

SUPPLEMENTARY DATA

Table S1. Average monthly and year vine-growing climatic conditions of May to September for 2020, 2021 and 2022 obtained from the AgroClimatic Information Service station of La Rioja (SIAR, Spain) in Aldeanueva de Ebro.

Year	Month	P (mm)	ET ₀ (mm)	GDD (°C day ⁻¹)
2020	May	44	151.7	273.3
	June	42.2	145	280.9
	July	10.2	207.2	422.6
	August	12	171.8	411.6
	September	9	125.7	295.6
2021	May	34	142.8	188.5
	June	31	164.9	317
	July	5.4	205.2	398.2
	August	2	186.3	399.1
	September	70.6	98.2	284.2
2022	May	17.2	174.6	291.1
	June	7.4	196.5	403.8
	July	26.8	220.1	468.7
	August	29.4	183.3	460.3
	September	8.8	127.5	300.5
2020		117.4	801.4	1684
2021		143	797.4	1587
2022 ^a		89.6 ^a	902 ^a	1924.4 ^a

^aP (mm): accumulated rainfall; ET₀ (mm): reference cumulative evapotranspiration; GDD (°C day⁻¹): growing degree days $T_{\text{mean}} - T_{\text{base}}$ (only positive values, $T_{\text{base}} = 10$ °C).

Table S2. Statistics description of Df, Dn-Df, F-value and significance of the harvest, carbon isotope ratio ($\delta^{13}C$) and pruning data. Asterisks indicate significant differences from the generalised linear model (GLM) at * $p < 0.05$, ** $p < 0.01$, and * $p < 0.001$.**

	Df; Dn Df	YW	F - value							
			CW	CV	$\delta^{13}C$	Df; Dn Df	PW	ASW	NMS	RI
Treatment	4; 30	7.461***	7.299***	2.2 ^{ns}	2.448 ^{ns}	4; 20	5.856**	5.390**	2.200 ^{ns}	1.028 ^{ns}
Year	2; 30	27.695***	28.333***	9.537***	49.681***	1; 20	16.973***	0.896 ^{ns}	9.537***	0 ^{ns}
Treatment x Year	8; 30	0.587 ^{ns}	0.187 ^{ns}	1.225 ^{ns}	0.577 ^{ns}	4; 20	1.582 ^{ns}	0.380 ^{ns}	1.225 ^{ns}	0.962 ^{ns}

YW: yield weight (kg/vine), CW: cluster weight, CV: clusters/vine, $\delta^{13}C$: carbon isotope ratio, PW: pruning weight (kg/vine), ASW: average shoot weight (g), NMS: number of main shoots/vine, RI: Ravaz Index (yield/pruning mas).

Table S3. Statistics description of Df, Dn-Df, F-value and significance of the normalised difference vegetation index (NDVI), normalised difference red edge (NDRE), and leaf blade nitrogen content (N). Asterisks indicate significant differences from the generalised linear model (GLM) at * $p < 0.05$, ** $p < 0.01$, and * $p < 0.001$.**

	Df	Dn Df	F - value		
			NDVI	NDRE	N
Treatment	4	60	5.963***	10.416***	9.046***
Phenology	1	60	161.538***	171.25***	378.212***
Year	2	60	27.904***	0.064 ^{ns}	96.402***
Treatment x Phenology	4	60	0.427 ^{ns}	1.595 ^{ns}	0.055 ^{ns}
Treatment x Year	8	60	0.418 ^{ns}	0.218 ^{ns}	0.196 ^{ns}
Phenology x Year	2	60	40.681***	4.344*	13.808***
Treatment x Phenology x Year	8	60	0.33 ^{ns}	0.1733 ^{ns}	0.255 ^{ns}
Treatment	4	30	1.926 ^{ns}	3.225*	3.442*
Flowering	2	30	60.402***	2.956 ^{ns}	71.359***
Treatment x Year	8	30	0.532 ^{ns}	0.287 ^{ns}	0.265 ^{ns}
Treatment	4	30	4.74**	7.35***	3.619***
Veraison	2	30	2.511 ^{ns}	1.841 ^{ns}	10.879***
Treatment x Year	8	30	0.181 ^{ns}	0.151 ^{ns}	0.084 ^{ns}

Table S4. Statistics description of Df, Dn-Df, F-value and significance of leaf (Ψ_{leaf}) and soil water potentials (Ψ_{soil}), whole plant hydraulic conductance (K_{plant}) and leaf gas exchange measures. Asterisks indicate significant differences from the generalised linear model (GLM) at * $p < 0.05$, ** $p < 0.01$, and * $p < 0.001$.**

	Df	Dn Df	F - value					
			Ψ_{leaf}	Ψ_{soil}	K_{plant}	A_N	g_s	WUE_i
Treatment	4	247	10.821***	58.019***	4.217***	27.189***	25.616***	20.114***
Phenology	3	247	70.839***	239.392***	178.49***	136***	153.442***	155.153***
Year	2	247	78.491***	355.209***	14.391***	138.128***	337.017***	332.062***
Treatment x Phenology	12	247	3.83***	3.958***	9.993***	14.179***	12.955***	7.44***
Treatment x Year	8	247	6.343***	7.566***	4.921***	9.484***	16.197***	7.24***
Phenology x Year	5	247	23.154***	362.108***	30.121***	96.286***	136.733***	77.638***
Treatment x Phenology x Year	20	247	3.821***	11.243***	5.037***	8.934***	8.753***	5.234***

A_N : net photosynthesis rate; g_s : stomatal conductance; WUE_i : intrinsic water use efficiency.

Table S5. Statistics description of Df, Dn-Df, F-value and significance of grape and must quality parameters. Asterisks indicate significant differences from the generalised linear model (GLM) at * $p < 0.05$, ** $p < 0.01$, and * $p < 0.001$.**

	Df	Dn Df	F - value									
			TSS (Brix)	pH	TA	Tartaric acid	Malic acid	Potassium	YAN	Berry weight	Anthocyanins	TPI
Treatment	4	30	1.181 ^{ns}	27.487***	0.471 ^{ns}	2.955*	17.022***	17.470***	6.268***	6.325***	3.357*	4.351**
Year	2	30	40.121***	215.763***	152.416***	57.403***	114.123***	26.077***	18.827***	50.337***	2.150 ^{ns}	49.153***
Treatment x Year	8	30	1.804 ^{ns}	1.133 ^{ns}	0.979 ^{ns}	2.329*	0.229 ^{ns}	0.741 ^{ns}	0.261 ^{ns}	1.458 ^{ns}	0.819 ^{ns}	6.456***

TSS: Total soluble solids; TA: total acidity; YAN: yeast assimilable nitrogen; TPI: Total polyphenol index.

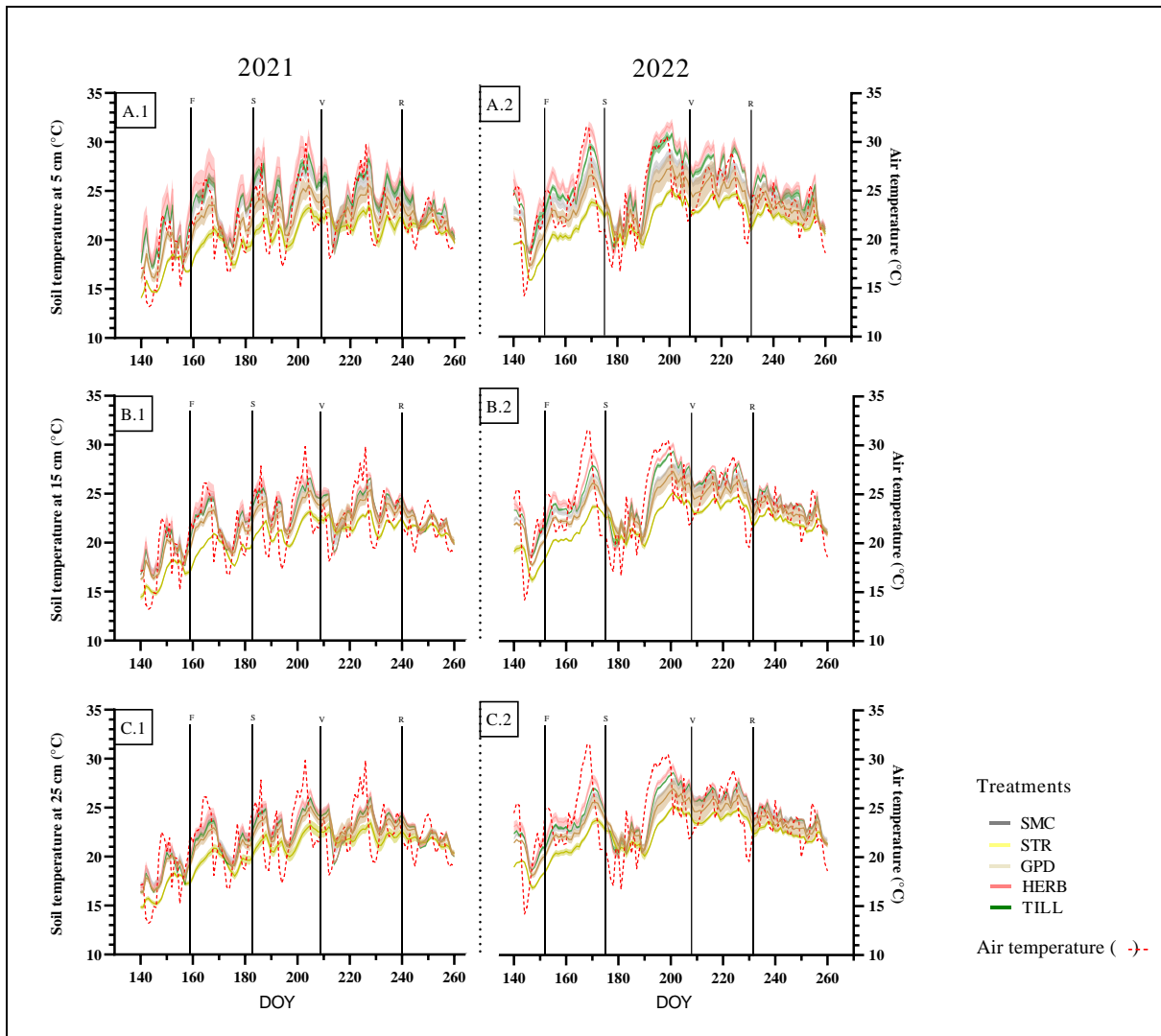


Figure S1. Soil temperature (°C) at 5 cm (A), 15 cm (B) and 25 cm (C) of the soil profile and mean daily air temperature (°C) of the soil management treatments from the end of May (DOY 140) to the end of September (DOY 260) in 2021 and 2022. The vertical black lines represent the phenological stages at flowering (F), fruit set (S), veraison (V) and ripening (R).

Table S6. Summary of the volumetric water content (%) at 5, 15 and 25 cm soil depth at flowering, fruit set, veraison and ripening in the different soil treatments analysed. Soil data of three days before and after selected for physiological measurements were used to analysed the water content at each phenological stage. Significant differences between soil management treatments were represented when $p < 0.05$.

		2021				2022				Average		
		Flowering	Fruit set	Veraison	Ripening	Flowering	Fruit set	Veraison	Ripening	2021	2022	
Volumetric soil water content %	5 cm	SMC	30.11 a	21.04 a	13.43 a	12.74 a	20.01 a	21.04	16.21 a	15.32 a	19.33 a	18.42 a
		STR	22.35 b	18.19 b	14.24 a	14.31 a	18.07 a	21.17	14.71 a	14.03 ab	17.28 ab	16.99 a
		GPD	22.82 b	16.73 b	13.64 a	13.38 a	16.39 a	18.7	12.12 b	12.3 bc	16.64 b	14.88 ab
		HERB	17.33 c	11.02 d	8.97 b	9.26 b	11.08 b	17.69	8.74 c	10.43 c	11.65 d	11.98 c
		TILL	20.69 bc	13.7 a	11.64 ab	10.63 b	13.1 b	19.54	11.38 b	12.86 ab	14.16 c	14.22 bc
	15 cm	SMC	26.11 a	22.52 a	19.72	18.28 ab	23.44 a	25.8	20.76 a	18.83 a	21.66 a	22.59 a
		STR	24.16 ab	21.02 a	19.66	19.19 a	22.47 a	25.94	19.43 b	18.61 a	21.01 a	21.61 a
		GPD	22.75 b	18.19 b	17.21	16.63 b	19.81 b	24.11	16.58 c	15.93 b	18.7 b	19.11 b
		HERB	26.06 a	20.43 ab	18.56	18.78 a	20.95 ab	25.07	18.23 bc	17.57 ab	20.96 a	20.45 ab
		TILL	26.91 a	21.52 a	19.88	18.8 a	21.67 ab	25.77	19.51 b	18.62 a	21.78 a	21.39 a
	25 cm	SMC	17.99	16.29	16.09	16.17	21.8 a	23.68	17.26 a	16.28 a	16.64 ab	20.5 a
		STR	18.49	16.66	16.36	15.94	18.33 b	21.93	16.42 ab	15.83 ab	16.86 a	18.13 ab
		GPD	16.98	14.98	14.87	14.5	16.71 bc	20.49	15.06 bc	14.38 bc	15.33 bc	16.66 bc
		HERB	16.82	14.36	13.62	13.88	15.6 c	19.07	13.76 c	13.2 c	14.67 c	15.41 c
		TILL	18.3	15.92	15.42	15.03	17.01 bc	20.68	15.59 bc	14.96 abc	16.17 ab	17.06 bc

Table S7. Mean and deviation values of carbon isotope discrimination ($\delta^{13}C$) in 2020, 2021, 2022 and its average. The interactions between independent variables were shown (ns, not significant; *, $p < 0.05$; **, $p < 0.01$; *, $p < 0.001$).**

Treatment	$\delta^{13}C$			Average
	2020	2021	2022	
SMC	-26.7 ± 0.5	-26.3 ± 0.8	-23.8 ± 0.7	-25.6 ± 1.4
STR	-27.1 ± 0.8	-27 ± 1.4	-24.8 ± 2.1	-26.3 ± 1.8
GPD	-27.5 ± 0.2	-27 ± 0.7	-24.7 ± 0.9	-26.4 ± 1.4
HERB	-27.2 ± 0.2	-26 ± 0.5	-23.7 ± 0.4	-25.6 ± 1.6
TILL	-27.3 ± 0.2	-25.5 ± 0.9	-23.3 ± 0.5	-25.4 ± 1.8

Two-way ANOVA: Treatment ns, Year ***, Treatment x Year ns