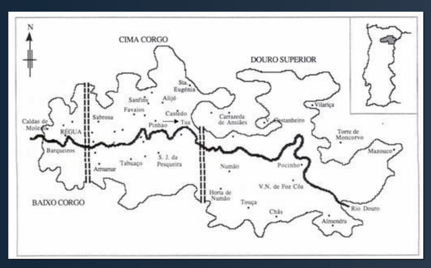

Climate change impacts on Douro Region viticulture and adaptation measures

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1. INTRODUCTION

Climate has a significant impact in the success of any agricultural system, with a direct influence on the crops suitability to a given region, interfering on yield and quality and also with the economic sustainability of the productive activity. In the Douro Demarcated Region (RDD), as in most regions of the Mediterranean climate, the scarce precipitation (33% has less than 600 mm per year), and your high variability, associated with high rates of evapotranspiration during the summer, is usually one of the fundamental factors that limit the grapevine development, as well as the production and quality of the harvest.

The development of this work, carried out in two commercial vineyards, one located in Soutelo do Douro, São João da Pesqueira, Cima Corgo sub-region, and another located in Numão, Vila Nova de Foz Côa, Douro Superior sub-region, it seeks to establish a relationship between climatic elements and physiological, productive and qualitative parameters, as well as to evaluate the effectiveness of adaptation measures, including different types of deficit irrigation (2002-2019) and the application of shading nets (2019-2020) in the physiological, viticultural and oenological behavior in the Touriga Nacional and Moscatel Galego Branco varieties, respectively.

2. METHODOLOGY

a) Deficit irrigation (2002-2019)

AREA (ha)	1,2
VARIETY	Touriga Nacional
YEAR	1997
ROOTSTOCK	196-17 C
TRAINING SYSTEM	Cordon de Royat (double)
DENSITY (plants/ha)	4545
SLOPE (%)	25%

NR– Control (Rainfed)
R30- 30% ETC irrigation
R60- 60% ETC irrigation

b) Application of shading nets (2019-2020)

AREA (ha)	2,3
VARIETY	Moscatel Galego Branco
YEAR	1996
ROOTSTOCK	1103-P
TRAINING SYSTEM	Cordon de Royat (single)
DENSITY (plants/ha)	4167
SLOPE (%)	15%

TSR – Control
REH 34% - horizontal shading net

3. RESULTS

a) Deficit irrigation (2002-2019)

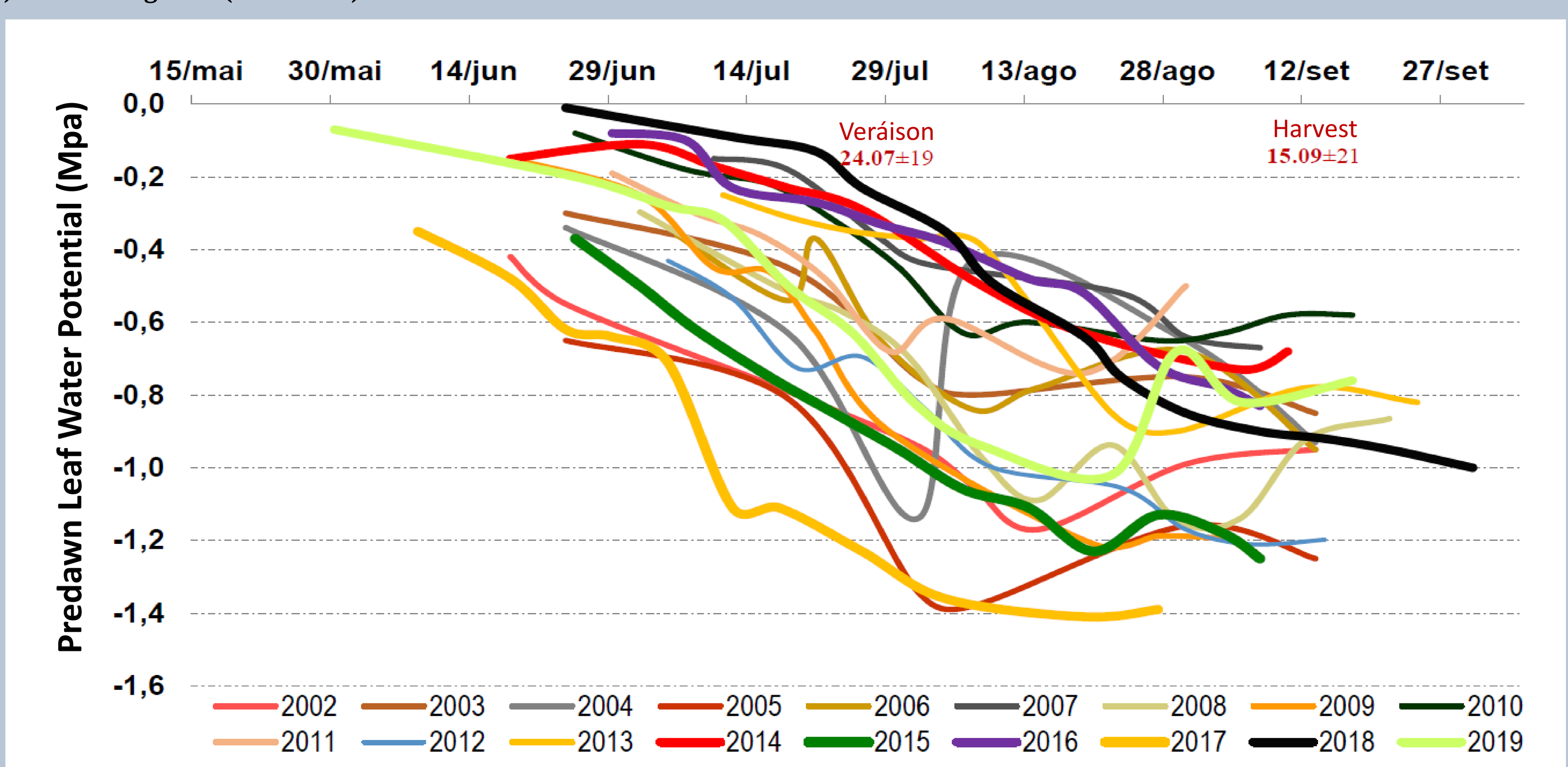
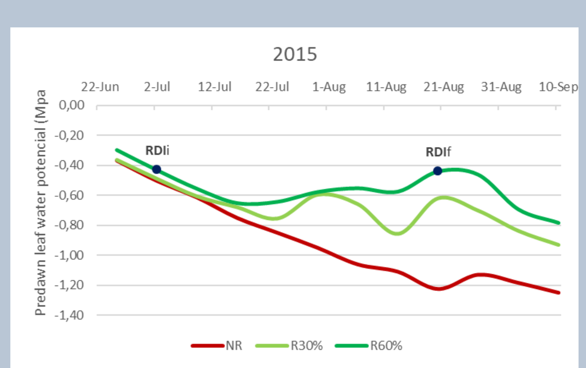


Figure 1. Predawn leaf water potential evolution of the control treatment (NR) for the period 2002-2019. Data are expressed in MPa. n=24.



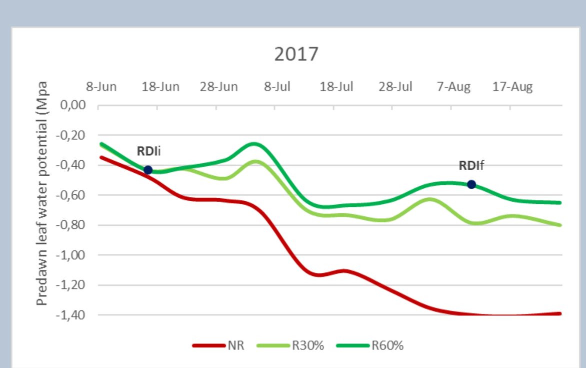


Figure 2. Predawn leaf water potential evolution of the 3 treatments for the years 2015 and 2017. Data are expressed in MPa. n=24.

Table 1. Mean values of yield and vigour parameters, for the NR, R30 and R60 treatments, period 2002-2019. (Means followed by distinct letters are significantly different for P < 0.05; n=80; nd=data not available).

		Bunches/Vine (nº)		Yield/Vine (kg)		Weight/Bunch (kg)		Pruning wood (kg)		Ravaz Index	
Treatment	NR	18,1	b	1,57	c	0,088	c	0,55	c	3,2	b
	R30%	20,1	a	2,28	b	0,113	b	0,62	b	4,0	a
	R60%	20,6	a	2,54	a	0,123	a	0,70	a	4,1	a
Year	2002	18,3	fg	1,65	hi	0,091	g	0,58	fg	3,3	def
	2003	16,5	h	2,18	f	0,138	bc	0,74	c	3,5	cdef
	2004	20,4	de	2,20	f	0,105	f	0,64	de	3,8	bc
	2005	19,3	ef	1,35	j	0,068	h	0,39	h	3,6	cd
	2006	17,0	h	1,49	ij	0,085	g	0,42	h	4,1	b
	2007	20,0	de	2,84	cd	0,145	b	0,64	de	4,8	a
	2008	21,9	bc	1,85	g	0,084	g	nd		nd	
	2009	20,8	cd	1,74	gh	0,084	g	0,60	ef	3,2	ef
	2010	18,5	fg	2,57	e	0,134	cd	0,55	g	5,0	a
	2011	20,7	d	2,16	f	0,103	f	0,66	d	3,6	cde
	2012	20,5	de	1,51	ij	0,075	h	0,54	g	3,1	f
	2013	17,5	gh	3,10	ab	0,172	a	0,67	cd	4,9	a
	2014	23,4	ab	3,26	a	0,133	cd	nd		nd	
	2015	23,5	a	2,72	de	0,116	e	0,82	b	3,7	bc
	2016	13,9	i	1,76	gh	0,125	de	1,02	a	1,9	g
	2017	17,4	gh	1,81	gh	0,100	f	0,63	def	3,1	f
	2018	19,5	def	2,90	bcd	0,145	b	0,88	b	3,6	cde
	2019	23,2	ab	3,08	abc	0,137	bc	0,67	cde	5,1	a

b) Application of shading nets (2019-2020)

Table 2. Mean values of photosynthetic rate (A), stomatal conductance (gs), intrinsic water use efficiency (A/gs), for the TSR and REH34% treatments, for the periods of July and August in 2019 and August in 2020, n=10. (Statistical significance: ns - non-significant difference (P>0.05); * - significant (P<0.05); ** -very significant (P<0.01); *** - highly significant (P<0.001)

			g_s	A	A/g_s	C_i/C_a
2019	July	TSR	179.0±6.8	11.5±0.2	64.8±1.8	0.639±0.007
		REH 34%	116.6±13.8	8.46±0.41	80.0±7.3	0.593±0.029
		Sig.	**	***	ns	ns
	August-natural PPFD	TSR	45.7±3.2	4.35±0.24	96.6±5.8	0.541±0.024
		REH 34%	94.2±9.2	8.43±0.51	92.7±4.1	0.534±0.016
		Sig.	**	***	ns	ns
	August-1600 PPFD	TSR	47.2±7.0	4.53±0.48	99.7±5.1	0.528±0.020
		REH 34%	118.8±19.5	10.1±0.9	89.8±6.6	0.537±0.023
		Sig.	**	***	ns	ns
2020	August-800 PAR	TSR	60.77±11.3	5.53±0.9	92.54±7.4	0.583±0.024
		REH 34%	234.3±20.7	11.35±0.7	48.76±3.4	0.720±0.015
		Sig.	***	***	***	***
	August-1750 PAR	TSR	47.1±15,9	4.89±1.44	106.4±11.9	0.524±0.044
		REH 34%	184.1±24.9	13.7±0.8	75.6±9,9	0.588±0.041
		Sig.	***	***	***	**

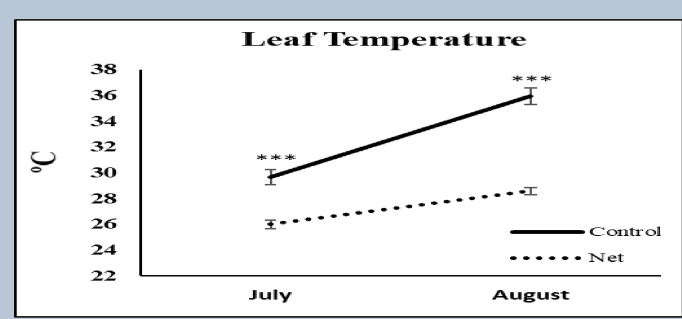


Figure 3. Mean leaf temperature (ºC) for the two treatments, TSR and REH 34%, in July and August 2019, n=10.

Table 3. Mean content of total chlorophyll (Chl(a+b)), carotenoids (Car) and chlorophyll/carotenoids ratio (Cl/Car). Mean values of soluble sugars (TSS), phenols content (TPC) and proteins content (TSP), for both treatments, TSR and REH 34%, in August 2019, n= 10.

	TSR	REH 34%	Sig.
$Chl_{(a+b)}$	3.93±0.07	6.88±0.19	***
Car	0.751±0.012	1.14±0.03	***
$Chl_{(a+b)}/Car$	5.24±0.10	6.04±0.12	***
TSS	126.1±10.1	89.6±8.0	*
TSP	16.3±0.1	17.1±0.2	ns
TPC	96.6±3.0	77.2±2.2	***

Table 4 Mean values of yield, number and weight of bunches per vine (kg) in TSR and REH34% treatments in 2019 and 2020.

Year	Treatment	Yield/Vine (kg)	Bunches/Vine (nº)	Weight/Bunch (kg)
2019	TSR	1,44±0,20	9,0±0,9	0,160±0,015
	REH 34%	1,55±0,21	5,5±0,4	0,272±0,020
	Sig.	ns	**	***
2020	TSR	0,94±0,05	3,4±0,5	0,342±0,056
	REH 34%	1,43±0,11	5,1±0,7	0,318±0,035
	Sig.	***	+	ns
2019+2020	TSR	2,38±0,22	12,4±0,9	
	REH 34%	2,98±0,21	10,6±0,8	
	Sig.	+	ns	

4. DISCUSSION AND CONCLUSIONS

The results showed that the application of deficit irrigation allowed to significantly reduce the impact of the adverse weather conditions at key moments in the development of the grapevine, particularly in the period immediately before veráison and maturation, reducing the negative effects on the physiological processes and productivity, without compromise the must quality parameters. On the other hand, the application of shading nets significantly reduced the leaves temperature, allowing to increase the water potential, stomatal conductance and photosynthetic rate of grapes, which was reflected in the yield increase in the 2nd year of the study. For the maturation indicators, higher levels of total acidity, malic acid and assimilable nitrogen were obtained. The last measure presents a huge potential, being essential to carry out more years of trials to obtain stronger conclusions in terms of production parameters, but also in characteristics as important as the grape ripening components and the organoleptic characteristics of wines.