

Supplementary material

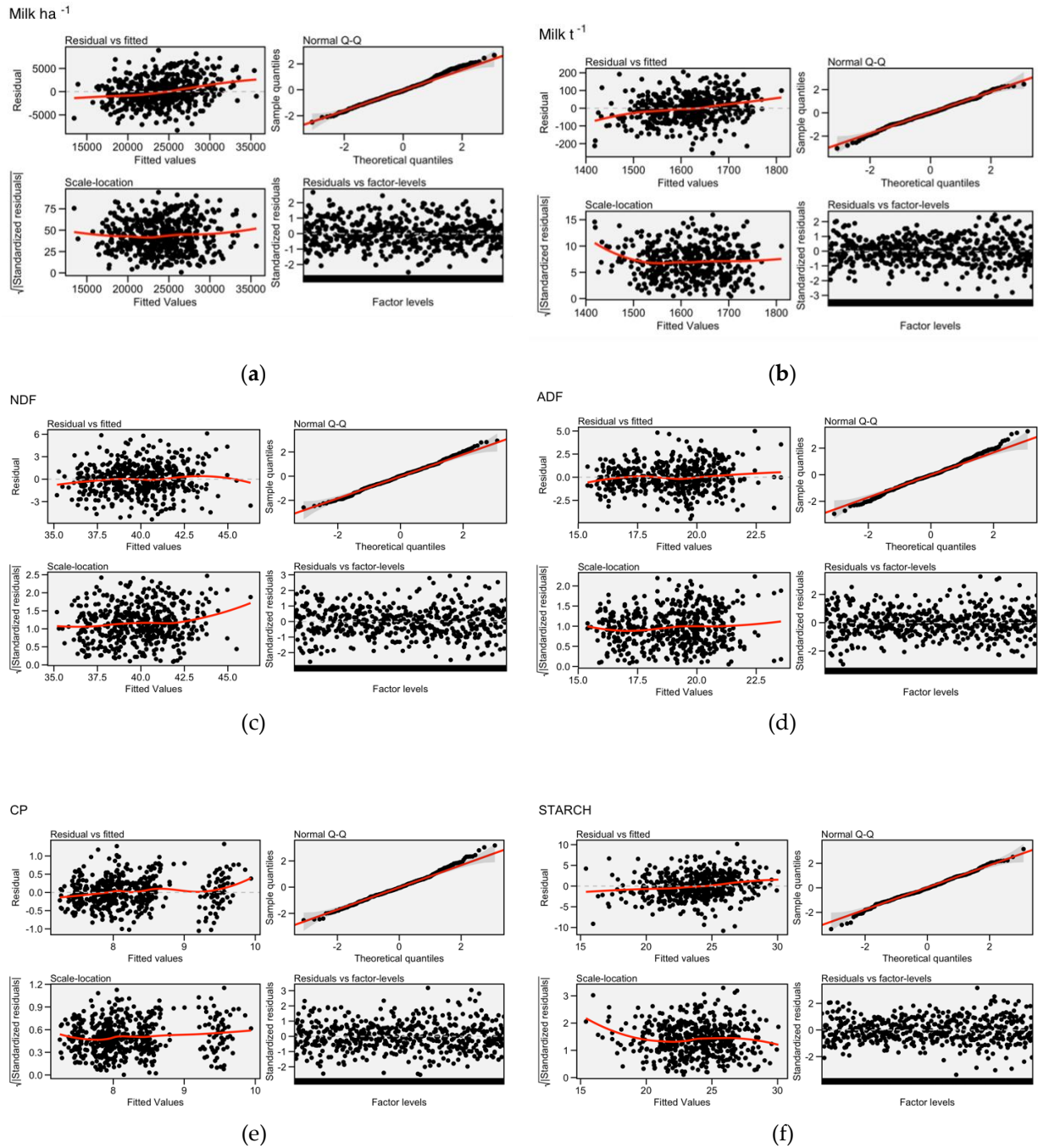


Figure S1. (a) Random effect Milk ha⁻¹ model fit; (b) Random effect Milk t⁻¹ model fit; (c) Random effect Milk NDF model fit; (d) Random effect ADF model fit; (e) Random effect Crude Protein content model fit; (f) Random effect Starch content model fit.

Table S1. Industry standards

Industry Standard	Registration Date ¹	Registration expiry date	Registration number
NS5010	31 January 2014.	N/A	320-04-1177/2/2012-11
NS6043	23 December 2019.	N/A	320-04-2024/2/2018-11
P0725	26 December 2012.	N/A	320-04-674/2/2011-11
AS160	19 March 2010.	19 March 2020	320-44-16/34-1/2020-11
MIKADO	26 January 2019.	N/A	320-04-1837/2/2013-11

¹ data taken from Registry of Variety Protection Department, Ministry of Agriculture Forestry and Water Management, Republic of Serbia.

Table S2. List of location-year combinations with corresponding planting and harvest dates

Environment	Location	Year	Planting Date	Harvest Date
1	Rimski Sancevi	2019	15 April	21 August
2	Rimski Sancevi	2020	07 April	18 August
3	Srbobran	2020	12 April	27 August
4	Lukicevo	2020	28 April	22 August
5	Rimski Sancevi	2021	26 April	20 August
6	Srbobran	2021	09 May	26 August
7	Lukicevo	2021	07 May	23 August

Table S3. LRT test for all-random model of each tested trait

VAR	model	npar	logLik	AIC	LRT	Pr(>Chisq)
Milk ha ⁻¹	GEN ¹	5	-4925.85	9861.7	69.91	0
Milk ha ⁻¹	REP(ENV) ²	5	-4891.41	9792.82	1.03	0.31
Milk ha ⁻¹	ENV ³	5	-4897.75	9805.5	13.71	0
Milk ha ⁻¹	GEN:ENV ⁴	5	-4898.1	9806.2	14.41	0
Milk t ⁻¹	GEN	5	-3057.75	6125.5	87.71	0
Milk t ⁻¹	REP(ENV)	5	-3014.16	6038.33	0.54	0.46
Milk t ⁻¹	ENV	5	-3017.88	6045.77	7.98	0
Milk t ⁻¹	GEN:ENV	5	-3016.24	6042.48	4.7	0.03
NDF	GEN	5	-1163.89	2337.78	67.25	0
NDF	REP(ENV)	5	-1131.23	2272.46	1.93	0.16
NDF	ENV	5	-1136.8	2283.61	13.08	0
NDF	GEN:ENV	5	-1130.27	2270.53	0.01	0.94
ADF	GEN	5	-1003.74	2017.49	62.24	0
ADF	REP(ENV)	5	-972.62	1955.25	0	1
ADF	ENV	5	-983.39	1976.77	21.52	0
ADF	GEN:ENV	5	-972.62	1955.25	0	1
CP	GEN	5	-342.99	695.98	8.76	0
CP	REP(ENV)	5	-339.7	689.41	2.19	0.14
CP	ENV	5	-348.7	707.4	20.18	0
CP	GEN:ENV	5	-340.13	690.26	3.04	0.08
STARCH	GEN	5	-1411.04	2832.09	87.69	0
STARCH	REP(ENV)	5	-1367.96	2745.92	1.53	0.22
STARCH	ENV	5	-1370.25	2750.5	6.11	0.01
STARCH	GEN:ENV	5	-1367.88	2745.76	1.37	0.24

¹ Genotype; ² Replication within environment; ³ Environment; ⁴ Genotype by environment interaction

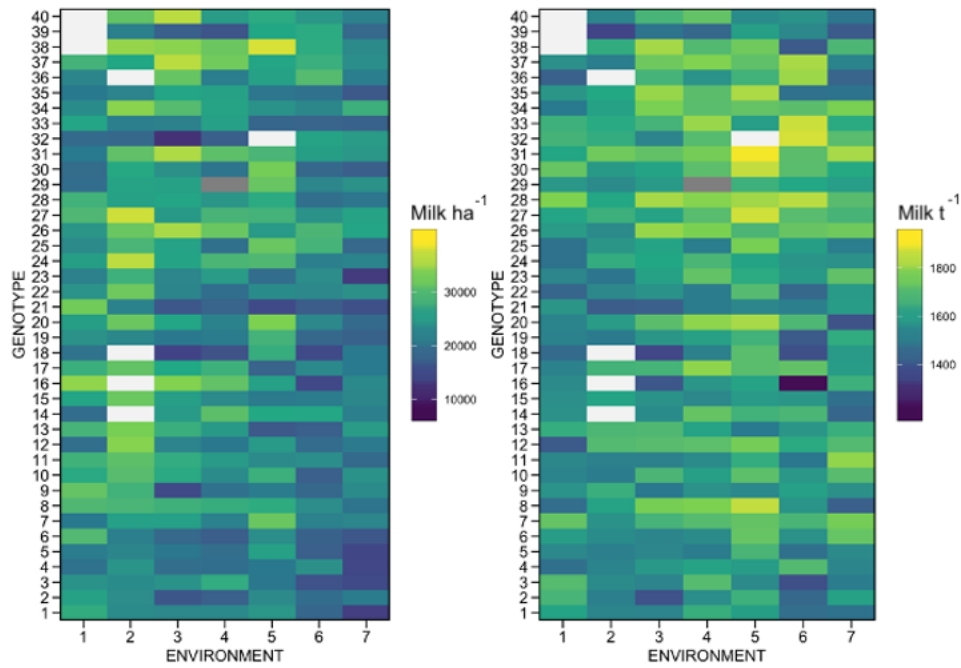


Figure S2. Milk ha⁻¹ and Milk t⁻¹ Genotype-environment heatmaps

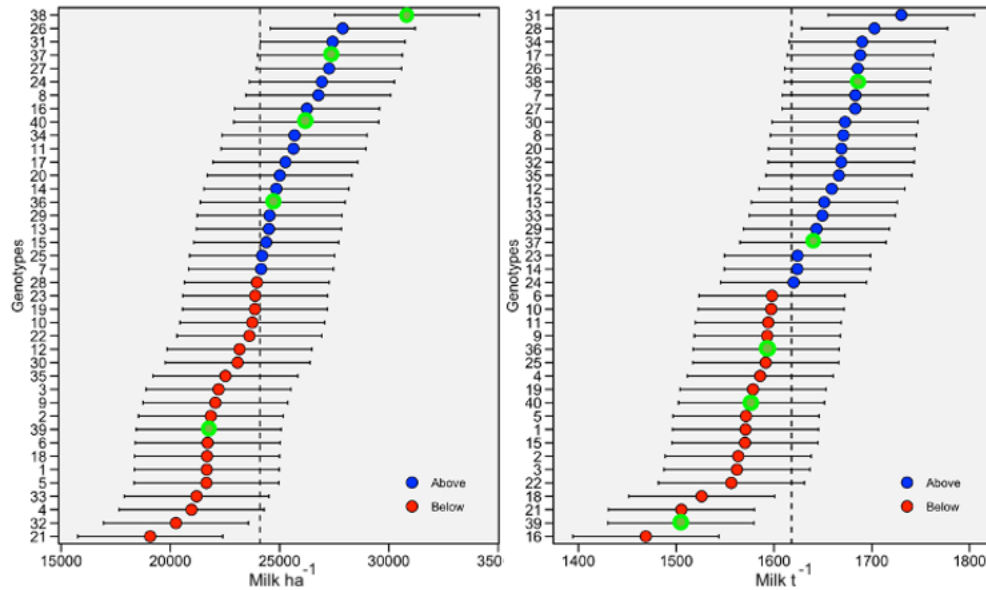


Figure S3. Ranked Milk ha⁻¹ and Milk t⁻¹ BLUP values in kg ha⁻¹ and kg Mg⁻¹. Vertical dashed lines represent grand mean of the experiment; error bars represent the 95% confidence interval considering a two-tailed t test; in red are the genotypes that performed below the mean for the experiment, in blue – genotypes with BLUP values above the mean value for the experiment; highlighted in green are the industry standards.

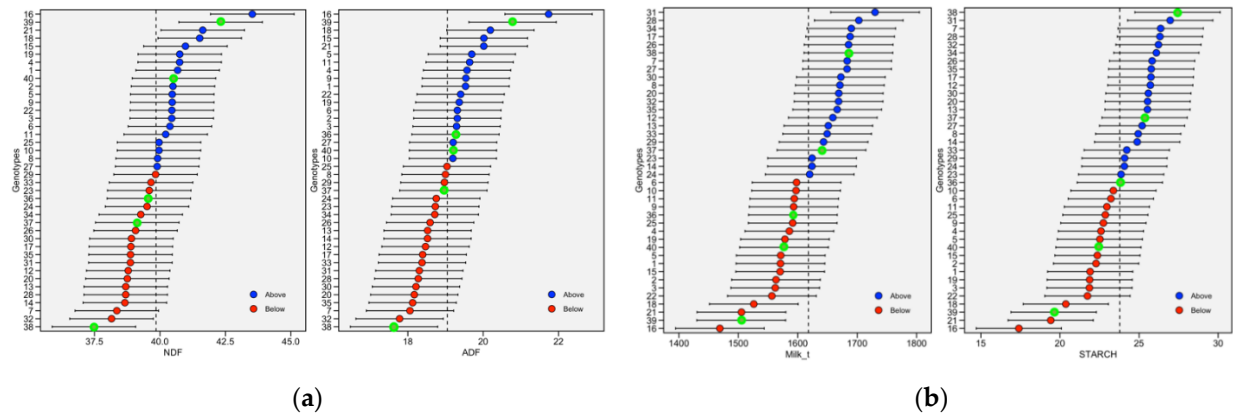


Figure S4 (a) Genotypes ranked for NDF BLUP values versus ADF BLUP values; (b) Genotypes ranked for Milk t^{-1} BLUP values versus starch fraction BLUP values. Vertical dashed lines represent the mean values for the experiment; error bars represent the 95% confidence interval considering a two-tailed t test; in red are the genotypes that performed below the mean for the experiment, in blue – genotypes with BLUP values above the mean value for the experiment, highlighted in green are the industry standards.

Table S4. Distribution of variance components per trait

Effect	v Milk ha^{-1}	v Milk t^{-1}	v NDF	v ADF	v starch	v CP
ENV	23.7	10.04	31.21	43.67	9.26	65.08
GEN	24.25	31.24	18.9	14.62	30.7	3.17
GEN:ENV	13.46	8.68	0.34	0	4.81	3.17
REP:ENV	0.69	0.61	1.23	0	1.2	1.59
Residual	37.9	49.43	48.32	41.71	54.03	26.98

1v Milk ha^{-1} , v Milk t^{-1} , v NDF, v ADF, v starch and v CP represent the percentages of phenotypic variance of corresponding traits, explained by individual effects in the model

Table S5. BLUP values of each trait

GENOTYPE	Milk ha ⁻¹	Milk t ⁻¹	NDF	ADF	CP	STARCH
1	21668.2	1570.92	40.68	19.53	8.23	21.91
2	21854.8	1563.4	40.5	19.31	8.17	22.28
3	22205.87	1562.14	40.45	19.29	8.25	21.86
4	20972.09	1585.89	40.75	19.57	8.26	22.59
5	21651.72	1571.35	40.47	19.7	8.2	22.52
6	21706.08	1597.94	40.38	19.31	8.19	23.22
7	24153.32	1683.16	38.35	18.06	8.3	26.36
8	26774.72	1670.92	39.91	19	8.3	24.95
9	22061.35	1593.08	40.47	19.54	8.2	22.74
10	23752.26	1597.1	39.96	19.19	8.17	23.38
11	25635.03	1594.15	40.22	19.64	8.24	22.96
12	23167.39	1659.08	38.79	18.47	8.18	25.71
13	24511.64	1651.4	38.69	18.53	8.25	25.53
14	24849.4	1623.86	38.66	18.52	8.19	24.88
15	24388.38	1570.36	40.97	20.02	8.16	22.37
16	26253.53	1468.93	43.53	21.74	8.3	17.4
17	25267.6	1688.14	38.89	18.39	8.49	25.75
18	21681.27	1526.01	41.52	20.19	8.25	20.37
19	23871.02	1578.49	40.76	19.37	8.14	21.88
20	25009.14	1669	38.76	18.17	8.26	25.54
21	19081.75	1505.29	41.63	20.02	8.34	19.42
22	23617.24	1556.39	40.46	19.4	8.24	21.74
23	23881.78	1624.02	39.59	18.73	8.24	23.86
24	26933.28	1620.06	39.51	18.75	8.22	24.07
25	24198.95	1591.55	39.97	19.04	8.23	22.87
26	27889.99	1685.58	39.07	18.59	8.23	25.83
27	27261.58	1682.99	39.89	19.2	8.29	25.19
28	23962.14	1702.73	38.69	18.28	8.18	26.32
29	24541.42	1643.46	39.83	18.97	8.15	24.08
30	23078.41	1672.63	38.91	18.22	8.08	25.59
31	27426.86	1730.12	38.87	18.3	8.12	26.97
32	20259.1	1668.71	38.15	17.78	8.25	26.22
33	21203.26	1649.46	39.66	18.38	8.36	24.22
34	25683.34	1690.1	39.27	18.72	8.1	26.09
35	22523.93	1666.35	38.88	18.13	8.11	25.77
36	24688.35	1591.93	39.58	19.26	8.17	23.78
37	27299.69	1639.84	39.13	18.94	7.98	25.35
38	30822.5	1685.23	37.48	17.63	7.99	27.43
39	21757.98	1504.93	42.32	20.78	8.17	19.6
40	26218.66	1576.95	40.54	19.2	8.2	22.43

¹ADF, NDF, starch fraction and CP content are expressed as percentage of dry matter, Milk ha⁻¹ and Milk t⁻¹ are expressed in kg ha⁻¹ and in kg Mg⁻¹, respectively

Table S6. AMMI significance table

Trait	Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Milk ha ⁻¹	ENV	6	3146856155.48	524476025.91	28.26	0
Milk ha ⁻¹	REP(ENV)	7	129892740.09	18556105.73	1.69	0.11
Milk ha ⁻¹	GEN	39	4076985933.34	104538100.85	9.54	0
Milk ha ⁻¹	GEN:ENV	225	4137432718.05	18388589.86	1.68	0
Milk t ⁻¹	ENV	6	651439.96	108573.33	9.61	0
Milk t ⁻¹	REP(ENV)	7	79069.52	11295.65	1.63	0.13
Milk t ⁻¹	GEN	39	2386595.31	61194.75	8.82	0
Milk t ⁻¹	GEN:ENV	225	2054166.09	9129.63	1.32	0.02
NDF	ENV	6	1245.13	207.52	24.67	0
NDF	REP(ENV)	7	58.87	8.41	1.97	0.06
NDF	GEN	39	1009.3	25.88	6.05	0
NDF	GEN:ENV	225	990.63	4.4	1.03	0.41
ADF	ENV	6	1057.54	176.26	74.05	0
ADF	REP(ENV)	7	16.66	2.38	1	0.43
ADF	GEN	39	504.23	12.93	5.42	0
ADF	GEN:ENV	225	515.33	2.29	0.96	0.62
CP	ENV	6	175.16	29.19	102.67	0
CP	REP(ENV)	7	1.99	0.28	1.64	0.13
CP	GEN	39	17.99	0.46	2.65	0
CP	GEN:ENV	225	50.16	0.22	1.28	0.03
STARCH	ENV	6	853.9	142.32	6.95	0.01
STARCH	REP(ENV)	7	143.43	20.49	1.99	0.06
STARCH	GEN	39	3252.27	83.39	8.11	0
STARCH	GEN:ENV	225	2701.2	12.01	1.17	0.12

Table S7. Environments ranked for Milk ha⁻¹ BLUP values

Env. Rank	ENV	BLUPe
1	2	3306.02
2	1	1753.16
3	5	1312.4
4	3	761.48
5	4	-483.27
6	6	-2676.69
7	7	-3973.11

Table S8. The WAASB and WAASBY Milk ha⁻¹ values of genotypes with their rankings, assuming 50:50 weight on stability vs. productiveness

GEN	Y	PctResp	PctWAASB	OrResp	OrWAASB	OrPC1	WAASBY	OrWAASBY
1	21310	23.91	99.05	31	2	4	61.48	13
2	21217.38	23.26	100	32	1	9	61.63	12
3	22115.84	29.57	78.38	29	13	23	53.98	20
4	20392.43	17.46	89.47	37	4	1	53.46	22
5	21207.14	23.18	37.48	33	35	37	30.33	39
6	21082.59	22.31	91.66	34	3	5	56.98	16
7	24602.71	47.06	78.51	18	12	22	62.79	11
8	27352.24	66.4	51.38	7	28	33	58.89	15
9	21671.21	26.45	54.45	30	27	34	40.45	31
10	23792.04	41.36	8	23	39	40	24.68	40
11	26132.87	57.82	32.09	11	37	38	44.96	30
12	23095.48	36.46	65.33	26	20	29	50.9	24
13	24700.86	47.75	84.8	16	7	13	66.28	7
14	24605.99	47.09	50.51	17	29	12	48.8	27
15	24753.43	48.12	80.77	15	9	17	64.45	8
16	26280.66	58.86	74.72	10	15	11	66.79	6
17	25590.97	54.01	41.37	12	34	32	47.69	28
18	20349.15	17.15	55.51	38	25	27	36.33	35
19	23700.83	40.72	68.66	24	18	26	54.69	19
20	25288.94	51.89	85.05	13	6	7	68.47	5
21	17910.37	0	63.03	40	22	20	31.51	38
22	23631.24	40.23	61.51	25	24	8	50.87	25
23	24012.62	42.91	62.99	22	23	25	52.95	23
24	27580.52	68	71.1	6	17	15	69.55	3
25	24411.07	45.72	27.74	19	38	36	36.73	34
26	28497.21	74.45	0	2	40	39	37.23	33
27	27978.32	70.8	55	4	26	10	62.9	10
28	24042	43.12	35.01	21	36	31	39.07	32
29	24827.86	48.65	78.54	14	11	18	63.59	9
30	22793.11	34.34	79.19	27	10	3	56.77	17
31	28173.79	72.18	66.28	3	19	14	69.23	4
32	18987.7	7.58	64.82	39	21	16	36.2	36
33	21021.53	21.88	42.74	36	32	35	32.31	37
34	26367.12	59.47	82.71	9	8	21	71.09	2
35	22329.15	31.07	89.38	28	5	19	60.23	14
36	24366.77	45.4	47.29	20	31	28	46.35	29
37	27829.92	69.76	41.47	5	33	30	55.62	18
38	32130.14	100	74.07	1	16	2	87.03	1
39	21046.12	22.05	76.5	35	14	6	49.27	26
40	26464.53	60.16	47.54	8	30	24	53.85	21

¹Y is response variable – Milk ha⁻¹ in kg ha⁻¹; WAASB - the weighted average of the absolute scores estimated by SVD (singular value decomposition) of BLUPs; PctWAAS and PctResp - the rescaled variable for the WAASB and Y, respectively; OrResp and OrWAASB are the ranks of genotypes attributed to Y or WAASB; WAASBY is the simultaneous selection index that weights between response variable and stability; OrWAASBY is the rank for the WAASBY value. The genotype with the largest WAASBY value is the first ranked genotype; the first 5 ranking genotypes by WAASBY are highlighted in red; Milk ha⁻¹ WAASBY value for ADF was calculated based on mean performance only, for p-values for ADF GE interaction were equal to 1

Table S9. The WAASB and WAASBY Milk t⁻¹ values of genotypes with their rankings, assuming 50:50 weight on stability vs. productiveness

GEN	Y	PctResp	PctWAASB	OrResp	OrWAASB	OrPC1	WAASBY	OrWAASBY
1	1562.98	37.52	71.96	32	17	30	54.74	25
2	1551.84	33.87	94.73	35	3	8	64.3	16
3	1561.25	36.95	46.99	33	30	18	41.97	32
4	1577.14	42.15	10.46	28	38	35	26.3	39
5	1557.7	35.79	64.43	34	21	4	50.11	27
6	1597.11	48.69	93.14	22	4	19	70.92	13
7	1691.19	79.49	87.11	8	8	26	83.3	4
8	1685.56	77.65	6.78	9	39	38	42.22	31
9	1585.01	44.73	36.81	27	32	36	40.77	33
10	1593.16	47.4	0	24	40	39	23.7	40
11	1587.57	45.57	57.64	26	25	32	51.61	26
12	1664.61	70.79	13.92	14	37	40	42.35	30
13	1648.72	65.59	30.22	16	33	29	47.9	28
14	1629.89	59.42	56.63	19	27	25	58.03	19
15	1568.18	39.22	74.78	31	14	27	57	20
16	1448.4	0	61.92	40	23	20	30.96	37
17	1693.84	80.36	79.75	6	11	24	80.05	6
18	1512.88	21.11	41.07	37	31	21	31.09	36
19	1569.4	39.62	71.74	30	18	12	55.68	23
20	1676.04	74.53	58.93	11	24	15	66.73	15
21	1482.34	11.11	47.67	39	29	11	29.39	38
22	1546.23	32.03	78.87	36	12	9	55.45	24
23	1618.02	55.54	17.23	21	35	37	36.38	34
24	1619.63	56.06	95.35	20	2	3	75.7	8
25	1588.29	45.8	90.35	25	7	14	68.08	14
26	1691.33	79.54	66.6	7	20	16	73.07	12
27	1699.53	82.23	29.28	4	34	23	55.75	22
28	1714.93	87.27	92.56	2	5	13	89.91	1
29	1641.86	63.34	63.74	17	22	1	63.54	17
30	1680.48	75.99	15.21	10	36	34	45.6	29
31	1753.82	100	57.36	1	26	33	78.68	7
32	1674.35	73.98	74.18	12	15	17	74.08	11
33	1661.14	69.65	81.39	15	10	31	75.52	9
34	1698.09	81.75	92.24	5	6	22	86.99	2
35	1672.98	73.53	77.37	13	13	5	75.45	10
36	1593.32	47.45	73.35	23	16	6	60.4	18
37	1636.87	61.71	100	18	1	10	80.85	5
38	1701.86	82.99	84.78	3	9	7	83.88	3
39	1489.44	13.44	51.66	38	28	28	32.55	35
40	1576.77	42.03	70.24	29	19	2	56.14	21

¹Y is response variable – Milk t⁻¹ in kg Mg⁻¹; WAASB - the weighted average of the absolute scores estimated by SVD (singular value decomposition) of BLUPs; PctWAAS and PctResp - the rescaled variable for the WAASB and Y, respectively; OrResp and OrWAASB are the ranks of genotypes attributed to Y or WAASB; WAASBY is the simultaneous selection index that weights between response variable and stability; OrWAASBY is the rank for the WAASBY value. The genotype with the largest WAASBY value is the first ranked genotype; the first 5 ranking genotypes by WAASBY are highlighted in red; Milk ha⁻¹ WAASBY value for ADF was calculated based on mean performance only, for p-values for ADF GE interaction were equal to 1

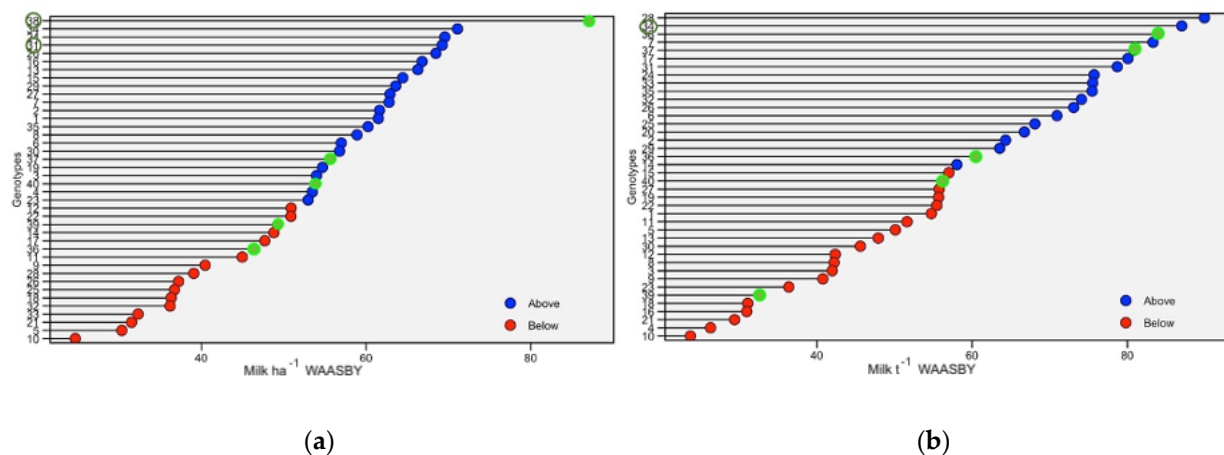


Figure S5. (a) Genotypes ranked for Milk ha⁻¹ WAASBY index with equal weights on productivity:stability scale (b) Genotypes ranked for Milk t⁻¹ WAASBY index with equal weights on productivity:stability scale; highlighted in green are the industry standards. Encircled on the left hand-side are the genotypes appearing in the 5 highest-ranking for BLUP and WAASBY for each trait

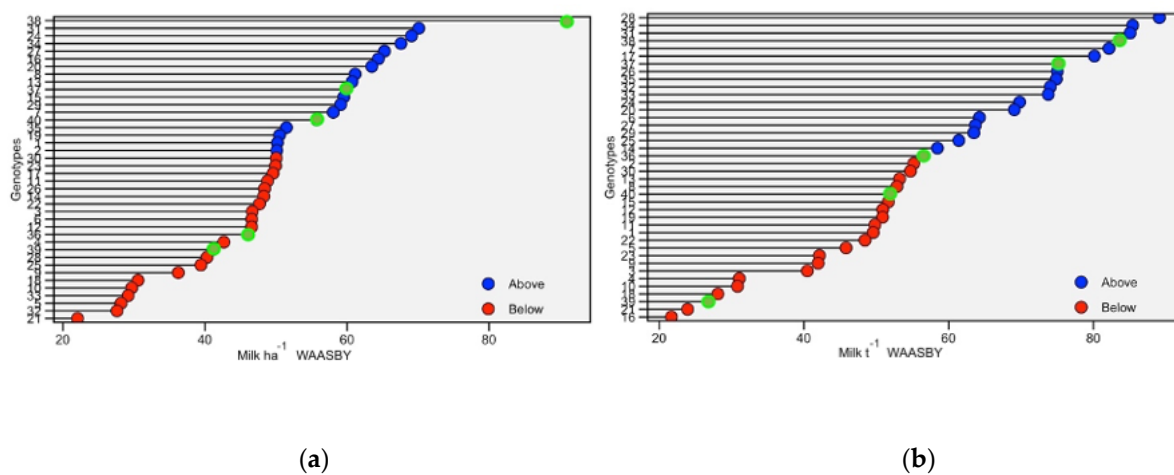


Figure S6. (a) Genotypes ranked for Milk ha⁻¹ WAASBY index with 65:35 weights on productivity:stability scale; (b) Genotypes ranked for Milk t⁻¹ WAASBY index with 65:35 weights on productivity:stability scale; highlighted in green are the industry standards

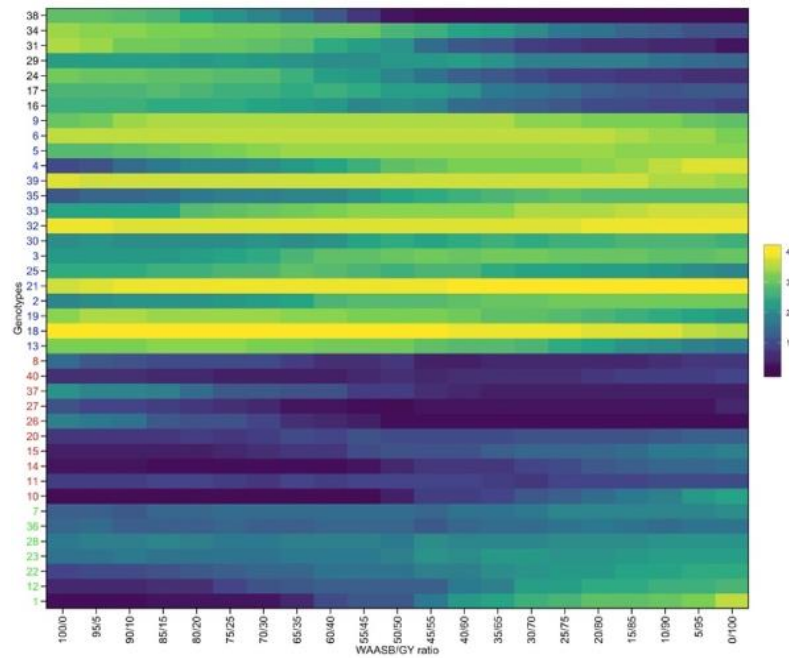


Figure S7. Heatmap of WAASB/Milk ha⁻¹ yield ratio scenarios, with genotypes in scenario 100/0, on the further left of the x-axis, being ranked purely on the basis of stability, and genotypes in scenario 0/100, on the further right of the x-axis, being ranked based on their performance in yield. The 4 color-coded clusters of genotypes: in blue – genotypes that are unstable and low-yielding, in black – highly productive, but low ranking when a lot of emphasis on stability is put on, in red – relatively leveraged, higher ranking genotypes for productivity and stability, and in green, genotypes that are stable, but low ranking in terms of productivity.

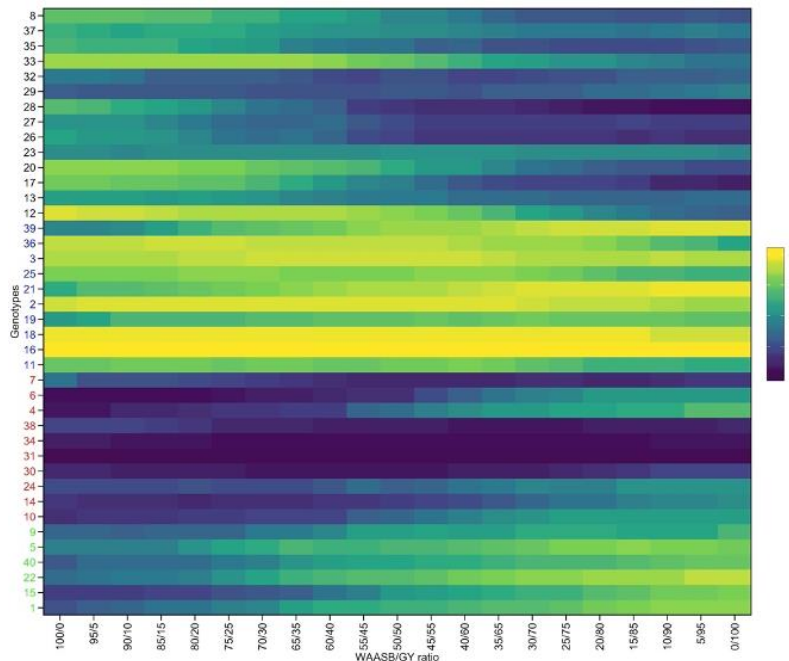


Figure S8. Heatmap of WAASB/ Milk t⁻¹ yield ratio scenarios, with genotypes in scenario 100/0, on the further left of the x-axis, being ranked purely on the basis of their stability, and genotypes in scenario 0/100, on the further right of the x-axis, being ranked based on their Milk t⁻¹ performance. The 4 color-coded clusters of genotypes: in blue – genotypes that are unstable and low-yielding, in black – relatively productive, but low ranking when an emphasis on stability is put on, red – relatively leveraged, higher ranking genotypes for productivity and stability, and in green, genotypes that are stable, but low ranking in terms of productivity.

Four distinctive clusters of genotypes behaving consistently can be separated. Genotypes that hold a very high ranking across the productivity:stability scenarios – the red cluster, the opposite – blue cluster – the genotypes that have relatively low ranking across the different productivity:stability ratios, black cluster – relatively productive, but low ranking when an emphasis on stability is put on and green - stable, but low ranking in terms of productivity.

The four clusters of genotypes on the y-axis (Figure S7, Figure S8) should be taken conservatively, because the clustering was done on the whole range of the scenarios, from 100/0 to 0/100; scenarios that are of interest for breeders, in most cases, are the ones that perform well in 50/50 scenario (Figure S5) and higher (Figure S6) in favor of productivity.

Table S10. Differentials between the means of selected genotypes and the total population.

VAR	Xo	Xs	D	%D
Milk_ha	24091.1	27357.2	3266.11	13.56
Milk_t	1617.59	1690.1	72.51	4.48

¹Xo is total population mean; Xs is selected genotypes mean; D is the differential, SG is the selection gain

Table 11. Differentials for stability (WAASB) and combined performance and stability (WAASBY) between the selected 15% of the genotypes and the total population

WAASB					WAASBY			
TRAIT	Xo	Xs	D	%D	Xo	Xs	D	%D
Milk_ha	11.71	9.27	-2.44	-20.81	52.91	71.36	18.45	34.87
Milk_t	1.34	1	-0.34	-25.62	57.93	79.22	21.29	36.75

¹Xo is total population mean; Xs is selected genotypes mean; D is the differential