–
113/22	+	+f	C	+	–	–
113/23	–	+	C	+	+	–
113/24	–	–	C	+	–	–
113/25	–	+f	C	+	+	–
113/26	–	+f	A	+	+	–
113/27	+	+	A	+	+	+
113/28	+	+f	A	+	+	–
113/29	+	+	C	+	+	–
113/30	–	–	C	+	–	–

Table S1 (continued)

Seed number	Tetraaristatum (+ yes; – no; al awnless)	Colored spike (+ black; +f funeral; – normal; g green)	Character (type) of awness (A <i>T. aeth.</i> ; C <i>T. carthl.</i> ; al awnless)	Teeth of awn (+ yes; +f furca; – no)	Hairy glume (+ yes; – no)	Baldness in the trichomes on the spike glume (+ yes; – no)
113/31	–	+	A	+	+	+
113/32	–	+	C	+	+	+
113/33	+	+f	C	+	–	–
113/34	+	g	C	+	–	–
113/35	+	+	C	+	+	+
113/36	–	+	C	+	+	+
112/1	–	+	C	+	+	–
112/2	–	+	C	+	+	–
112/3	–	+f	C	+	+	–
112/4	–	–	C	+	–	–
112/5	–	+	A	+	+	+
112/6	+	+f	C	+	+	+
112/7	+	+f	C	+	+	+
112/8	–	+f	C	–	+	+
112/9	–	+f	C	+	+	+
112/10	–	+	C	+	+	+
112/11	–	+	C	+	+	–
112/12	–	–	C	+	–	–
112/13	–	+f	C	+	–	–
112/14	–	+	C	+f	+	+
112/15	+	+f	C	+	+	+
112/16	+	+	C	+	+	+
112/17	–	+f	C	+f	+	–
112/18	–	+	C	+	+	+
112/19	+	+	C	+	+	–
112/20	al	+f	al	+	+	+
112/21	–	+f	C	+	+	+
112/22	–	+f	C	+	+	–
112/23	–	+f	A	+	+	+
112/24	–	+	C	+	+	–
112/25	+	+f	C	+	+	–
112/26	–	+f	C	+	+	+
112/27	–	–	C	+	–	–
112/28	–	–	C	+	–	–
112/29	–	–	C	+	–	–
112/30	–	+	C	+	+	–
112/31	–	–	C	+	–	–
112/32	–	+	C	+f	+	–
112/33	–	+	C	+	+	+
112/34	+	+	C	+f	+	–
112/35	al	–	al	+	–	–
112/36	–	+	A	+	+	+
112/37	–	–	C	+	–	–
112/38	+	+f	A	+	+	–
112/39	+	+	C	+	+	+
112/40	–	+	C	+f	–	–
112/41	–	+	C	+	+	+
112/42	–	+	A	+	+	–
112/43	–	+	C	+f	+	+
112/44	–	–	A	+	–	–
112/45	–	+	A	+	+	+
112/46	–	–	C	+	–	–
112/47	–	+f	C	+f	–	–

Table S1 (end)

Seed number	Tetraaristatum (+ yes; – no; al awnless)	Colored spike (+ black; +f funeral; – normal; g green)	Character (type) of awnness (A <i>T. aeth.</i> ; C <i>T. carthl.</i> ; al awnless)	Teeth of awn (+ yes; +f furca; – no)	Hairy glume (+ yes; – no)	Baldness in the trichomes on the spike glume (+ yes; – no)
112/48	–	+	C	+	+	–
112/49	–	+f	C	+	–	–
112/50	–	+	C	+	+	+
112/51	–	+f	C	+	+	+
112/52	–	–	A	+	–	–
112/53	–	+	A	+	+	+
112/54	–	+f	C	+	–	–
112/55	–	+f	C	+	+	–
112/56	+	+	C	+	+	–
112/57	–	+f	A	+	+	–
112/58	–	+f	A	+	–	–
112/59	–	g	C	+f	–	–
112/60	–	+f	A	+	–	–
112/61	–	+	A	+	+	–
112/62	–	+	A	+	+	+
112/63	+	+	C	+	+	–
112/64	+	–	C	+	–	–
112/65	–	+	C	+f	+	–
112/66	–	+	A	+	–	–
112/67	–	+	A	–	+	–
112/68	–	–	C	+	–	–
112/69	+	g	C	+	–	–
112/70	+	–	C	+	–	–
112/71	al	–	al	+f	–	–
112/72	+	g	C	+	–	–
112/73	+	g	C	+	–	–
112/74	–	g	C	+	–	–
112/75	–	g	A	+	+	+
112/76	+	g	C	+	–	–

Table S2. List of morphometric parameters of the spike calculated based on the image (see Fig. S1). For the characteristics, the ordinal number, designation, name, and units of measurement are given (in the case of a dimensionless parameter, the unit is indicated as b/r)

No.	Feature designation	Parameter	Unit of measurement
Features based on the quadrilateral model			
1	q_x1	Length of the basal segment	mm
2	q_x2	Length of the central segment	mm
3	q_x3	Length of the apical segment	mm
4	q_y1	The half-width of the basal segment	mm
5	q_y2	The half-width of the apical segment	mm
6	q_ym	Spike half-width (q_y1+ q_y2)/2	mm
7	q_L	Spike model length (q_x1 + q_x2 + q_x3)	mm
8	q_S1	Half of the area of the basal segment	mm ²
9	q_S2	Half of the area of the central segment	mm ²
10	q_S3	Half of the area of the apical segment	mm ²
11	q_S	Half of the area of a model of quadrilaterals	mm ²
Contour and awn characteristics			
12	SL	Length	mm
13	SP	Perimeter	mm
14	SA	Area	mm ²
15	SAA	Awns area	mm ²
16	SCI	Roundness	b/r
17	SRO	Circularity	b/r
18	SSO	Integrity	b/r
19	SRU	Roughness	b/r

Table S3. Means, variances for the distributions of two classes of spikes estimated based on a mixture of two distributions for features obtained based on image analysis. The number of spikes in classes, their ratio, the value of the χ^2 statistic, and the p -value for checking whether the number of spikes in classes is equal to 3:1 are shown. The rows for which the ratio is not significantly different from 3:1 are shown in gray. The data are presented for four projections of the spike

Projection 1									
Trait	mean1	var1	mean2	var2	num1	num2	numratio_1vs2	chisq	chisq_p
q_x1	11.7	61.6	32.3	182.9	92	95	0.97	60.46	0.0000
q_x2	74.7	167.1	59.4	163.3	61	126	0.48	6.29	0.0121
q_x3	18.6	113.3	6.8	14.6	10	177	0.06	37.95	0.0000
q_L	110.7	218.1	83.8	120.9	79	108	0.73	30.99	0.0000
q_y1	6.4	0.7	5.1	0.5	73	114	0.64	20.68	0.0000
q_y2	37.3	0.0	5.1	1.1	1	186	0.01	59.14	0.0000
q_ym	5.1	0.2	4.2	0.2	86	101	0.85	45.65	0.0000
q_S1	115.4	2,682.1	41.0	753.9	64	123	0.52	9.11	0.0025
q_S2	423.6	6,312.5	302.5	5,044.2	71	116	0.61	17.70	0.0000
q_S3	73.8	1,715.2	18.2	126.5	12	175	0.07	33.88	0.0000
q_S	542.5	9,135.2	383.8	5,568.1	64	123	0.52	9.11	0.0025
SL	110.7	218.1	83.8	120.9	79	108	0.73	30.99	0.0000
SP	330.3	1,565.5	257.9	1,077.6	63	124	0.51	8.11	0.0044
SA	1,082.6	50,635.4	812.3	2,5012.6	60	127	0.47	5.47	0.0194
SAA	792.3	151,092.6	244.6	32,393.1	41	146	0.28	0.80	0.3709
SCI	0.1	0.0	0.2	0.0	84	103	0.82	41.17	0.0000
SRO	0.1	0.0	0.1	0.0	26	161	0.16	11.85	0.0006
SSO	0.8	0.0	0.8	0.0	39	148	0.26	1.52	0.2173
SRU	5.0	0.0	1.3	0.0	1	186	0.01	59.14	0.0000
Projection 2									
Trait	mean1	var1	mean2	var2	num1	num2	numratio_1vs2	chisq	chisq_p
q_x1	9.8	42.3	27.0	137.3	78	109	0.72	29.13	0.0000
q_x2	77.7	155.1	59.0	114.7	78	109	0.72	29.13	0.0000
q_x3	17.2	86.7	5.2	9.7	28	159	0.18	9.62	0.0019
q_L	115.8	190.7	84.0	121.6	62	125	0.50	7.17	0.0074
q_y1	4.3	0.4	5.5	0.3	89	98	0.91	52.80	0.0000
q_y2	5.5	0.9	3.9	0.4	30	157	0.19	7.63	0.0057
q_ym	4.5	0.2	3.8	0.2	49	138	0.36	0.22	0.6358
q_S1	25.6	306.0	74.4	1,359.3	87	100	0.87	47.97	0.0000
q_S2	366.4	6,656.2	265.3	3,004.0	67	120	0.56	12.44	0.0004
q_S3	45.4	912.3	10.8	49.6	33	154	0.21	5.07	0.0243
q_S	473.5	10,736.0	332.4	4,123.0	53	134	0.40	1.32	0.2502
SL	115.8	190.7	84.0	121.6	62	125	0.50	7.17	0.0074
SP	311.4	1,419.7	249.2	1,172.8	52	135	0.39	0.96	0.3269
SA	974.7	44,724.9	718.2	18,524.8	43	144	0.30	0.31	0.5777
SAA	574.1	119,803.5	147.5	12,517.7	42	145	0.29	0.53	0.4681
SCI	0.2	0.0	0.1	0.0	88	99	0.89	50.35	0.0000
SRO	0.1	0.0	0.1	0.0	40	147	0.27	1.13	0.2872
SSO	0.8	0.0	0.9	0.0	59	128	0.46	4.70	0.0301
SRU	1.4	0.0	1.2	0.0	68	119	0.57	13.67	0.0002

Table S3 (end)

Projection 3									
Trait	mean1	var1	mean2	var2	num1	num2	numratio_1vs2	chisq	chisq_p
q_x1	10.2	31.3	30.0	137.5	72	115	0.63	19.16	0.0000
q_x2	74.1	152.8	58.3	155.7	76	111	0.68	25.57	0.0000
q_x3	19.1	172.7	7.2	15.8	6	181	0.03	46.79	0.0000
q_L	113.6	284.7	88.0	194.8	55	132	0.42	2.22	0.1364
q_y1	5.3	0.8	6.0	1.5	80	107	0.75	32.91	0.0000
q_y2	35.5	0.0	5.1	1.2	1	186	0.01	59.14	0.0000
q_ym	5.1	1.7	4.5	0.3	12	175	0.07	33.88	0.0000
q_S1	29.1	265.6	94.6	1,884.8	71	116	0.61	17.70	0.0000
q_S2	408.3	8,894.2	302.2	4,968.8	78	109	0.72	29.13	0.0000
q_S3	145.3	827.6	21.0	207.3	3	184	0.02	54.02	0.0000
q_S	545.4	9,255.3	388.4	5,651.9	60	127	0.47	5.47	0.0194
SL	113.6	284.7	88.0	194.8	55	132	0.42	2.22	0.1364
SP	328.8	2,975.4	270.9	1,556.0	36	151	0.24	3.04	0.0813
SA	1,099.5	43,055.3	810.7	24,266.5	56	131	0.43	2.75	0.0971
SAA	759.0	136,893.6	229.9	30,079.3	48	139	0.35	0.09	0.7590
SCI	0.2	0.0	0.2	0.0	42	145	0.29	0.53	0.4681
SRO	0.5	0.0	0.1	0.0	1	186	0.01	59.14	0.0000
SSO	0.8	0.0	0.8	0.0	27	160	0.17	10.70	0.0011
SRU	2.1	0.6	1.3	0.0	8	179	0.04	42.26	0.0000
Projection 4									
Trait	mean1	var1	mean2	var2	num1	num2	numratio_1vs2	chisq	chisq_p
q_x1	32.5	126.3	13.5	56.4	41	146	0.28	0.80	0.3709
q_x2	80.0	229.0	58.5	135.6	72	115	0.63	19.16	0.0000
q_x3	91.0	0.0	6.3	23.8	1	186	0.01	59.14	0.0000
q_L	111.5	225.1	83.5	135.5	54	133	0.41	1.74	0.1870
q_y1	4.4	0.9	5.3	0.5	70	117	0.60	16.30	0.0001
q_y2	5.1	1.1	4.0	0.3	34	153	0.22	4.34	0.0373
q_ym	4.3	0.6	3.9	0.2	31	156	0.20	6.72	0.0095
q_S1	95.9	1,204.4	33.6	397.5	37	150	0.25	2.48	0.1157
q_S2	381.7	8,545.9	269.2	34,14.0	57	130	0.44	3.34	0.0674
q_S3	145.2	77.6	14.6	141.4	2	185	0.01	56.55	0.0000
q_S	460.4	13,888.6	335.6	4,196.3	37	150	0.25	2.48	0.1157
SL	111.5	225.1	83.5	135.5	54	133	0.41	1.74	0.1870
SP	303.7	1,968.5	239.4	1,134.0	75	112	0.67	23.88	0.0000
SA	953.8	49,118.4	704.3	17,344.2	47	140	0.34	0.02	0.8828
SAA	578.4	127,534.0	133.5	11,256.2	51	136	0.38	0.66	0.4174
SCI	0.2	0.0	0.1	0.0	88	99	0.89	50.35	0.0000
SRO	0.1	0.0	0.1	0.0	29	158	0.18	8.60	0.0034
SSO	0.8	0.0	0.9	0.0	81	106	0.76	34.89	0.0000
SRU	1.6	0.2	1.2	0.0	15	172	0.09	28.21	0.0000