

INTRODUCTION

Grapevine has a huge socio-economical impact all around the world, as stated by the total production and areas devoted for this culture. The Mediterranean basin is one of the major regions for grapevine, and the Douro Demarcated Region, in Portugal, is subjected to adverse climatic conditions, especially in the summer. This region is likely to face even more extreme conditions, with the onset of the expected climate changes that will result in a decrease of the already small rainfall with simultaneous increase of temperature. From this point of view, it is of great importance to identify the most suitable varieties and rootstocks able to endure such adverse conditions.

MATERIALS AND METHODS

The experimental trial was conducted at *Quinta da Cavadinha* (41° 13' 08,20" N; 7° 32' 49,50" W) (Symington Family Estates), Sabrosa, Douro region (altitude of 220m a.s.l), installed in 1997.

In the study, varieties *Tinta Barroca* (TB), *Tinta Roriz* (TR), *Touriga Franca* (TF) and *Touriga Nacional* (TN) grafted onto the rootstocks *Rupestris du Lot* (Rup du Lot), 110R, 1103P and 196-17Cl were evaluated.



- Measurements include *leaf micromorphoanatomical characteristics* (leaf blade, upper and lower epidermis and cuticles, and palisade (PP) and spongy parenchyma (SP));
- *Leaf biochemistry* (chlorophyll, total phenolics, soluble sugars, starch, soluble proteins, thiobarbituric acid reactive substances);
- *Leaf gas exchange parameters*;
- *Productivity and grapevine vigour*.

RESULTS

Table 1 – Values (mean ± standard deviation, µm) for micromorphological traits of leaves. In each column, different letters indicate significant differences ($p < 0.05$).

Variety x Rootstock	Upper cuticle	Upper epidermis	Palisade parenchyma (PP)	Spongy parenchyma (SP)	Lower epidermis	Lower cuticle	Leaf blade	PP/SP
TB x 196-17Cl	1.40±0.61b	17.59±2.62a	55.09±9.98	76.06±17.11b	16.29±2.88a	1.37±0.51ab	167.81±25.12ab	0.75±0.17a
TB x 110R	1.12±0.33c	16.29±3.95b	52.56±9.35	75.95±19.14b	13.72±5.75b	1.26±0.36bc	160.91±29.29b	0.72±0.17a
TB x Rup du Lot	1.62±0.62a	15.98±2.57b	53.21±7.92	72.68±17.64b	16.34±3.04a	1.43±0.58a	161.27±22.12b	0.76±0.18a
TB x 1103P	1.18±0.34c	15.69±3.85b	53.49±9.88	87.29±20.63a	13.02±3.57b	1.17±0.46b	171.85±28.44a	0.64±0.16b
P value	0.000	0.000	0.158	0.000	0.000	0.000	0.001	0.000
TR x 196-17Cl	1.35±0.54a	14.38±2.84ab	49.48±8.27bc	64.94±11.38b	14.16±3.04b	1.22±0.49ab	145.15±16.19b	0.78±0.16a
TR x 110R	1.19±0.34b	11.59±3.19c	47.06±9.11c	72.23±11.14a	13.86±4.67c	1.19±0.38ab	147.13±17.33b	0.67±0.16b
TR x Rup du Lot	1.37±0.52a	14.87±2.69a	54.64±8.28a	74.95±15.46a	16.81±2.70a	1.31±0.47a	163.82±22.09a	0.75±0.14a
TR x 1103P	1.12±0.32b	13.42±3.93b	51.45±11.02b	68.25±15.19b	12.52±3.95c	1.11±0.38b	147.87±27.51b	0.77±0.16a
P value	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000
TF x 196-17Cl	1.72±0.47a	15.42±2.75b	46.21±5.72b	73.01±9.82ab	14.15±3.63b	1.89±0.59a	152.42±13.1b	0.64±0.12b
TF x 110R	1.19±0.42b	14.71±3.99b	44.41±7.19b	69.11±11.52c	14.65±4.02b	1.21±0.38c	145.29±20.37c	0.65±0.10ab
TF x Rup du Lot	1.69±0.71a	17.60±3.49a	44.87±5.10b	70.68±9.29bc	16.80±3.43a	1.55±0.74b	153.20±13.63b	0.64±0.11b
TF x 1103P	1.24±0.32b	15.93±5.03b	51.09±8.36a	76.45±16.12a	15.21±4.76b	1.22±0.48c	161.16±26.40a	0.69±0.13a
P value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014
TN x 196-17Cl	1.82±0.45a	16.24±2.99a	43.73±8.71a	65.78±16.50a	15.45±3.44a	1.79±0.46a	144.82±23.43a	0.69±0.16ab
TN x 110R	1.26±0.34c	13.91±3.92b	41.36±9.43ab	67.99±16.45a	13.97±4.74b	1.22±0.39c	139.72±26.74a	0.63±0.18b
TN x Rup du Lot	1.61±0.29b	15.15±2.72a	43.83±6.77a	68.07±17.12a	15.99±3.04a	1.48±0.68b	146.13±21.22a	0.68±0.18ab
TN x 1103P	1.29±0.29c	12.05±4.18c	40.41±9.29b	57.68±14.96b	13.76±3.87b	1.23±0.43c	126.44±24.83b	0.76±0.19a
P value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

- Varieties TB and TF grafted onto 1103P rootstock resulted in an increase of chlorophyll, indicating a better adaptability, if considering lower contents of photosynthetic pigments as a characteristic sign of oxidative stress and chlorophyll degradation;
- The content of carbohydrates was also significantly influenced by the interaction of Variety x Rootstock with few exceptions;
- Phenolic content did not varied significantly in none of the combinations, while TBARS was higher in rootstocks Rup du Lot and 196-17Cl, for TB and TF, respectively;
- This pattern was not the same for protein content, as higher values were recorded for the 1103P rootstock for TB and 196-17Cl, for TR.

Table 2 – Values (mean ± standard deviation, mg/dm²) for biochemical parameters of leaves. In each column, different letters indicate significant differences ($p < 0.05$).

Variety x Rootstock	Total chlorophyll	Soluble sugars	Starch	Total phenolics	TBARS	Protein
TB x 196-17Cl	1.88±0.59c	177.78±38.74	60.39±24.09b	63.04±39.29	12.71±4.76a	27.06±16.97b
TB x 110R	2.74±0.82b	177.22±61.07	116.42±64.86a	67.97±29.53	9.51±3.24b	30.68±21.92ab
TB x Rup du Lot	2.13±0.54bc	201.69±54.98	98.89±79.57ab	49.11±29.61	15.59±5.04a	31.41±15.69ab
TB x 1103P	3.91±1.45a	188.54±72.92	101.39±42.36ab	75.39±48.94	9.84±4.29b	46.29±20.17a
P value	0.000	0.569	0.028	0.209	0.000	0.017
TR x 196-17Cl	3.30±1.11	159.96±53.22	76.87±42.75	86.53±50.35	10.59±4.50	46.49±27.03a
TR x 110R	2.93±1.39	156.65±51.43	54.53±26.16	72.14±34.36	12.79±6.22	23.64±18.68b
TR x Rup du Lot	3.08±1.10	180.78±54.88	57.06±29.93	82.40±47.87	14.39±6.24	25.91±15.58b
TR x 1103P	3.75±0.77	151.90±42.93	53.42±32.99	90.28±40.78	11.22±5.08	29.58±29.52ab
P value	0.152	0.343	0.130	0.634	0.157	0.037
TF x 196-17Cl	1.58±0.52c	142.31±41.53	81.44±49.84b	59.46±38.27	9.62±3.24a	21.99±13.38
TF x 110R	1.94±0.99bc	174.74±61.14	126.36±64.97a	62.62±37.27	6.91±5.16ab	43.01±29.51
TF x Rup du Lot	2.62±0.97ab	165.55±61.93	53.91±29.64b	65.33±16.41	7.69±2.36ab	40.21±35.69
TF x 1103P	3.31±1.03a	147.13±46.14	62.59±37.91b	68.08±35.83	6.83±2.36b	51.31±41.50
P value	0.000	0.251	0.000	0.884	0.041	0.060
TN x 196-17Cl	2.02±0.83	154.84±51.03b	73.81±39.10	67.13±23.37	11.21±4.73	26.54±19.66
TN x 110R	3.01±1.82	139.33±40.99b	64.62±39.45	91.93±65.76	8.68±3.49	33.48±23.35
TN x Rup du Lot	2.85±0.74	146.23±39.39b	63.00±41.69	59.44±22.04	8.76±2.49	34.07±24.56
TN x 1103P	3.13±2.52	217.56±98.93a	80.25±65.52	62.22±18.41	9.79±3.54	26.99±15.92
P value	0.184	0.001	0.671	0.057	0.141	0.185

Table 3 – Values (mean ± standard deviation) for leaf gas exchange parameters. In each column, different letters indicate significant differences ($p < 0.05$). A - photosynthetic rate; g_s - stomatal conductance; E - transpiration rate; A/g_s - intrinsic water-use efficiency.

Variety x Rootstock	A (µmol/m ² .s)	E (mmol/m ² .s)	g_s (mmol/m ² .s)	A/g_s (µmol CO ₂ /mol H ₂ O)
TB x 196-17Cl	3.50±1.08	2.24±0.71	59.04±11.95	58.61±7.65
TB x 110R	4.82±1.51	3.02±0.91	78.97±35.84	64.64±11.45
TB x Rup du Lot	2.74±1.39	2.10±0.66	44.00±17.19	64.51±29.02
TB x 1103P	4.97±2.08	3.08±1.13	72.12±33.99	72.50±17.71
P value	0.064	0.138	0.149	0.635
TR x 196-17Cl	4.47±1.95	2.98±0.69	84.14±30.55	51.76±9.84
TR x 110R	4.47±1.97	3.22±1.07	80.85±29.29	58.61±16.95
TR x Rup du Lot	4.06±1.72	2.82±0.67	62.89±23.90	64.04±9.34
TR x 1103P	5.43±2.10	3.23±1.26	76.19±37.16	77.15±26.08
P value	0.662	0.850	0.705	0.097
TF x 196-17Cl	4.16±0.81	2.63±0.58	70.78±19.31	62.46±19.07
TF x 110R	4.11±1.37	3.12±0.64	78.17±27.29	56.53±17.74
TF x Rup du Lot	5.28±0.94	3.19±0.47	71.72±9.83	73.84±10.0+
TF x 1103P	4.52±1.84	3.54±0.76	82.74±19.67	55.86±21.96
P value	0.404	0.119	0.701	0.296
TN x 196-17Cl	4.11±1.39	2.64±0.69	82.78±30.14	51.84±14.73b
TN x 110R	5.03±3.24	2.62±0.97	72.59±51.37	71.65±10.57ab
TN x Rup du Lot	4.77±1.33	3.34±0.84	78.69±23.44	61.32±6.73ab
TN x 1103P	3.81±1.52	2.49±1.03	52.32±23.62	75.62±15.89a
P value	0.711	0.373	0.439	0.016

- Leaf gas exchange parameters show only A/g_s significantly affected by the rootstock, for TN plants;
- The use of the 110R rootstock resulted in higher number of clusters, namely for TB and TR;
- Yield results indicate 110R is the most suitable for TB and TR, 1103P for TF and Rup du Lot for TN;
- Weight of clusters was higher for TB and TF when grafting onto 1103P, although similar to TB x 110R and TF x Rup du Lot, respectively;
- The vigour of vines was considerably higher when grafting was performed onto the 1103P rootstock, with the exception of TN.

Table 4 – Values (mean ± standard deviation) for productivity and grapevine vigour. In each column, different letters indicate significant differences ($p < 0.05$).

Variety x Rootstock	Clusters per vine	Yield (kg/vine)	Cluster weight (kg)	Pruning weight (kg/vine)
TB x 196-17Cl	11.00±5.24ab	0.85±0.64b	0.08±0.04b	0.32±0.22b
TB x 110R	14.61±5.34a	2.02±1.10a	0.13±0.05a	0.50±0.31b
TB x Rup du Lot	8.88±4.33b	0.84±0.62b	0.09±0.03b	0.30±0.15b
TB x 1103P	12.11±6.28ab	1.96±1.62a	0.14±0.06a	0.84±0.32a
P value	0.021	0.001	0.000	0.000
TR x 196-17Cl	9.72±4.32b	1.72±0.14ab	0.17±0.09	0.36±0.17b
TR x 110R	14.39±5.84a	2.88±1.57a	0.19±0.06	0.37±0.19b
TR x Rup du Lot	8.67±5.31b	1.62±1.31b	0.17±0.07	0.36±0.18b
TR x 1103P	11.17±5.14ab	2.16±1.23ab	0.19±0.06	0.60±0.42a
P value	0.009	0.023	0.611	0.018
TF x 196-17Cl	9.29±3.24	0.78±0.36b	0.09±0.03b	0.30±0.10bc
TF x 110R	11.50±4.10	1.21±0.65b	0.10±0.04b	0.28±0.10c
TF x Rup du Lot	8.61±3.18	1.41±0.69b	0.17±0.10a	0.39±0.13b
TF x 1103P	11.00±4.69	2.39±1.07a	0.22±0.07a	0.61±0.14a
P value	0.090	0.000	0.000	0.000
TN x 196-17Cl	16.61±4.82	1.21±0.56b	0.07±0.03	0.31±0.15b
TN x 110R	20.94±11.35	1.60±1.01ab	0.08±0.02	0.46±0.16ab
TN x Rup du Lot	22.78±7.94	1.95±0.86a	0.08±0.02	0.59±0.34a
TN x 1103P	17.22±7.22	1.16±0.61b	0.07±0.02	0.36±0.13b
P value	0.077	0.010	0.136	0.001

CONCLUSIONS

The present results illustrate the intricate variation of characteristics as a result of different Variety x Rootstock combinations, that must be carefully considered when installing a vineyard. Overall results, and always keeping in mind the complex dynamics found, appear to indicate combination TRx110R as the most suitable. Physiological measurements showed similar values to other combinations, with higher yields, increased cluster weight and intermediate vigour. These same arguments can be used to point out TBx110R, TFx1103P and TNxRup du Lot as the most appropriate combinations for each of the other varieties.