Understanding and reducing yield gap under Mediterranean climate

Searching for adapted wheat varieties

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Climate change impacts are becoming apparent in Europe, where for example farmers in the different countries are already experiencing the impacts of severe weather events such as droughts, floods, and landslides. Climate change can, for example, cause decreasing wheat yields in parts of Europe, namely due to heat stress and reduced rainfall. (UNFCCC, 2015).

Climate related risks in Europe, namely in the Mediterranean region, that will affect farmers include, among others, modifications on crop phenology, crop season will be shorter. It was estimated a mean change in dates of flowering and full maturation, for winter wheat, for the period 2031-2050 compared with 1975-1994, more precisely a decrease in both from -25 to -10 days. (EEA, 2012).

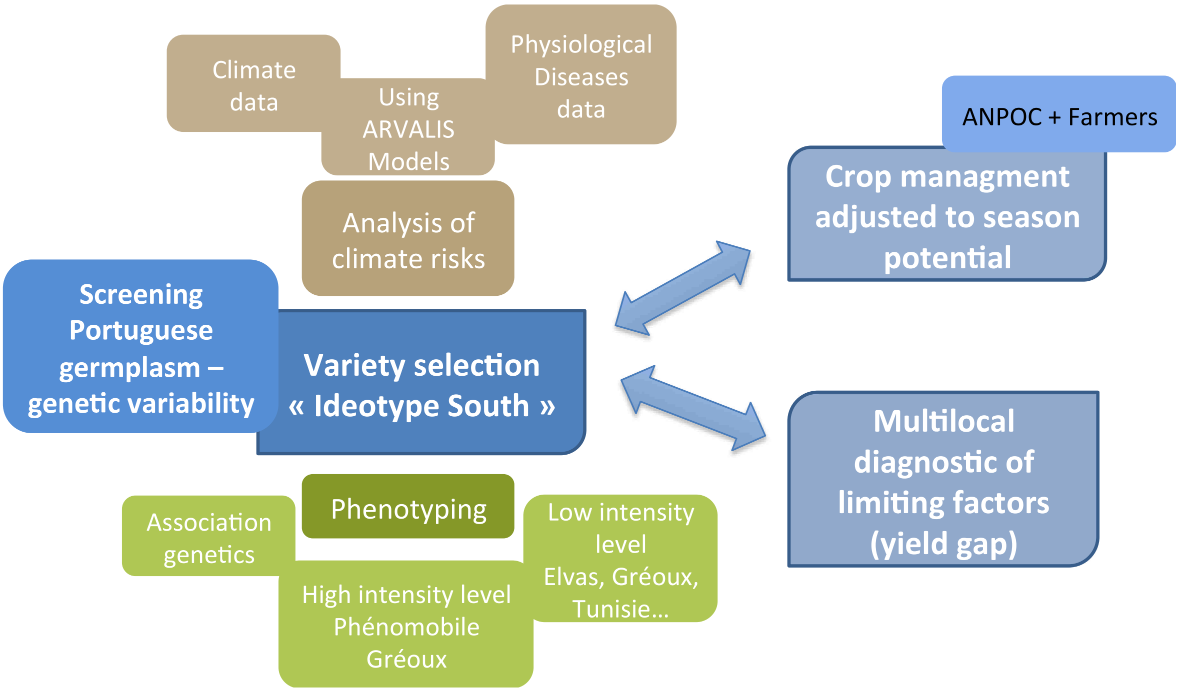
Urgent action is required in order to improve productivity and promote the adaptive capacity of agriculture, as it may not be possible to return to previous production conditions. Adaptation measures suited to local circumstances and productive systems must be identified; such measures included, inter alia, the development of improved seed varieties adapted to new agro-climatic conditions, heat and/or water stress and exposure to different pests. (UNFCCC, 2015).

A key approach must be the comprehension of adaptation and effectiveness will be added when studied in cooperation. In this context, a research Program is being developed in Portugal and France designated the Wheat Ideotype South Project, aiming the definition of wheat variety type (ideotype South) in face of current and future climate risks in the Mediterranean region of southern Europe.

Wheat Ideotype South Project

This research program is carried out since 2011, by the Portuguese Institute of Agrarian and Veterinarian Research (INIAV), a research institute under the umbrella of the Ministry of Agriculture; the Portuguese farmer's association for cereals and pulses (ANPOC) and ARVALIS – Institut du Végétal, an agricultural applied research French organization financed and managed by farmers. In 2015, also the Institut National des Grandes Cultures, situated in Tunis participated on the program.
This research Program studies and evaluates the performance and response of French and Portuguese bread and durum wheat varieties and advanced lines obtained by INIAV, in both countries. The main goals are: to understand and reduce the yield gap in bread and durum wheat in the Mediterranean part of southern Europe; to increase yield efficiency, by defining best fit traits of a new plant (wheat) ideotype, which enable agricultural systems adaptation to climate change scenarios, that are expected to occur in the near future (breeding new wheat varieties) and to adjust inputs management (nitrogen, water, pesticides) fitting on-going crop season potential - climatic potential (Figure 1).

Figure 1
Wheat Ideotype South outline



Common trials of bread and durum wheat in Portugal and France

Common trials of bread and durum wheat are annually installed in Portugal and France. Trials are located at Arvalis research site, in southeast France (Gréoux-les-Bains) and at INIAV Plant breeding Station, in southeast Portugal (Elvas). From 2011/2012 crop season to present (2015/2016), 12 bread wheat and 7 durum wheat varieties were evaluated in both sites. On last season, trials were also conducted in Tunisia by Institut National des Grandes Cultures (INGC). From 2011 to 2014 trials were conducted under rainfed conditions and in 2014/2015 season irrigation was introduced. Each year, trials are installed as classic randomized block varieties trial. Varieties of bread and durum wheat were chosen in both countries for their ability expected in tolerance to stress or, contrariwise their supposed sensitivity, but their good behaviour in a favourable situation. In addition, the trial protocol was designed to gather accurate information about the stress experienced by the varieties and its impact on yield components.

The main region for bread and durum wheat production in Portugal, which is located in the Center and South of the country, is under a strong Mediterranean influence where rainfall occurs on a high unpredictable way and heat stress occurs during wheat grain filling. Cereals are sown in autumn, after the first rains, when daylenght is still long and the vegetative phase develops during winter. Heading occurs in the beginning of spring when photoperiod and temperature increases and wheat reaches maturity, during the first two weeks of June.

Portugal is a country that is presently highly dependent on the importation of wheat. In this context, the internal demand for this commodity is quite important and quality tends to not be an important trait due to the multitude of possible end-uses. In the last several years this trend is changing and specialization for quality characterization is becoming an important challenge for the wheat sector.

The possibility of irrigation opens new avenues for the utilization of wheat varieties with superior milling quality. Changes are occurring in the agricultural systems of southern Portugal linked with an enlargement of irrigated areas for crop cultivation, made possible by the increasing availability of water for irrigation from a huge public dam (Alqueva).

The baby food sector represents another example of specialization for quality. Portugal has good wheat production conditions in specific regions, mainly under rainfed conditions, to produce cereals with low pesticide content that fulfil the requirements of the baby food industry.

The analysis of climate data (Table 1) showed that total rainfall in southeast France was always higher than in the south Portugal. Major difference between Elvas and Gréoux-les-Bains is the rain distribution during spring, which is markedly more irregular (and scarce, 2012 and 2013) at Elvas concerning the quantity (mm) and the distribution (number of days with precipitation).

Inter-annual variation of total precipitation and erratic distribution during growth cycle is one of the wheat production constraints in Portugal. Also high temperatures during grain filling, causing heat stress are an important factor-limiting yield. During grain filling, wheat plants generally face rising temperatures resulting in early senescence, when compared with cooler climates. The grain-filling stage is very critical for grain yield, since senescence tends to occur before physiological maturity, often resulting in a low harvest index.

The significant difference that is noted for the number of days with temperatures above 25°C and 30°C, during wheat grain filling period, supports the idea that heat stress is stronger at Elvas than at Gréoux-les-Bains, showing the importance of running trials in this environment, replicating future scenarios that are expected as a consequence of climate change that may occur in Mediterranean south region of France. Also on 2014/2015 season plants were submitted to more days with temperatures higher than 30°C during grain filling in Portugal (32 days) in comparison with France (9 days), resulting in higher heat stress (Figures 2 and 3).

Table 1
Climate data of 3 crop seasons (2012, 2013, 2014) in Portugal and France

Climate data	2011/12		2012/13		2013/14	
	PT	FR	PT	FR	PT	FR
Rainfall						
Total rainfall (mm) (1oct - 30 jun)	239	551	589	690	475	576
Winter rainfall (mm) (jan, feb, mar)	8	37	263	193	205	281
Spring rainfall (mm) (apr, may, jun)	74	201	38	183	91	129
Number of days with rainfall (1oct - 30 jun)	60	92	107	113	87	138
Temperatures - heading + grain filling (1 apr - 15 jun)						
Average of max. Temp. (°C)	24.4	21.9	24.4	20.7	26.3	23.4
Number of days temp >25°C	35	26	39	14	48	16
Number of days temp >30°C	20	4	13	1	21	8

Figure 2

Daily rainfall and maximum temperatures during heading and grain filling periods at Elvas (Portugal) during 2014/2015 crop season

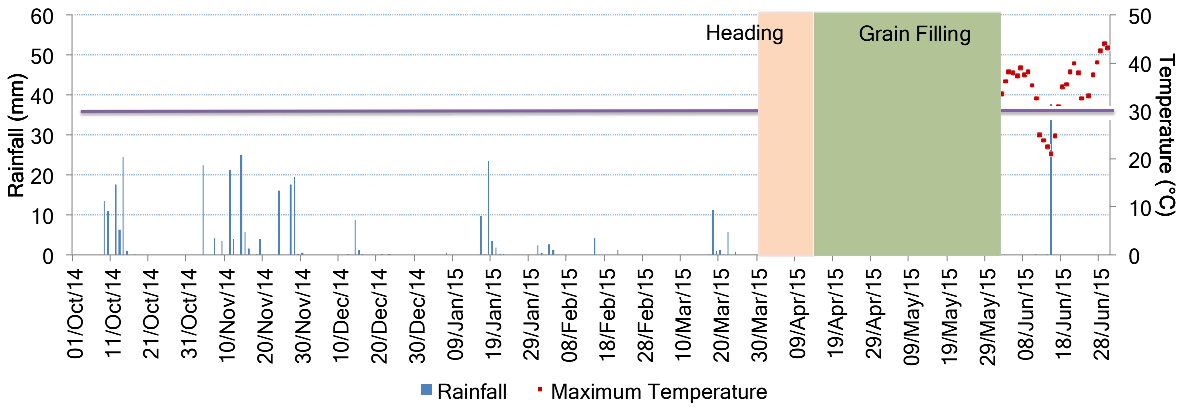
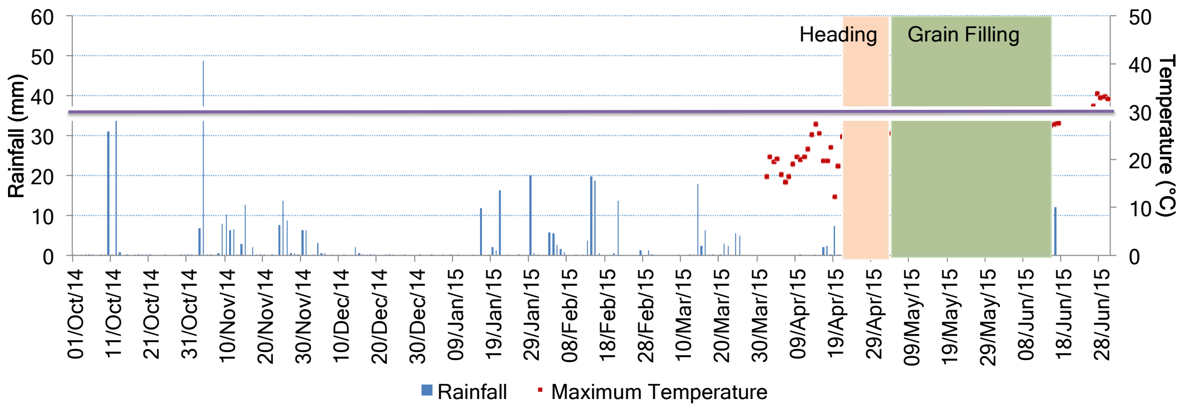


Figure 3

Daily rainfall and maximum temperatures during heading and grain filling periods at Gréoux-Les-Bains (France) during 2014/2015 crop season



Results provided an opportunity to researchers of each country to discover other varietal types. For example, durum wheat Portuguese varieties are more limited in yield during more unfavorable seasons (concerning weather) but for bread wheat Portuguese varieties, which are varieties with spring growth habit and consequently with shorter cycle, the ratio grain quality/yield are more interesting. These varieties are less fragile concerning test weight (volume weight), an important trait for evaluating adaptation to heat stress.

In the southeast France varieties developed/selected in France were always superior in yield, when compared with the genotypes bred at INIAV (Portugal), especially in 2012/2013 season (French germplasm, in average, yielded more 2.6 ton/ha than the Portuguese genotypes). Portuguese varieties showed good plasticity with similar yield in both sites (Table 2). French varieties had lower yields at Elvas trials than in Gréoux-les-Bains. The difference was lower in durum wheat. Bread and durum wheat Portuguese varieties showed higher test weight than French germplasm, even when tested in France (Table 3). Results show the good adaptability of the genotypes selected in harsh environments, being test weight an excellent indicator of good sink capacity even if the expression of yield potential might be sacrificed.

Table 2
Yield, average of 12 bread wheat (8 FR and 4 PT) and 7 durum wheat (5 FR and 2 PT)

Yield 15% (kg/ha)	2011/12		2012/13		2013/14	
	PT	FR	PT	FR	PT	FR
Bread wheat						
Average PT wheat	3396	7689	7058	7203	5950	6172
Average FR wheat	3575	8360	7120	9833	5868	6927
Durum wheat						
Average PT wheat	4102	7653	7355	7334	6773	5528
Average FR wheat	4994	7939	7949	8566	5919	6059
Mean trial	3909	7985	7380	8416	6020	6282
Coefficient of Variation (%)	26.3	5.8	14.4	13.8	9.8	10.1

Table 3
Test weight, average of 12 bread wheat (8 FR and 4 PT) and 7 durum wheat (5 FR and 2 PT)

Test weight (kg/hl)	2011/12		2012/13		2013/14	
	PT	FR	PT	FR	PT	FR
Bread wheat						
Average PT wheat	84.3	85.5	84.7	82.2	83.2	82.5
Average FR wheat	80.3	80.8	78.8	80.0	77.5	76.9
Durum wheat						
Average PT wheat	83.4	84.3	84.8	83.5	83.5	82.0
Average FR wheat	82.1	83.2	82.5	83.6	80.2	81.9
Mean trial	81.9	82.9	82.2	82.0	80.5	80.6
Coefficient of Variation (%)	3.0	2.9	3.5	3.7	3.9	3.6

On 2014/2015 crop season, irrigation was introduced. Results (Tables 4 and 5) showed that in Portugal, yield was not significantly different comparing rainfed and irrigated conditions. Despite a dry winter (only 72 mm), rainfall that occurred in April 2015 (110 mm), made possible the germplasm recovery, contributing for a minor difference between trials.

At Elvas, yield response to supplementary irrigation was higher on Portuguese varieties compared with French varieties. At Gréoux-les-Bains it was found a significant difference between water conditions (rainfed vs. irrigated). In France, bread wheat Portuguese varieties showed similar yield (7432 kg/ha) when compared with that obtained in Portugal (7234 kg/ha). French varieties suffered a lot under higher heat stress, as it is common in the south Portuguese Mediterranean environment.

Table 4
Yield, average of 8 bread wheat (2 FR and 6 PT) and 12 durum wheat (2 FR and 10 PT)

Yield 15% (kg/ha)	2014/15			
	PT		FR	
Bread wheat	Rainfed	Irrigated	Rainfed	Irrigated
Average PT wheat	6351	7234	4407	7432
Average FR wheat	7316	7519	4835	9950
Durum wheat				
Average PT wheat	7594	8628	3995	7508
Average FR wheat	7885	8255	4960	10450
Mean trial	7208	8080	4251	7877
Coefficient of Variation (%)	13.5	12.7	12.2	14.4

Table 5
Test weight, average of 8 bread wheat (2 FR and 6 PT) and 12 durum wheat (2 FR and 10 PT)

Test weight (kg/hl)	2014/15			
	PT		FR	
Bread wheat	Rainfed	Irrigated	Rainfed	Irrigated
Average PT wheat	79.9	77.7	79.9	82.4
Average FR wheat	75.2	71.8	73.2	79.6
Durum wheat				
Average PT wheat	81.5	79.5	79.1	83.1
Average FR wheat	80.2	78.3	78.9	83.0
Mean trial	80.2	78.1	78.7	82.5
Coefficient of Variation (%)	2.8	3.6	3.2	2.19

Outlook

Direct comparison between varieties performance in Portugal and France results in immediate information, which helps to make decisions for the choice of varieties to be used by farmers. The working methodology that is being used has proved quite suitable for anticipation of actions to be performed with regard to adaptation of farming systems to climate change scenarios. The comparison of varieties selected in different origins and therefore subject to selection pressure imposed by local environments, reveals the importance of identifying varieties with tolerance to multiple stresses, including heat stress, which turns out to be also an important limiting factor in Portugal and in southern France, although lower.

Another important singular outcome of this research program is to promote the recombination of Portuguese and French germplasm in order to obtain genetic variability that will allow in the near future the selection of genotypes with adaptation traits, enclosing present and forecast climate risks. An intensive artificial crossing program, in each season, is being developed combining both Portuguese and French advanced lines, carrying the desired traits that are being identified by researchers, since the beginning of this joint research program. This network is, also, an important way for the identification of the most suitable germplasm that can overpass future environmental constraints.

Bibliography / More information

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