Supplementary Materials

Figure S1. Experimental sites: open field (left) and high tunnel (right) at the NDSU Agricultural Experiment Station, Fargo, ND, USA.



Table S1. Cultivars, seed source, and days to maturity.

Cultivar	Seed source	Days to Maturity
Green Magic	Johnny's Seeds	57
Gypsy	Johnny's Seeds	60
Jacaranda	Territorial Seeds	50
Monty	Johnny's Seeds	56
Purple Peacock	Johnny's Seeds	70
Romanesco	Pinetree Seeds	78

Days to maturity are the values given by the seed suppliers. In this study, the estimated mean time from transplanting to harvest ranged from 53.7 days (Monty) to 77.0 days (Jacaranda) (Table 3 of the main text). Romanesco formed no curds at any planting date in either environment or year.

Table S2. Monthly air and soil temperatures, dates of first observed frost injury, and dates of last harvest in the high tunnel and the open field in 2023 and 2024.

Year	Month	Air Temperature (°C)						Soil Temperature (°C)					
		Minimum		Mean		Maximum		Minimum		Mean		Maximum	
		HT	OF	HT	OF	HT	OF	HT	OF	HT	OF	HT	OF
2023	**Jul**	21.5	9.8	25.5	21.3	39.1	38.3	18.4	18.1	26.5	23.2	39.5	38.3
	Aug	12.1	2.4	23.5	20.9	38.8	44.9	21.7	14.1	24.1	20.5	26.9	28.5
	Sep	6.3	-5.5	20.3	15.1	43.2	39.4	17.1	9.1	21.1	15.3	27.5	21.4
	Oct	-8.3	-10.8	10.6	3.3	36.3	29.0	5.3	1.9	14.6	6.3	24.8	13.7
2024	**Jul**	15.1	12.5	26.4	24.6	38.3	34.1	24.4	19.7	28.6	26.6	34.2	33.4
	Aug	11.2	9.8	23.9	21.8	45.8	33.4	20.1	14.4	25.2	22.2	33.7	30.9
	Sep	11.7	7.1	22.5	21.3	34.8	32.9	17.5	14	23.1	20.3	29.4	25.6
	Oct	2.6	-1.7	18	13.4	31.1	30	7.5	3.3	20.4	12.2	24.3	19.6

HT, high tunnel; OF, open field. Values are the monthly minimum, mean, and maximum of hourly data-logger records (WatchDog 1000 Series, Spectrum Technologies, Aurora, IL, USA). Frost injury was first observed on plants on 14 October 2023 and 28 October 2024 in the open field and on 4 November 2023 and 18 November 2024 in the high tunnel (21 days later in both years). The last heads were harvested on 4 November 2023 and 7 November 2024 in the open field and on 19 November 2023 and 7 November 2024 in the high tunnel; in 2024, plants without heads remained in the high tunnel and were observed until 17 November.

Table S3. Data corrections and exclusions (Applied before analysis full record-level log available from the authors).

Data set	Variable	Records	Correction	Reason
Broccoli yield	Root length	3	Values of 215.9, 215.9, and 114.3 cm corrected to 21.59, 21.59, and 11.43 cm	Decimal error during conversion from inches; corrected values reproduce the means used in the original analysis
Broccoli growth	Leaf number	1	242 corrected to 24	Typing error; the same plant had 23 leaves at 50 DAT
Broccoli growth	Leaf number	2	Set to missing	Value more than twice both the preceding and the following count on the same plant
Broccoli growth	Replication label	3	Duplicated "Rep 4" records relabelled "Rep 3"	Rep 3 record missing for the same plant and date; assigned by continuity with the plant's trajectory
Broccoli gas exchange	WUE	80	Set to missing (WUE = 0)	Net CO_2 assimilation not registered; WUE undefined
Broccoli gas exchange	WUE	37	Set to missing (WUE < 0)	Net CO_2 efflux at the time of reading; WUE not physiologically meaningful
Broccoli gas exchange	WUE	14	Set to missing	Implied net assimilation (WUE × E) at the instrument limit (>90 μmol m^{-2} s^{-1})
Broccoli gas exchange	g_s	38	Missing in the original records (entered as ".")	Not available; E, WUE, and F_v'/F_m' of these readings were retained
Romanesco growth	Plant height	1	1270 corrected to 127.0 cm	Decimal error; the same plant was 94.0 cm at 50 DAT
Romanesco growth	Height/leaf number	40	Zero values set to missing	Zeros recorded for dead or missing plants
Romanesco roots	Root width	1	0 set to missing	Zero width not possible for a measured root system
Romanesco gas exchange	WUE	27	Set to missing	Zero, negative, or saturated net assimilation (as above)
Broccoli yield	Defect class / market grade	51 / 50	Reclassified (corrected classification supplied by the person who graded the heads)	Re-check of the grade and defect records against the field notes before analysis; head weights and all other measurements unchanged
Broccoli yield	Defect and grade	100	Treated as not applicable	Plants without a harvested head (died, frost-killed, or blind); defect and grade labels apply only to harvested heads

Apart from the exclusions listed, g_s, E, and F_v'/F_m' were retained for all readings. In total, 317 of 448 broccoli WUE readings and 410 of 448 g_s readings were analyzed. DAT, days after transplanting; WUE, water-use efficiency.

Table S4. Results of the sensitivity analysis with year and year × treatment interactions as random effects

Source of variation	DTH	HW	HD	YP	MY	RFW	RL	RW
Environment (E)	0.207	0.355	0.053	0.355	0.337	0.181	0.286	0.229
Planting date (P)	0.070	0.152	**<0.001**	**0.002**	**0.002**	**<0.001**	0.272	**0.019**
Cultivar (C)	**<0.001**	**0.002**	**0.002**	**<0.001**	**<0.001**	**0.031**	**0.003**	**<0.001**
E × P	0.484	**0.043**	**0.009**	0.777	0.561	0.537	0.885	0.307
E × C	0.093	0.802	0.509	0.527	0.595	0.129	0.547	0.120
P × C	0.428	0.528	0.205	**0.038**	**0.015**	0.230	0.157	0.102
E × P × C	0.210	0.079	0.070	**0.015**	**0.018**	0.636	0.464	0.548

Fixed effects: environment, planting date, cultivar, and their interactions; random effects: year, year × environment, blocks within year × environment, year × planting date, year × cultivar, year × environment × planting date, year × environment × cultivar, and year × planting date × cultivar. In this model, treatment effects are tested against their variation between years; with only two years, the tests are conservative. *p*-values below 0.05 are in bold. Abbreviations as in Table 1 of the main text.

Table S5. Quadratic regressions of plant height (cm) and leaf number (Days after transplanting (DAT): $y = b_0 + b_1 \cdot \mathrm{DAT} + b_2 \cdot \mathrm{DAT}^2$).

Trait	Environment	Group	Level	b_0	b_1	b_2	R^2	n
Plant height	High tunnel	Planting date	10 July	-2.21	2.341	-0.0182	0.41	153
Plant height	High tunnel	Planting date	25 July	4.32	2.074	-0.0145	0.50	148
Plant height	High tunnel	Planting date	10 August	-8.15	2.931	-0.0240	0.68	187
Plant height	High tunnel	Planting date	25 August	11.85	1.534	-0.0065	0.59	195
Plant height	Open field	Planting date	10 July	-8.37	2.691	-0.0244	0.61	146
Plant height	Open field	Planting date	25 July	16.91	1.391	-0.0105	0.35	125
Plant height	Open field	Planting date	10 August	9.18	1.612	-0.0098	0.69	136
Plant height	Open field	Planting date	25 August	-3.27	2.019	-0.0164	0.53	194
Plant height	High tunnel	Cultivar	Green Magic	-8.62	2.848	-0.0222	0.67	139
Plant height	High tunnel	Cultivar	Gypsy	6.44	2.123	-0.0130	0.60	138
Plant height	High tunnel	Cultivar	Jacaranda	6.35	2.084	-0.0135	0.59	150
Plant height	High tunnel	Cultivar	Monty	-1.42	2.478	-0.0214	0.51	114
Plant height	High tunnel	Cultivar	Purple Peacock	4.15	1.606	-0.0093	0.58	142
Plant height	Open field	Cultivar	Green Magic	-1.91	2.392	-0.0214	0.51	117
Plant height	Open field	Cultivar	Gypsy	-3.97	2.548	-0.0219	0.63	139
Plant height	Open field	Cultivar	Jacaranda	7.99	1.569	-0.0102	0.56	117
Plant height	Open field	Cultivar	Monty	6.11	1.949	-0.0190	0.41	112
Plant height	Open field	Cultivar	Purple Peacock	-1.19	1.806	-0.0143	0.68	116
Leaf number	High tunnel	Planting date	10 July	-12.40	1.339	-0.0101	0.37	152
Leaf number	High tunnel	Planting date	25 July	0.09	0.468	0.0005	0.56	148
Leaf number	High tunnel	Planting date	10 August	2.45	0.327	0.0027	0.64	187
Leaf number	High tunnel	Planting date	25 August	1.77	0.408	-0.0009	0.50	195
Leaf number	Open field	Planting date	10 July	-22.61	1.977	-0.0179	0.59	146
Leaf number	Open field	Planting date	25 July	-5.71	0.895	-0.0052	0.49	124
Leaf number	Open field	Planting date	10 August	1.61	0.376	0.0019	0.63	136
Leaf number	Open field	Planting date	25 August	-1.47	0.592	-0.0037	0.54	194
Leaf number	High tunnel	Cultivar	Green Magic	-10.09	1.127	-0.0063	0.47	139
Leaf number	High tunnel	Cultivar	Gypsy	-7.05	0.853	-0.0034	0.48	138
Leaf number	High tunnel	Cultivar	Jacaranda	4.51	0.270	0.0009	0.55	149
Leaf number	High tunnel	Cultivar	Monty	1.12	0.481	-0.0016	0.53	114
Leaf number	High tunnel	Cultivar	Purple Peacock	2.48	0.410	0.0002	0.55	142
Leaf number	Open field	Cultivar	Green Magic	-21.89	1.937	-0.0177	0.47	117
Leaf number	Open field	Cultivar	Gypsy	-14.19	1.293	-0.0094	0.53	139
Leaf number	Open field	Cultivar	Jacaranda	1.83	0.374	0.0001	0.60	117
Leaf number	Open field	Cultivar	Monty	-7.15	1.073	-0.0106	0.40	111
Leaf number	Open field	Cultivar	Purple Peacock	-3.31	0.835	-0.0060	0.49	116

Regressions were fitted to individual-plant observations from 20 to 60 DAT, pooled over years and over cultivars (planting-date curves) or planting dates (cultivar curves); *n*, number of plant × date observations.

Table S6. Root traits by environment, planting date, cultivar, and year (estimated marginal means ± SE).

Factor	Root fresh weight (g)	Taproot length (cm)	Root system width (cm)

Environment			
High tunnel	78.4 ± 2.7	17.2 ± 0.4	24.4 ± 0.5
Open field	71.6 ± 2.9	17.7 ± 0.4	25.1 ± 0.5
Planting date			
10 July	89.5 ± 3.4^{a}	17.7 ± 0.5^{a}	24.6 ± 0.7^{a}
25 July	76.4 ± 3.7^{b}	17.5 ± 0.6^{ab}	25.1 ± 0.7^{a}
10 August	69.7 ± 3.4^{bc}	18.6 ± 0.5^{a}	26.8 ± 0.7^{a}
25 August	60.6 ± 4.1^{c}	15.4 ± 0.6^{b}	21.5 ± 0.8^{b}
Cultivar			
Green Magic	75.7 ± 3.8^{b}	16.8 ± 0.6^{b}	24.4 ± 0.7^{bc}
Gypsy	72.1 ± 3.8^{b}	14.0 ± 0.6^{c}	20.1 ± 0.7^{d}
Jacaranda	115.3 ± 4.5^{a}	20.6 ± 0.7^{a}	29.8 ± 0.9^{a}
Monty	57.6 ± 3.7^{c}	17.1 ± 0.6^{b}	24.1 ± 0.7^{c}
Purple Peacock	65.5 ± 4.3^{bc}	20.4 ± 0.7^{a}	27.4 ± 0.8^{ab}
Year			
2023	75.1 ± 2.8	17.7 ± 0.4	23.6 ± 0.5
2024	75.3 ± 2.7	17.2 ± 0.4	25.7 ± 0.5

Means are estimated marginal means ± SE from the linear mixed model in Table 1 (n = 236 plants), averaged over the other factors. Within a factor with more than two levels, means followed by the same superscript letter do not differ (Tukey's HSD, $p < 0.05$); letters are shown only when the factor was significant. Effects of environment and year are given in Table 1.

Table S7. Comparison of Romanesco with the broccoli cultivars (Dunnett's test)

Trait	Broccoli cultivar	Difference (cultivar − Romanesco) ± SE	*p*
Plant height (cm)	Green Magic	−9.1 ± 1.7	**<0.001**
Plant height (cm)	Gypsy	−7.0 ± 1.7	**<0.001**
Plant height (cm)	Jacaranda	−11.1 ± 1.7	**<0.001**
Plant height (cm)	Monty	−14.9 ± 1.7	**<0.001**
Plant height (cm)	Purple Peacock	−21.6 ± 1.7	**<0.001**
Leaf number	Green Magic	10.0 ± 0.7	**<0.001**
Leaf number	Gypsy	6.4 ± 0.7	**<0.001**
Leaf number	Jacaranda	2.3 ± 0.7	**0.010**
Leaf number	Monty	3.0 ± 0.7	**<0.001**
Leaf number	Purple Peacock	4.6 ± 0.7	**<0.001**
g_s (mmol m^{-2} s^{-1})	Green Magic	28.4 ± 40.5	0.886
g_s (mmol m^{-2} s^{-1})	Gypsy	94.9 ± 40.1	0.085
g_s (mmol m^{-2} s^{-1})	Jacaranda	−24.0 ± 41.6	0.931
g_s (mmol m^{-2} s^{-1})	Monty	68.6 ± 41.6	0.341
g_s (mmol m^{-2} s^{-1})	Purple Peacock	−30.0 ± 41.4	0.877
E (mmol m^{-2} s^{-1})	Green Magic	−0.04 ± 0.33	0.999
E (mmol m^{-2} s^{-1})	Gypsy	0.37 ± 0.33	0.665
E (mmol m^{-2} s^{-1})	Jacaranda	−0.33 ± 0.33	0.742
E (mmol m^{-2} s^{-1})	Monty	0.29 ± 0.34	0.818
E (mmol m^{-2} s^{-1})	Purple Peacock	0.12 ± 0.33	0.978
WUE (mmol CO_2 mol^{-1} H_2O)	Green Magic	0.46 ± 0.52	0.803
WUE (mmol CO_2 mol^{-1} H_2O)	Gypsy	−0.14 ± 0.51	0.990
WUE (mmol CO_2 mol^{-1} H_2O)	Jacaranda	0.44 ± 0.52	0.825
WUE (mmol CO_2 mol^{-1} H_2O)	Monty	0.07 ± 0.53	0.999
WUE (mmol CO_2 mol^{-1} H_2O)	Purple Peacock	1.09 ± 0.54	0.185
F_v'/F_m'	Green Magic	0.014 ± 0.017	0.830
F_v'/F_m'	Gypsy	0.038 ± 0.017	0.129
F_v'/F_m'	Jacaranda	0.024 ± 0.017	0.510
F_v'/F_m'	Monty	0.022 ± 0.017	0.559
F_v'/F_m'	Purple Peacock	0.035 ± 0.017	0.177
Root fresh weight (g)	Green Magic	−40.2 ± 7.6	**<0.001**
Root fresh weight (g)	Gypsy	−43.1 ± 7.6	**<0.001**
Root fresh weight (g)	Jacaranda	−2.7 ± 8.3	0.984
Root fresh weight (g)	Monty	−55.6 ± 7.6	**<0.001**
Root fresh weight (g)	Purple Peacock	−50.2 ± 8.1	**<0.001**
Taproot length (cm)	Green Magic	−4.1 ± 1.1	**<0.001**
Taproot length (cm)	Gypsy	−6.9 ± 1.1	**<0.001**
Taproot length (cm)	Jacaranda	−0.5 ± 1.2	0.963
Taproot length (cm)	Monty	−3.7 ± 1.1	**0.004**
Taproot length (cm)	Purple Peacock	−0.5 ± 1.1	0.959
Root system width (cm)	Green Magic	−6.0 ± 1.4	**<0.001**
Root system width (cm)	Gypsy	−10.0 ± 1.4	**<0.001**
Root system width (cm)	Jacaranda	−0.6 ± 1.5	0.971
Root system width (cm)	Monty	−6.0 ± 1.4	**<0.001**
Root system width (cm)	Purple Peacock	−2.9 ± 1.5	0.201

Growth: n = 64 plants per cultivar, measured at 20–60 days after transplanting; roots: 37–54 plants per cultivar; gas exchange: 14–16 plants per cultivar, depending on the trait. Negative differences indicate lower values than Romanesco. p-values below 0.05 are in bold.