SWUP-MED Project

Sustainable Water Use Securing Food Production in Dry Areas of the Mediterranean Region

***Deliverable* 7.1:** **Guidelines on best suited crops, cultivars and management practices for multiple stress resistance in targeted environments, including rainfed and irrigated systems (3m).**

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Authors:	Sven-Erik Jacobsen and Manuela Chaves
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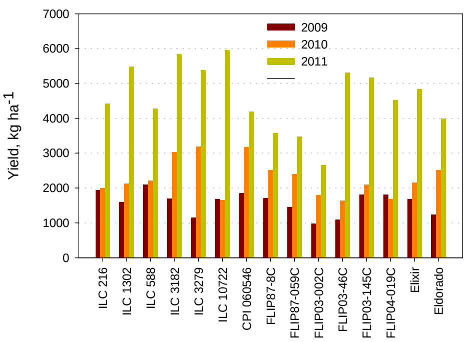
D7.1 (month 48) Guidelines on best suited crops, cultivars and management practices for multiple stress resistance in targeted environments, including rainfed and irrigated systems (3m).

Genotypes of legumes (chickpea, faba bean and lentils) and New crops (quinoa, amaranth and lupin) with improved tolerance to the most important abiotic stresses occurring in the Mediterranean were identified, characterised and tested for stability in Syria, Turkey, Italy, Portugal and Morocco).
Phenology (earliness) together with agronomic information, namely yield, were the most important traits to discriminate genotypes in our study and relatively easy to use to support early selection. In the Mediterranean climate, due to its large inter-annual variability, it is important to identify genotypes that can cope with different types of environment (wet and dry) and not only the ones which can stand very adverse climate. These ones will be very much penalized in wet years because they are far from the yield potential for that crop. Supplemental irrigation namely at flowering was shown to have a positive effect on increasing biomass, plant height, and rhizobium weight, with the intensity of the response depending on the genotypes.

LEGUMES
In **chickpea**, we identified genotypes FLIP03-145C and ILC 3182 from the ICARDA collection that stand out by their high yield in the two regions and three years, showing good adaptation across all environments, including under moderate and severe water scarcity conditions. In addition, genotypes FLIP87-008C and ILC 588 showed good adaptation for poor environments; indeed in the most stressful years FLIP87-008C and ILC 588 were on the top 5 of chickpea yield both in Portugal and Syria (Fig 1). In rainy years (like 2011 in Portugal) chickpea grain yield can rise up to 6t ha^{-1} in the best performing genotypes. In Syria highest performance led to grain yields of 1.4 t ha^{-1}.



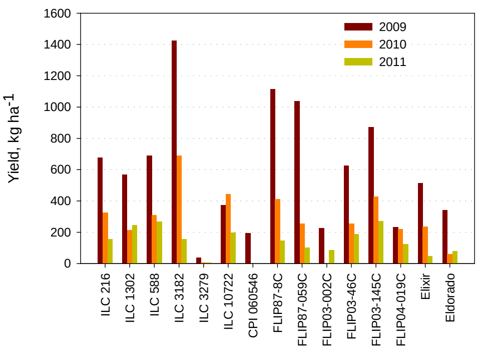


Fig 1: Mean grain yield (kg ha^{-1}) of chickpea accessions grown in two locations (A- Elvas, Portugal and B- Aleppo, Syria) with respect to all field trials (2009, 2010 and 2011). Annualand growth cycle rainfall in the years of highest yield were 647and 234 mm (2011) in Portugal and 271 and 13 mm (2009) in Syria.

Differences in phenological development and in plant water relations indicate that chickpea genotypes that fasten their development cycle showed in general higher grain yield, especially in drought years. FLIP03-145C and ILC588, which are highly tolerant to drought, present the lowest number of days to maturity. ILC588 is the earliest in flowering.

Faba bean grain yield varied significantly between accessions and between different water regimes across all the years in ICARDA trials.

From the studies on eleven faba bean accessions (8 breeding lines and 3 cultivars, Table 1) performed in ICARDA, it was shown that phenological and agronomical traits are affected by terminal drought. Accession 3 of Faba Bean (DT/B7/9043/2005/06) showed the best tolerance to drought in Syria; however, accession 2 (DT/B7/9013/2005/06) was the most stable, showing highest yield on average during the four years of study. Yield ranged from 1000 to 3500 kg/ha in Syria in rainfed conditions and up to 5000 kg/ha under supplementary irrigation. In Morocco the yield ranged between 1000 and 4500 kg/ha under rainfed conditions, with ILB 1270 being the best yield performer. Supplemental irrigation at flowering stages, podding and grain filling had a positive effect in the biomass, plant height, rhizobium weight for the different studied genotypes. The developed faba bean drought tolerant lines performed homogenously under rainfedconditions, with water distribution during cropping season of the order of 300 to 400mm. In extreme drought (with less than 250 mm), yield dropped to 1.2 t/ha on average of all developed lines, while traditional varieties went down to less than 1 ton/ha. Days to maturity (DMAT), days to flowering time (DFLR) and distance between nodes. (DTN) explained 87.5% of the grain yied (GY in dry land system, while DMAT, DTN and Rhizobium weight (RHWP) explained 65 % of Biological yield. Faba bean lines genotypes responded positively to supplemental irrigation, with 50% of irrigation of soil water capacity being enough to increase the yield to maximum for some breeding lines.

Table 1: The names and origins of Faba bean genotypes evaluated for drought tolerance in the field

Entry No.	Name	Selection name	Origin
1	FLIP08-054FB	DT/B7/9028/2005/06	ICARDA
2	FLIP06-010FB	DT/B7/9013/2005/06	ICARDA
3	FLIP06-008FB	DT/B7/9043/2005/06	ICARDA
4	FLIP08-057FB	DT/B7/9035/2005/06	ICARDA
5	FLIP12-001FB	DT/B7/9005/2005/06	ICARDA
6	DT/B7/9020/2005/06	DT/B7/9020/2005/06	ICARDA
7	DT/B7/9008/2005/06	DT/B7/9008/2005/06	ICARDA
8	Reina Blanca	ILB 1270	Spain
9	DT/B7/9009/2005/06	DT/B7/9009/2005/06	ICARDA
10	Syrian local large	ILB 1814	Syria
11	Aguadolce	ILB1266	Spain

Fifteen promising **lentils** breeding lines were selected under rainfed conditions and with supplemental irrigation at two locations in Syria (Tel Hadya and Breda) during four years (2009, 2010, 2011, and 2012). The highest grain yield in lentils growing under rainfed conditions was recorded in ILL 7670 and in ILL 6994, with grain yields around 1000kg/ha. Early maturing lines with high biomass in general performed better under water deficit condition. Heat emerged as a major confounding effect on drought evaluation. Pods and seeds per plant, seed size and harvest index can be useful selection criteria for rainfed condition. As expected, water availability affects both vegetative and reproductive growth of lentils. The response to supplementary irrigation depends on the genotype but also on the year, namely on the total rainfall during the season and its distribution. Genotypes ILL 590, ILL 6002, ILL7537, ILL8068, ILL10135, ILL10072, ILL 10707 responded positively to irrigation, whereas ILL6994, ILL7670, ILL7947, ILL19691 barely responded. ILL 7537 (1190 kg/ha) and ILL 10707 (1160 kg/ha) were the top yielders under irrigated conditions. In general, high yielding genotypes had lower response to supplementary irrigation as compared to low yielders. Also, small seeded genotypes tended to respond more positively to irrigation than genotypes with larger seeds.

NEW CROPS

Introduction of drought and salt tolerant crop species such as quinoa, amaranth and lupin may result in more resilient crop rotations and high value cash crop products in the Mediterranean region. In the new crops, yield increases may arise from selection for early vigour, deep roots, increased transpiration efficiency, improved disease resistance, and high assimilate storage and remobilization that will confer more tolerance to abiotic stresses. A range of crop and management strategies might be combined for a specific target environment in order to optimize crop productivity. These combinations can then be used as a guidance to future decision support systems for crop production at limited water supply under arid Mediterranean conditions.

Among new crops, **quinoa** showed a large potential for growing under abiotic stress conditions, with higher economic and water saving values of seed and straw yields in new reclaimed sandy soils as compared to the results of wheat yields.

An extensive phenotypic diversity was revealed within the quinoa collection (78 accessions) studied in Morocco, with the more productive line (L142) yielding 1890 kg/ha, twice the yield of the lowest producer (L123) that produced 910 kg/ha. In Turkey yields were much higher than in Morocco with 3.5 t ha^{-1} in non-irrigated plots. WUE ranged from 0,3 to 0,7 kg/m3. The evaluation of the agro-morphological diversity through univariate and multivariate analysis performed in Morocco pointed out the most performing genotypes, with *earliness*, *short plants* and *seed yield* being the main traits common to the advanced lines. Therefore those are relevant selection criteria for quinoa breeding programs in the Mediterranean region. In Italy, among the seven quinoa varieties studied, Titicaca and Puno showed the better yield, being more adaptable to the environment of Southern Italy. As a food ingredient, chemical composition of the Titicaca seeds shows that this variety can be successfully used to develop new products with interesting nutritional and organoleptic properties. Puno is a potentially better cultivar because of its high milling performance and the low content of total saponins. The introduction of 10% quinoa in mixtures with rice or maize showed a composition comparable to the commercial gluten-free pasta. Overall, our results gave useful information to improve and develop new quality products for celiac consumers, taking into account the enrichment of quinoa doughs with higher concentration of HDP inulin from cardoon, or mixing quinoa with other gluten-free flours.

Amaranth is moderately tolerant to salinity, especially when the drought is more severe. It was confirmed a higher protein content in amaranth seeds than in common cereals, together with high fat content.

In **lupin**, there are large differences in phenology, namely in what concerns the beginning of flowering and the type of growth (determinate versus indeterminate) as well as in yield parameters, which ranged from 600 to 1600 kg/ha were observed in the collection studied. This leads to a high potential for adaptation in the Mediterranean area.