SUSTAINABLE WATER USE SECURING FOOD PRODUCTION IN DRY AREAS OF THE MEDITERRANEAN REGION (SWUP-MED) PROJECT

Work Package 3: *Sustainable agronomic interventions against multiple abiotic stresses*

D3b.1 Agronomic interventions (best management practices)

Work Package 3: *Sustainable agronomic interventions against multiple abiotic stresses*

SUMMARY

With a focus on agronomic interventions such as crop rotation (wheat, chickpea, and quinoa), supplemental irrigation of legumes (chickpea, fababean and lentil), introduction of new crops (quinoa and amaranth) and their response to deficit and full irrigation, seed treatment technology, reduced tillage, water harvesting, use of marginal quality water for irrigation of new crops, and legumes have been determined, and suitable cultural practices have been identified to reduce the impact of multiple abiotic stresses in order to stabilize and improve yield and quality of selected crops in partner countries involved in Work Package 3.

WP3 reports the following research findings during the period covering from 2009 to 2011: (1) Crop rotation including quinoa-wheat-chickpea was compared with monocropping in Turkey and Morocco, and the three years results revealed the positive impact of crop rotation over monocropping on yield, and soil organic matter; (2) Supplemental irrigation increased yield, and water productivity of legume crops in Turkey, Syria, and Portugal. Trade-off between the amount of water used for supplemental irrigation and the additional yield harvested of food legume crops above the rainfed conditions except fababean in Turkey, where winter rainfalls were sufficient enough to provide crop water requirements fully. The results reveal that by using a relatively small amount of water for supplemental irrigation under rainfed conditions, farmers in dry areas can get substantial increases in crop yield; (3) Saline water irrigation of food legume crops with water of up to 4 dS/m did not increase soil salinity significantly in Syria; however, further increase in irrigation water salinity caused a significant increase in soil salinity. Quinoa and amaranth were irrigated with saline water with electrical conductivity (EC) values up to 40 dS/m, and the results revealed that quinoa can be irrigated with saline water up to 20 dS/m without significant yield reduction in Turkey, Italy and Denmark. However, increased irrigation water salinity caused severe soil degradation; (4) Although deficit irrigation showed considerable potential to increase water-use efficiency and yield, there were implications for salinity build up in the soil because of less water availability for leaching of salts added via irrigation. This was particularly crucial when deficit irrigation was undertaken with water of higher salinity; (5) Introduction of climate proof crops such as quinoa and amaranth and traits revealed the potential to increase farmers' income and livelihoods in arid areas of the Mediterranean region to save freshwater resources for other valuable purposes. The results suggest good adaptation and a high degree of flexibility of quinoa and amaranth for tolerance or resistance to drought and salt stress in a Mediterranean-type environment; (6) The replacement of traditional spring sowing of chickpea with winter sowing is possible but only with cultivars possessing cold tolerance and resistance to key fungal diseases. Winter planting resulted in almost two fold yield increase as compared to spring planting in 2010 (The mean chickpea yields were 3.97 t/ha for winter planting, and 2.72 t/ha for spring planting); (7) Reduced tillage, ridge tillage and direct sowing techniques were compared. The tillage systems were examined and analyzed in terms of fuel and time consumptions, working efficiency, the percentage of emergence, soil moisture content, porosity, bulk density, yield, biological yield, straw yield, height of plant, 1000 kernel weight, harvest index, number of spike, and hectoliter weight. The result revealed that maximum efficiency on wheat production was obtained with the minimum tillage technique; the minimum efficiency was found from the two rows of bed planting systems. The lowest fuel consumption and the maximum working efficiency was found with direct sawing. Zero-tillage generated the highest total income followed by reduced tillage; (8) Pre-sowing seed treatment approaches and seed priming have been used on wheat in order to improve germination both under laboratory and field conditions. According to laboratory and field experiments, PEG application to the seeds of bread wheat could increase some germination properties and some yield components of bread wheat; (9) The performance of a small runoff-basin (micro-catchment) water-harvesting system (***negarim***) was evaluated under an arid environment in Southeastern Anatolia region of Turkey in 2010/2011. Plastic cover generated the highest runoff as compared to other surface treatments, the

pistachio trees performed better (maximum tree height, trunk diameter) in the plastic covered negarim plots, followed by surface compaction since these two treatments utilized more water than other treatments.

Crop Rotation:

Mono-cropping systems consisting of low-yielding cereals are crucial productivity constraints in dry areas of the Mediterranean region. Although these systems are known to be affected by multiple abiotic stresses, recent events of climate change have further impacted crop yields and overall agricultural productivity per unit of water and land under mono-cropping systems. Wheat-based monoculture (cultivation of wheat after wheat) is common in several parts of the Mediterranean region countries such as Morocco, Syria, and Turkey. It is crucially important to revisit mono-cropping systems in these countries by introducing other crops such as grain legumes and new crops in the wheat-based mono-cropping systems.

A four year crop rotation experiment was set up at the Hacıali Farm of Çukurova Agricultural Research Institute in Adana, Turkey in 2008/2009. This year is the third year of the crop rotation study (2010/2011). The experimental desing was randomized block desing with four replications. Crop rotation study will continue for four years.

Biomass samples were collected at two weeks intervals and on these samples leaf area was measured and leaf area index (LAI) was also determined. LAI reached its maximum value of 3.85 at the end of March 2011, then LAI gradually decreased toward the end of the growing season. In the 2008/2009 growing season maximum LAI was observed as 6.3 on April 10, 2009; and in the second year (2009/2010) LAI reached a maximum value of 3.8 on March 25, 2010.

Wheat yield and yield components such as harvest index, straw yield, number of heads per square meter was determined on the samples taken. Average wheat grain yield varied from 7830 to 8830 kg ha^{-1} in the 2010/2011 growing season. Average wheat biomass yield in crop rotation study varied between 25860 and 26960 kg per ha; straw yield varied from 19000 to 20550 kg ha^{-1}. Average harvest index for wheat changed between 23.1 and 25.4%. Average 1000 seed weight varied from 40.0 to 41.56 g in wheat plots. Similar results were obtained in the first two year of the study. As for the effect of previous crop on wheat yield and yield components in crop rotation study, the results revealed that there was no significant difference in biomass (dry matter) and grain yield, plant height, harvest index, number of grains per spike and 1000 grain weight. Therefore, the effect of previous crop on wheat yield and yield components in the first three years of the rotation study was not significantly different.

In the third year of the crop rotation study, local chick pea (*Cicer arietinum*) variety *inci* was planted at 45 cm row spacing and 6 cm in the row with a four row planter on 8 December, 2010. Chick pea was harvested on July 4, 2011. The chickpea grain yields varied between 3977 and 4143 kg/ha in 2009; and 2654 and 3778 kg/ha among the plots in 2010; plant height varied from 80-84 cm in 2009; and 68 to 78 cm in 2010; number of pods per plant changed from 87 to 139; number of grains per plant fluctuated between 98-186 in 2009; and 223 and 252 in the second year of the study. 100 seed weight varied from 40-40.5 g in 2009; and 36-37 g in the second year. To evaluate the effect of previous crop on chickpea yield (third year yield data are not available for the moment) statistical analysis will be carried out, and the results will be presented in the next report.

Development of leaf area index and dry matter accumulation in chickpea with time in the first three years of the project was observed. Maximum leaf area of chickpea was observed during the flowering and early pot formation growth stage as 2.9. Then LAI started to decline towards the end of the growing season due to leaf senescence and yellowing of the leaves. Maximum average dry matter yield reached 1650 g/m^2 on May 31, 2011. Due to abovenormal rainfall received during the growing season *Ascochyta Bligh* fungal disease infected the chickpeas in crop rotation.

In the crop rotation experiment Quinoa (*Chenopodium quinoa* Willd. L 37) was planted by hand on March 29, 2011. The first emergence was observed on April 14. First flowering was observed on June 2, 2011. The plants were harvested on July 20, 2011. Quinoa in crop rotation study was grown under supplemental irrigation conditions in 2010, but it was grown under rainfed conditions in 2011 growing season due to wet year. Drip irrigation laterals were placed between the plant rows in 2010. Quinoa was irrigated three times and a total of 225 mm of irrigation water was applied. Due to uneven plant stand in the plots, grain yields and yield components were determined on plant basis. Quinoa grain yield changed between 587 and 1310 kg/ha in 2009; grain yield per plant varied from in 22.66 to 45.66 g per plant; panicle weights varied from 42.98 to 92.88 g per plant; 1000 seed weights varied between 1.95 to 2.2 g in 2009; and 1.35 and 1.79 g in 2010; and stem weight per plant changed between 32.06 to 52.27 g per plant. In 2011 growing season average grain yield varied from 588.6 to 1678.6 kg/ha; 1000 seed weight varied from 1.544 to 1.922g; harvest index changed between 34.9 and 42.1 %; biomass yield varied from 1474,4 to 4598 kg/ha; yield per plant varied from 5.886 to 16.786 g. As indicated by the large variation in yield and other features among the plots in crop rotation study caused by uneven plant establishment (stand) in the plots as well as the effect of previous crop.

Crop Rotation: Precedent crop effect on wheat production in Morocco

Rotation effect on bread wheat production was investigated under farmer trials at Bouchane locality of Ben Guerir in Morocco. At Daiif Abdelkader farm, where we are conducting the rotation trials since the first year of the project, the effect of three precedents (Chick pea, Quinoa and Bread wheat) on bread wheat production was tested under rain fed condition. The analysis of the data showed that quinoa and chick pea precedents were classified far away from bread wheat with more than 1.5 t/ha of grain yield. Both crops produced around 230% more grains than bread wheat as precedent which produced only 0.5 t/ha. Both crops produced also more biomass, 80% for chick pea and 60% more quinoa, compared to only 2.23 t/ha for the bread wheat. The differences were mainly influenced by the spikes density per hectare, which was higher than 250 10^4 per hectare for the first two crops and of only 101 10^4 spikes/ha for the bread wheat precedent. Differences were noticed between harvest indexes also. The HI value of *32%* and *30%* were reached for respectively quinoa and chick pea precedents, and was of only *18%* for bread wheat. This great scope between wheat and the two other crops is probably the result of the special status of the plot which was under cereals monoculture since the beginning of the project.

Manure supplementation to the soil

On Kaine farm in Morocco, we tested the effect of manure supplementation to the soil. The plot of about 1 hectare was split into two parts; one half received about 2 tones of manure few days before the planting and the other half did not. Data analysis showed the dominance of fertilized plot. The differences were highly significant for spike density per surface unit, 344.8 10^4 spikes/ha, the biomass 4.5 t/ha and for measured yield 2.65 t/ha, compared to respectively 187.2 10^4 spikes/ha, 1.95 t/ha and 1.14 t/ha for the check. Grain yield increase by 132% on plot supplemented with manure, but still the harvest index stayed the same as 37% on both plots.

Reduced Tillage and Bed Planting of Wheat in Turkey

This study was carried out for comparing conservation tillage and sowing systems for wheat in at Çukurova Agricultural Research Institute Directorate Hacıali Station in 2008/2009 Both the highest biomass and straw yield was obtained from the reduced tillage, followed by zero-tillage or direct seeding. RP II resulted in minimum biomass yield. There was significant difference among the tillage systems regarding to harvest index. RT resulted in the highest number of heads per square meter value followed by zero-tillage. The results showed that there was no significant difference among the treatments regarding 1000 grain weight values. There was no significant difference among the treatments considering the plant height.

Average porosity in 0-10 cm soil depth under zero tillage was significantly higher than other tillage methods. However, in 20-30 cm deph, zero tillage had the minimum porosity. In deeper layers, there was no significant difference in porosity among the tillage methods. Zero-tillage had the lowest bulk density in top (0-10 cm) soil layer as compared to other tillage systems. In 20-30 cm depth, zero-tillage resultd in maximum bulk density, in depper soil layers, there was no significant difference among the tillage methods. Average soil water content in top 10 cm soil layer was highest in RP followed by RT and zero-tillage. RP had higher soil water content in all soil depths considered among the treatments.

With less tilling, farmers save on machinery use, fuel, labour and their own time. Reducing tillage is important from the viewpoint of environmental-farming for a number of reasons. The cover of crop residue helps prevent soil erosion by water and air, thus conserving valuable top soil. Soil structure improves because heavy machinery (which causes soil compaction) is not used and soil tilth is not tampered with artificially. With earthworms not being routinely disturbed by deep tillage, their numbers increase bringing with them the accompanying benefits of better soil aeration and improved soil fertility.

Reduced tillage in Morocco

Reduced tillage experiment was held at **Jabrane farm** on about 1.5 hectare where the precedent crop is bread wheat. The chisel plowing was skipped on half of the plot at the tillage before the sowing. During the crowing season, three to four visits were planned to collect data on the crop growth. Data analysis shows net disparity between the two sections of the field. Total biomass and grain yield under reduce tillage (1 cover crop) were higher than regular plowing (chisel plow+ cover crop). Effect of two planting methods on vegetative shoots, fertile shoots, plant height, and number of grains per spike was evaluated. Seedling, even growing taller under total tillage practice (65.6 cm height vs 53.2cm) and shooting better (5.3 spikes/plant vs 2.4), reduced tillage overpass it by higher number of seeds per spike (23.38 vs 17.2), larger seeds (48.7 vs 42.3) and higher biomass (2.5 t vs 2 t) and grain yield (1.79 t vs 1.52 t) per hectare (see figures below). Even if the differences were insignificant statistically, total biomass increases by 20%, 1000 seeds weight by 15% and the grain yield by 18%. This trend needs more investigation next year to display clearly to the local growers the benefit of reduced tillage on crops productivity, more than just reducing the cost of the tillage.

Bed Planting Systems vs Conventional Planting of Wheat

In this study, different tillage and planting methods were compared for wheat in terms of grain yield, straw yield, number of heads per square meter, harvest index. A local bread variety wheat Adana-99 was planted on 1 November, 2010, and harvested on 7 June 2011.

Tillage and planting treatments considered in this study are described as following;

T1: Direct narrow bed planting (on 70 cm wide ridgde): With a lister, beds were renewed, and with ridge planter 3 rows of wheat were planted.
T2: Narrow bed planting (on 70 cm wide ridgde): Soil was cultivated with a tooh-harrow, then new ridged were constructed with a lister then with ridge planter 3 rows of wheat were planted.
T3: Broad Bed Planting (140 cm): Soil was cultivated with a tooh-harrow, then wide beds were established with a rotavator; and wheat was planted using conventional plnater.

T4: Conventional planting + making narrow ridges after planting (Post-Plant Ridges)
Seeds were planted with a conventional planter on flat surface, then using a lister 70 cm wide ridges were constructed after planting.
T5: Conventional planting + making broad beds after planting (Post-Plant Ridges, 140 cm) Seeds were planted with a conventional planter on flat surface, then using a rotovator 140 cm wide beds were constructed after planting
T6: Conventional planting: Soil was cultivated with a tooh-harrow, then seeds were planted on flat surface with a conventional planter.

Grain yield, biological yield, straw yield, number of heads per square meter, 1000 seed weight, harvest index and plant height data for the different planting methods were evaluated. Planting method was found significant on yield and contributing characters of wheat.
Planting on flat then constructing broad ridge planting (T5) along with conventioanl planting (T6) systems produced the highest yield as compared to other treatments. Broad bed planting (T3) resulted in similar yields to T5 and T6 treatments, while T2 and T1 planting techniques, which are new ridge planting and permenant ridge planting, respectively, produced the lowest yield. T5 treatment also resulted in highest biological and straw yields. T2 and T1 also produced the lowest biological and straw yields. Similar results are obtained for 1000 seed weight and number of heads per square meter features. Conventional planting resulted in maximum HI value.
The system used by farmers in Turkey is quite unique in that the wheat is generally planted only on top of the raised beds, with a defined number of rows on each bed and a specific spacing between the rows. The adoption of planting wheat on beds by farmers in Turkey can be more accurately characterized as a farmer decision to reduce production costs rather than a strategy to increase yields per se. However, as both farmers and researchers gain more experience in managing wheat in bed-planted systems, opportunities to reduce production costs while achieving higher yields are becoming apparent. In addition, new options for more sustainable production systems that include reduced tillage and management of crop residues under surface-irrigated conditions are becoming more feasible. There are very few examples around the world where useful technologies have been developed that combine major reductions in tillage with crop residue retention and yet allow irrigation of wheat by gravity systems.
. In the study the minimum tillage, ridge tillage and direct sowing techniques were practiced. The systems were examined and analyzed in terms of the fuel and time consumptions, working efficiency, the percentage of emergence, soil moisture content, porosity, bulk density, yield, biological yield, straw yield, height of plant, 1000 kernel weight, harvest index, number of spike, and hectoliter weight.

Treatments considered:

1. Reduced Tillage (RT): Stuble burned+Discharrowed once+ Planter
2. Zero-tillage (direct sowing): In stuble, straw was cleaned +T. Herbicide applied+Planter
3. Ridge Planted (RP II): Stuble + Disc-harrowed twice+Lister+Ridge Float+Planted into ridge as two rows
4. Ridge Planted (RP III): Stuble + Discharrowed twice+Lister+Ridge Float +Planted into ridge as three rows

The highest grain yield was obtained from the reduced tillage, followed by zero-tillage or direct seeding. Ridge planting at two rows resulted in the minimum grain yield. The result revealed that maximum efficiency on wheat production was obtained with the minimum tillage technique; the minimum efficiency was from the two rows of bed planting systems. The minimum fuel consumption and the maximum working efficiency was found with direct sowing. RT generated the highest total income, followed by zero-tillage and RP system.

New Crops: Quinoa and Amaranth Studies at Cukurova University in Turkey:

An adaptation experiment for evaluating yield performance of one quinoa line (Q-52) and 5 amaranth lines *(Amaranthus spp.)* (A2, A5, A7, A12, A14) was conducted under the Mediterranean climatic conditions in Adana, Turkey. Since the first year of the project no grain yield was obtained form the other 9 Quinoa lines, only Q-52 is included in the second and third year of the study. The varieties selected for adaptability trials included a range of species and morphological types that have agronomic potential. The second study on new crops is response of quinoa and amaranth to both fresh and saline water as well as to deficit irrigation.

Quinoa seeds were sown by hand at 3-4 cm apart in the row and at 50 cm row spacing on March 28, 2011. Amaranth seeds were sown by hand at 10-12 cm apart in the row at 50 cm row spacing on March 30 and on May 5, 2011. Therefore, two different planting times will be compared.

Grain yields of amaranth varieties tested in 2009 under the Mediterranean climatic conditions varied from a low of 2441 kg/ha in *A-7* to a high of 4441 kg/ha in *A-14*. Other traits yields were in between these two values. However, in the 2010 growing season, *A14, A12, A5* and *A2* lines outyielded *A7* as shown in Table 1. Average grain yields were 4.5 tons/ha for *A14*, 4.3 t/ha for *A2* and *A12,* 4.4 t/ha for *A5*; and lowest yield was 2.1 t/ha for A7 line. In 2010, average 1000 seed weights also varied from a low of 0.47 g in *A-5* to 0.66 g in *A-12* .

The two year results indicated that *A14* followed by *A2* and *A12* lines performed better than other amaranth lines tested in the study. Third year results are not available for the moment. From the two previous years results it can be concluded that ***A-14*** trait is the most promising variety under the environmental conditions of the study.

Table 1. Grain yield (2009, 2010, and average), stem and panicle weight per plant, and 1000 seed weight for different amaranth lines in 2010.

Amaranth Lines	Stem g/plant	Panicle g/plant	Grain g/plant	1000 Grain Weight, g	Grain Yield kg/ha		**Average yield kg/ha**
					2010	**2009**	
A2	48,46	73,84	31,45	0,643	4290	3887	**4089**
A5	49,96	82,17	32,25	0,656	4450	3391	**3920**
A7	67,47	54,83	15,71	0,647	2140	2441	**2290**
A12	36,01	76,17	32,34	0,846	4270	2605	**3478**
A14	53,02	88,62	32,44	0,647	4490	4441	**4465**

Supplemental irrigation of wheat using drainage canal water:

The field experiment was carried out during the growing season of 2009, 2010 and 2011 between the months of December through June, on the experimental field of Tarsus Research Institute of Soil and Water Resources, situated in Tarsus (Turkey). 2010/2011 wheat growing season especially March through May was more wet as compared to both long-term means and 2009/2010 means. Since no supplemental irrigation was applied to wheat because rainfalls were sufficient to meet water reqirements of wheat so that data are collected only for the rain-fed treatment in 2011 growing season. Average wheat grain yield from the study was 8674 kg/ha; harvest index 39 %; plant height was 104 cm. Other yield components such as average 1000 seed weight were 43.2 g; number of spikes per m^2 was 786. These figures are well over the long-term average yield from the rain-fed wheat grown under the Mediterranean climatic conditions.

In this study, unfortunately no supplemental irrigation using drainage water was applied due to normal or above normal rainfall in 2009 and 2011, and no drainage water was available in 2010. Therefore, the expected results from this project have not been obtained. The fourth year, the trial with wheat will continue.

Supplemental irrigation with fresh-water

Application of small amounts of freshwater, usually extracted from groundwater, at critical crop growth stages under rainfed conditions has the potential to cause significant increase in crop productivity. However, this may have implications on groundwater quality and recharge rate as well as long-term water balance in the area. Although deficit irrigation has the potential to increase water-use efficiency and save water for use on other areas, there may be implications for the soil salinity build up because of less water availability for leaching of salts added via irrigation. The impacts of deficit irrigation need to be evaluated through water balance and soil salinity monitoring. The work under this task are carried by Cukurova University, Turkey (Chickpea and faba bean); Evora University in Portugal Chickpea); and ICARDA in Syria (chickpea, lentil, and faba bean). The implications of supplemental irrigation are based on three studies on food legume crops at the experimental station of ICARDA in Syria. There are three food legume crops, i.e. chickpea, lentil, and faba bean. A certain number of accessions of each food legume have been used (chickpea 15 accessions; lentil 15 accessions; and faba bean 10 accessions).

With the results of the first two years of the cropping season, it is evident that these food legumes responded to the supplemental deficit irrigation in terms of growth and yield. However, there were differences among the food legume accessions for plant height, biomass production, harvest index, and other crop attributes.

Chick Pea and Faba Bean Experiments in Turkey:

Both the chick pea and faba bean experiments were set up at the Hacıali Farm of the Cukurova Agricultural Research Institute (36^o48’ N and 35^o17’ E, 7 m msl), Adana, Turkey. Experiment was designed as randomized blocks with four replications. In the study, four different treatments in Faba bean; five treatments in chickpea were tested under the Mediterranean climatic conditions. These treatments are for Faba: full irrigation (FI), deficit irrigation (DI), partial root-zone drying (PRD) and non-irrigated treatment. Full irrigation (FI) treatment plots will be irrigated at weekly interval throughout the growing season and weekly soil water deficit in the effective root zone depth will be replenished to field capacity. DI and PRD treatment plots will receive 50% of the water applied to FI plots. In PRD treatment plots, drip laterals laid out at the center of adjacent crop rows will supply water in an alternate matter. Thus, half of the root-zone remains dry. A drip system was installed in the experiment. In chick pea; FI, PRD, DI-75, DI-25, and rain-fed treatments were studied. DI-75 and DI-25 received irrigation water 75 and 25 % of water applied to FI treatment plots. Drip laterals of 16 mm in diameter, with discharge of 2 L/h inline emitters spaced at 20 cm apart were laid in the center of adjacent crop rows.

The 2009 growing season is a wet year after experiencing several years of dry years in the region. However, 2010 season was relatively drier as compared to previous year. Monthly rainfall received in the experimental area in 2010 was 105 mm in January, 54 mm in February, 2.6 mm in March and 38.6 mm in April, and 0.4 mm in May. The 2011 growing season was unexceptionally wet year as indicated by Figure A18. In 2011, 198 mm in December, 97 mm in January, 86 mm in Febrauary, 110 mm in March, 115 mm in April, 68 mm in May and 36 mm of rainfall in June was recorded. Therefore, no supplemental irrigation was required by faba bean, winter chick pea, wheat and also quinoa crop in this particular year.

Chick pea: In the third year of the project, chick pea was planted both in winter and spring times in order to evaluate effect of sowing dates on yield and plant growth. For winter planting, a local chick pea (*Cicer arietinum*) variety *inci* was planted at 45 cm row spacing and 6 cm on the row with a four row planter on December 8, 2010. The spring planting of chick pea was done on March 3, 2011. Evolution of LAI and plant biomass with time was evaluated. In general, winter planted chickpeas had greater LAI than the spring planted chickpeas in respective irrigation treatments. Above ground plant biomass variation with time for winter and spring planted chickpeas as indicated by the Figure A20a, b average biomass yields were greater for winter planting than the spring planting. Winter planted chick pea was harvested on July 4, 2011.

Total irrigation water applied, evapotranspiration (ET), grain yield, water use efficiency, and irrigation water use efficiency for winter and spring planted chickpea in 2010 was summarized in Table 2.

Table 2. Total irrigation water applied, evapotranspiration (ET), grain yield, water use efficiency, and irrigation water use efficiency for winter and spring planted chickpea in 2010.

Planting Time	Treatment	Irrig. mm	ET mm	Yield g/plant	Yield kg/ha	WUE, kg/m^3	IWUE, kg/m^3	100 seed weight g	Biomass Yield g/m2	HI %
Winter Chickpea	FI	315	734	242	4399	0,599	0,90	32.00	2272	19.4
	PRD	158	575	233	3636	0,632	0,00	34.53	1904	19.1
	DI-75	236	661	223	3379	0,511	0,00	34.49	1911	17.7
	DI-25	79	497	231	4337	0,872	2,82	33.20	1706	25.0
	DRY	0	446	238	4115	0,924	0,00	32.31	1736	23.7
Spring Chickpea	FI	225	488	223	2849	0,584	1,73	32.10	1184	24.1
	PRD	113	363	224	2691	0,742	2,06	31.43	1002	26.9
	DI-75	169	430	223	2812	0,654	2,09	32.49	1048	26.8
	DI-25	56	327	224	2763	0,845	5,39	31.80	846	32.7
	DRY	0	239	224	2460	1,030	0,00	31.71	751	32.8

Total amount of water applied to different treatments varied from 255 and 315 mm in full irrigation treatment plots (FI); to 65 and 80 mm in DI-25 plots. Winter chickpea received more irrigation water than the spring planting. PRD and DI-75 treatment plots received irrigation water varying from 127 and 157 mm; and 190 and 235 mm, respectively. Seasonal crop water use values rangrd from 446 to 734 mm for winter planted chickpeas, and from 239 to 488 mm in spring planted chickpeas. Thus, seasonal ET of the winter planted chickpeas were relatively greater than the spring planted chickpeas since the length of the growing season for winter planting was longer than the spring planting. In both planting times, water use increased with increasing irrigation water. Irrigation treatments had no significant effect on yield in both planting time, however, planting times were significantly different effect on grain yields. Winter planting resulted in significantly higher yields than spring planted chickpeas. Although the effect of irrigation treatments was not significant on yield, FI (4.4 t/ha) and DI-25 (4.3 t/ha) along with DRY (4.1 t/ha) treatments resulted in higher yields as compared to PRD

(3.6 t/ha), DI-75 (3.4 t/ha) treatments in winter planting. In spring planting, yields increased with increasing irrigation water, but the effect was not significant. Average yield values ranged from 2.46 t/ha in DRY treatment to 2.85 t/ha in FI treatment. Water use efficiency values varied from 0.511 to 0.924 kg/m^3 in winter planting; and from 0.584 to 1.030 kg/m^3 in spring planting. WUE in general increased with decreasing crop water use in both planting time. Harvest index values were smaller for winter planting than the spring planting. HI values ranged from 17.7 to 23.7 %for winter planted chickpeas, and from 24.11 to 32.8 % for spring planted chickpeas.

In the present work, the indeterminate chickpea responded to soil moisture and there was prolonged flowering and podding, which eventually increased grain yield. The highest yields for local cultivar and normal sowing date (november-december) were achieved when drought stress was completely eliminated by irrigating throughout the growing season. Seed yield was doubled in November-sown chickpea (4.6 t/ha) as compared to spring planted chickpeas. Winter planting resulted in significantly higher yields than spring planted chickpeas. Although the effect of irrigation treatments was not significant on yield, FI (4.4 t/ha) and DI-25 (4.3 t/ha) along with DRY (4.1 t/ha) treatments resulted in higher yields as compared to PRD (3.6 t/ha), DI-75 (3.4 t/ha) treatments in winter planting. In spring planting, yields increased with increasing irrigation water, but the effect was not significant. Average yield values ranged from 2.46 t/ha in DRY treatment to 2.85 t/ha in FI treatment and there was no indication of a critical period of sensitivity to water stress.

Supplemental irrigation of chickpea with fresh water in Portugal

In order to evaluate the effect of supplemental irrigation on chickpea grain yield, four irrigation treatments (rainfed, 25%, 50% and 100% of crop irrigation requirements- IR) were tested on five varieties: Elvar, Elixir and Eldorado (Kabuli type); Elite and Elmo (Desi type). Sowing dates were February 27th, 2009, and March 19th, 2010. There was a delay in sowing date for the second year because the soil was waterlogged due to the excess of rainfall in the winter.

The field site, both years, was located at National Plant Breeding Station, Unit Genetic Resources, Ecophysiology and Plant Breeding (INRB/L-INIA, Elvas, with 38º 53’ of latitude, 7º 09’ of longitude and 208 m of altitude. The soil was a "Gleyic Luvisol" (FAO classification) or Aquic Haploxeralf" (American classification) with the following characteristics: sandy clay loam texture, 1.34 (g/cm^3) bulk density, 26.9 (% vol) field capacity, 11.9 (% vol.) wilting point, and 2.45 % organic matter in the 0-20 cm layer.

The amount of water applied both years was different because the 2008/09 agricultural year (from Set/2008 to Aug/2009) was a dry one, with only 312 mm of rainfall while the 2009/10 agricultural year was very wet, with 807 mm of rainfall.

Grain and biomass yield values by irrigation treatment and variety, evaluated in 2009 and 2010 are shown in Table 4. In 2009, the effect of supplemental irrigation was very important for all varieties even at the 25% IR treatment as compared to rainfed, with respect to both variables. In the second year, response to irrigation was less evident especially for the Desi varieties, Elmo and Elite.

The interaction between irrigation treatments and varieties was not significant, both years. Looking at the overall means by variety (Table 4), the results point out Elixir variety as exhibiting the highest grain yield in the first year and also a trend to be the best in the second year. Concerning biomass yield, the effect of variety was not significant.

Table 4. Grain yield (GY, kg ha^{-1}) and biomass (BY, kg ha^{-1}) by chickpea variety in 2009 and 2010 growing seasons.

Chickpea variety	2009		2010	
	GY	BY	GY	BY
Elixir	**2154**	**4930**	**1736**	4496
Eldorado	1786	5165	**1664**	5163
Elvar	1615	5183	**1417**	4361
Elmo	1873	4712	1211	4629
Elite	1890	4752	1186	4399
LSD (0.05)	185	n.s.	368	n.s.

The results point out for supplemental irrigation being worth applying, depending on the price of the water and the economic value of the grain, especially in dry years such as 2009, as it would be expected.

- Elixir variety exhibited the highest grain yield, harvest index, and high grain yield water use efficiency, both years. It also produced high total biomass, mainly in 2009, with eventual positive effects on soil fertility.
- The data also showed that grain yield was positively correlated with predawn leaf water potential, for each irrigation treatment, both years.

Chickpea Studies at ICARDA

Sixteen genotypes (CPI 060546, FLIP03-145C, FLIP03-2C, FLIP03-46C, FLIP04-19C, FLIP87-59C, FLIP87-8C, FLIP97-116C, ILC10722, ILC1302, ILC216, ILC3182, ILC3279, ILC588, Elexire, and Eldorado) were planted in split-plot arrangements in a randomized complete block design (RCBD). The year 2011 was relatively dry around Aleppo; the rainfall data collected at ICARDA's main research station revealed 259 mm total annual rainfall compared to 350 mm long-term average. During March-April, about 69 mm rainfall was recorded, which was 20 mm more than recorded last year. The same sixteen chickpea genotypes were tested in drought tolerance nursery with two levels of irrigations, 30% of field capacity and full field capacity, namely T2 and T3, respectively. The third treatment (T1) was rain-fed.

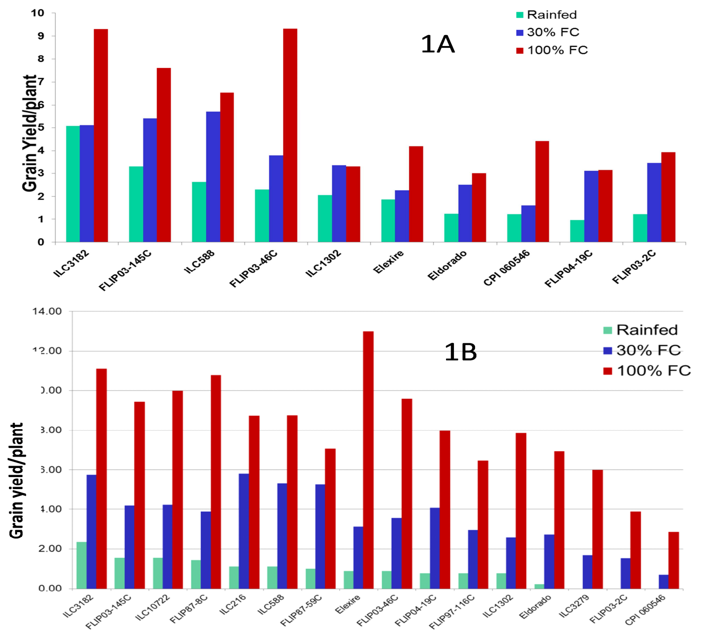

Figure 3. Chickpea grain yield (g/plant) across three treatments in 2009 (3A) and in 2010 (3B). In 2009 five genotypes (FLIP87-59C, FLIP87-8C, ILC10722, ILC216, and ILC3279) were affected by Fusarium wilt.

The treatment effect was obvious on plant height with an average of 30.4 cm under 100% moisture level followed by 28.0 and 19.7 cm under 30% and rainfed treatments, respectively. The tallest genotypes under the three treatments were FLIP04-19C and ILC3279. In case of days to 50% flowering, the genotype FLIP87-8C was the earliest under rainfed condition for this year; however, FLIP03-145C, ILC588 and ILC10722 were the earliest under both irrigated conditions.

Supplemental irrigation definitely icreased grain yields in all the genotypes tested. In 2009, ILC3181 and FLIP03-46C outyilded the other genotypes under full irrigation; in 2010, Elexire genotype performed superior to othet genotypes under full irrigation.

Faba bean study in Turkey

A local faba bean (*Vicia faba)* variety ERESEN-87 was planted at 45 cm row spacing and 10 cm on the row with a four row planter on December 8, 2010. Due to rainfalls received during the growing season was well above long-term average, no irrigation was applied to faba bean in 2011. Therefore, measurements were carried out under rain-fed conditions. Evolution of faba bean plant biomass and plant height with time was evauated. Maximum dry matter yield was observed as 1800 g/m^2 on April 27, 2011. The maximum plant height of 98 cm was observed on April 20, 2011. Faba bean in the third year of the study was harvested on July 1, 2011.

Faba bean was not irrigated in 2009 growing season due to sufficient rainfall received in that particular season, and average faba bean yield was 2776 kg/ha, and 100 bean weight was 169.2 g. As shown in table, there was no significant difference in faba bean yields and most of the yield components among the irrigation and rain-fed treatments in 2010 growing season. Average yields varied from 2164 to 2221 kg/ha among the treatments. PRD resulted in greatest number of pods per plant and number of beans per plant. However, the bean mass was relatively smaller as compared to other treatments. Full irrigation increased the first pod height from the ground level, PRD resulted in smallest first bean height. Full irrigation increased plant height as compared to other treatments. Rainfed treatment produced the highest yield, but the difference was not significant.

Irrigation had no significant effect on faba bean yield and yield components in 2009, 2010 and 2011 in the Mediterranean region of Turkey. Due to rainy growing season in 2011, no irrigation was applied to faba therefore the results are obtained under rainfed conditions. The three years results revealed that faba bean can be produced under rainfed conditions without requiring any supplemental irrigation under normal (650 mm average annual rainfall, of which 65 % falls during the winter months) and/or above normal rainfall conditions in the Mediterranean region of Turkey. However, in dry years, supplemental irrigation during the critical growth stages of faba bean (flowering and seed filling) increases yields considerably. In Syria, supplemental irrigation resulted in significant yield increase.

Faba bean study at ICARDA

Eleven faba bean accessions were evaluated in order to characterize them for drought tolerance at the experimental station of ICARDA. Three treatments of water regimes were used: (1) rainfed, irrigation at 50% of soil field capacity, and irrigation at 100% of soil field capacity. The total precipitation received during the growing seasons 2008-2009, 2009-2010 and 2010-2011 varied from 255 mm to 289 mm. Data for the following parameters were collected: date of maturity (number of days from planting date to maturity), plant height (cm), root depth (cm), dry weight of rhizobium per plant, grain yield (g/m^2), biomass (g/m^3), and harvest index (g).

The rainfall distribution varied from one year to another. In the first year and the third year, the rainfall distribution was extended from November to May, however for the second year, the rain stopped in early March, which explains the occurrence of high terminal drought during that year. The cropping season for the year was humid with moderate temperature; sudden periods of cold during January (early January); the weather conditions were favorable for faba bean. The ANOVA analysis showed significant differences for days to maturity (DMAT), plant height, grain yield, and biomass. Significant differences between three water regimes were observed for all the faba bean accessions. Differences between genotypes were observed for several parameters for the data recorded in three years. During the third year, plant height revealed that faba bean plants were higher in the 50% IRR and 100% IRR treatments than the rainfed treatment. In most cases, plant height increased with the increase in irrigation level, i.e. from 50% to 100% IRR. Plant height was higher for the accession 2 (DT/B7/9013/05/06) and the check number 11 (ILB1266) than other genotypes. Similar results have been obtained during the first two seasons. The accession 2 (DT/B7/9013/05/06) showed high performance across the three years of field evaluation of faba bean genotypes.

Faba bean grain yield (kg/ha) varied significantly between accessions and between different water regimes across all the years. Some genotypes such as DT/B7/9043/2005/06 (accession 3) performed better under dry conditions than other genotypes during the first years; however the accession 2 (DT/B7/9013/2005/06) showed highest yield. However, all the genotypes responded to the irrigation with an increase of 25% for the genotype "3" in year 1 and genotypes 2 to 200% for the local genotypes in full irrigation (100% IRR). The more yield genotype to drought has less response to irrigation than the checks numbered 8, 10 and 11. There is significant differences were obtained between rainfed and the two water irrigation and between 50% irrigation and 100% irrigation.

Grain yield (kg/ha) produced by different faba bean accessions as affected by irrigation treatments – rainfed across all years, supplemental irrigation (IRR) in 2009, irrigation at 50% of soil field capacity (50% IRR), and irrigation at 100% of soil field capacity (100% IRR) in 2010 and 2011 are given in Table 6.

Table 6. Grain yield (kg/ha) produced by different faba bean accessions as affected by irrigation treatments – rainfed across all years, supplemental irrigation (IRR) in 2009, irrigation at 50% of soil field capacity (50% IRR), and irrigation at 100% of soil field capacity (100% IRR) in 2010 and 2011. Details of the accessions are available in Table A19.

Entry	**2009**		**2010**			**2011**		
	IRR	Rainfed	Rainfed	50% IRR	100% IRR	Rainfed	50% IRR	100% IRR
1	2716.67	2512.50	1058.03	2251.60	2634.63	1266.67	3566.67	4333.33
2	3456.94	3011.11	1203.10	2501.53	3139.23	2133.33	3833.33	4966.67
3	4399.31	3615.28	1159.20	2017.90	1828.97	1933.33	3200.00	4133.33
4	3504.17	2036.81	923.50	1971.00	2748.10	1600.00	3700.00	4133.33
5	4054.17	2900.00	1158.93	2359.83	2784.47	1666.67	2266.67	3866.67
6	3267.36	3503.47	1053.13	2397.4	2309.90	2066.67	3000.00	4300.00
7	3772.22	3284.03	1225.13	2208.73	2761.87	1633.33	3233.33	3360.00
8	3625.69	2885.42	1176.10	1880.5	2772.73	1466.67	3133.33	3433.33
9	3643.75	2693.75	973.60	2068.63	2702.50	1733.33	4266.67	4500.00
10	4459.03	2991.67	1347.73	2766.13	3159.37	1900.00	3466.67	4200.00
11	4690.28	2392.36	1150.77	2660.00	3296.80	2523.33	3100.00	4900.00

Biological yield, i.e. biomass expressed in terms of kg/ha, varied across accessions, treatments and years. Biomass increased significantly with irrigation, however, no significant differences were found between irrigated plots.

The harvest index of faba bean accessions varied among genotypes, treatments and years are given in Table A20. With almost the same harvest index under the different conditions, accession 3 (DT/B7/9043/2005/06) had better tolerance to drought in 2010 and accession 2 in 2009 and 2011. However, the harvest index was significantly increased with the increase in irrigation level from 50% IRR to 100% IRR .

Our results show that phenological and agronomical traits were affected by terminal drought in the first and second years and by intermittent drought during the third year. Supplemental irrigation at flowering stages, pod and grain filling stages had a positive effect on increasing biomass, plant height, and rhizobium weight for the genotypes. Therefore, the results presented show significant effect on pod abortion in case of rainfed conditions as was reported earlier researchers (Wery et al. 1994; Siddique et al. 1999; Ricciardi et al. 2001). The accession 2 showed high yield across all the three years in rainfed and irrigated plots. This accession would be a promising line under rainfed agro-ecological zones where faba bean is grown.

Effect of supplemental irrigation of lentil under rainfed Mediterranean environments

Effect of supplemental irrigation under rainfed conditions was studied involving two levels of irrigation (no and one) and 15 lentil genotypes with three replications during 2010-11. Sowing of these accessions was undertaken on 3 December 2010. The analysis of variance showed significant effect of irrigation, genotypes and their interaction for grain yield. Irrigation had positive effect on grain yield. The grain yield increased by 47% from 601 kg/ha under rainfed to 884 kg/ha under irrigation conditions. Similarly, supplemental irrigation showed positive effect on biological yield from 1290 kg/ha to 1599 kg/ha, an increase of 24%. Under supplemental irrigation, all genotypes responded positively for grain and biological yields. Genotypes with significant yield improvement under supplemental irrigation were ILL 6037 (102%), ILL 6002 (82%), ILL 7947 (80%), 6994 (20%), ILL 7670 (52%) and ILL 7537 (48%).

Combined analysis over the years (2009 through 2011) indicated that under rainfed conditions, four short duration genotypes, namely ILL 6994, ILL7201, ILL7670 and ILL 10707 not only performed well but also responded positively to supplemental irrigation at pod filling stage. The extent of response measured was 10-40% yield increase among these genotypes. However, some of the poor performers responded to supplemental irrigation with more than 50% yield advantage. These genotypes are ILL 6037 (77%), ILL 10072 (67%), ILL 6002 (55%), ILL7537 (54%). Analysis over the years indicated that lentil respond by 34% yield increase to supplemental irrigation at pod filling stage in dry areas (Figure 5). Other characters of these promising genotypes are given in Table 7.

Table 7. Important characteristics of promising lentil genotypes

Genotype	Days to maturity		Pods/ peduncle		Pods/plant		Seeds/plant		100-seed weight (g)		Biological yield (kg/ha)		Grain yield (kg/ha)		Harvest index (%)	
	SI	RF	SI	RF	SI	RF	SI	RF	SI	RF	SI	RF	SI	RF	SI	RF
ILL6994	128	125	2	2	44	41	48	46	3.81	3.81	1789	1534	926	824	49	47
ILL7201	129	125	2	3	46	36	50	41	4.41	4.18	1849	1496	1117	800	52	49
ILL7670	130	129	2	3	36	36	36	36	5.24	5.05	1770	1358	903	817	50	49
ILL8068	127	127	2	2	33	33	33	33	4.55	5.05	1822	1486	1015	764	38	39
ILL10707	129	128	3	2	42	42	46	47	4.06	4.43	1727	1532	995	799	48	49

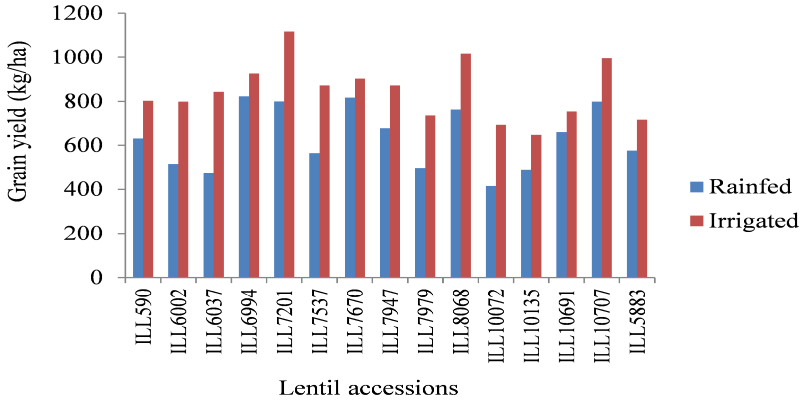

Figure 4. Effect of supplemental irrigation on grain yield (kg/ha) in lentil genotypes over three years

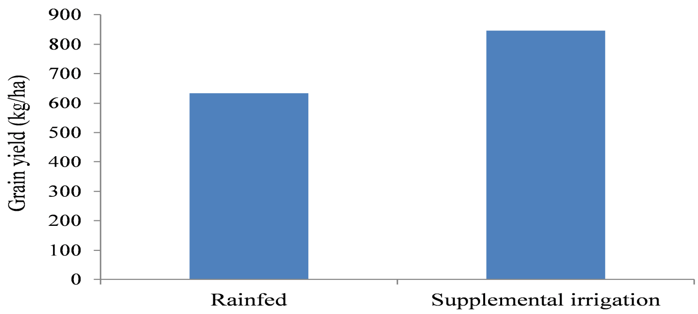

Figure 5. Effect of supplemental irrigation on grain yield (kg/ha) in lentil combined over three years

Supplementary irrigation in Morocco

Supplementary irrigation experiment was carried at ***Daiif abderkader Farm***. The data analysis of the variance showed high significant differences of 5 out of 6 yield component parameters. Plot supplemented by two full soil capacity irrigations at vegetative stage and flowering stage, dominate largely the rain fed plots. Supplemented plot biomass almost twice the chick pea precedent plot, and three and half time the bread wheat precedent. The gap is even bigger when we compare the grain yield and 1000 grains weight, which were 4.98 t/ha vs 0.51 t/ha and 48.6 g vs 18.1 g respectively. Seeds from rain fed plots were shriveled because of the effect of drought and high temperature during the grain filling stage. Under semi arid climatic environment, water is undoubtedly the most significant factor to the crop production. Two full irrigations at the most sensitive stages of the plant growth could increase the yield by 9.8 times. Precedent helped 3.3 times compared to wheat monoculture. Other factors have probably positive effect to reach this high yield with irrigated treatment, such the precedent and the weeds density since a cucumber crop was cultivated during summer season. The irrigation, as well as the precedent could affect the harvest index too. This ratio reached its highest value at the irrigated plot (39%), and was of only 19% on the bread wheat monoculture plot.

Supplementary irrigation and nitrogen effect on quinoa production in Morocco

At Daiif farm, we tested supplementary irrigation and nitrogen effects on quinoa growth and production. We were comparing between 4 treatments, two full soil capacity irrigations at flowering stage one with nitrogen supplementation and the second without and two rain-fed treatments one with nitrogen supplementation and the other without. We could show clearly through the data the dominance of irrigated treatments compared to rain-fed ones, particularly for grain yield. Nitrogen supplementation had positive effect on vegetative biomass but did not increase the grain yield. Irrigation alone increases quinoa grain yield by 74% and the biomass by only 13%. The highest biomass increase was that of irrigation with nitrogen supply. Adding nitrogen alone without irrigation reduced the yield by 34% and the biomass by 10%. Irrigation has therefore more determinant effect on quinoa grain yield than nitrogen. From this finding, a paper is under preparation for publication in the coming months.

Seed treatments

Pre-sowing seed treatment approaches and seed priming will be used to improve germination in saline conditions. Seed treatment experiments are carried out by Cukurova University (CU) to assess the possibility of early sowing to escape as much as possible terminal drought and consequently to reduce complementary irrigation water amount. Seed priming (soaking in water and drying back to storage moisture conditions until sowing) has been shown to improve crop establishment and, in some instances, to increase crop yields. A promising variation of the priming concept is the seed treatment with liquid solutions containing a limited amount of nutrients (Ajouri et al, 2004). Earlier sowing and seed priming treatments will be used to improve germination and to escape multiple abiotic stresses.

Pre-sowing seed treatment approaches and seed priming will be used to improve germination in saline conditions. Seed treatment experiments are carried out by Cukurova University to assess the possibility of early sowing to escape as much as possible terminal drought and consequently to reduce complementary irrigation water amount. Seed priming (soaking in water and drying back to storage moisture conditions until sowing) has been shown to improve crop establishment and, in some instances, to increase crop yields. Seed treatments studies are initiated at Laboratories of the Çukurova University so that results from the laboratory studies are applied during the second year of the Project.

In this study, five osmopriming agents were used to investigate their effects on seed germination properties, yield components and grain yield of bread wheat for optimum and late sowing time at research and implementation area of Department of Field Crops, Faculty of Agriculture, University of Cukurova. Seed priming was done by soaking in water containing 100 ppm indole-3-acetic acid (IAA), 2.5% potassium chloride (KCl), 1% potassium hydrophosphate (KH_2PO_4), 10% polyethylene glycol (PEG). Non primed seeds were used as control. Two bread wheat cultivars namely, Adana99, and Panda were used as a seed material for this study. This research was conducted two years.
The seeds of the Adana-99 and Panda bread wheat cultivars were used as seed material and the effect of six different priming solution (1: distilled water, 2: 100 ppm Indole-3 asetic acid, 3: %2.5 KCl, 4: %1 KH_2PO_4, 5: %10 PEG, 6: control) were investigated. 500 g seed samples of each cultivar were primed which was prepared 1 lt solution of priming. The seeds were primed at room temperature (22-23 ^oC) for 12 hours. The primed seeds were air-dried after priming application and prepared for sowing.

The means and LSD groupings of germination rates at different temperatures, coleoptile length, seedling emergence and seedling growth rate were evaluated. Germination rates at different temperatures, coleoptile length, seedling emergence and seedling growth rate were higher in Adana-99 than Panda cultivar. PEG and KCl applications increased the germination rate at low temperature and coleoptile length was increased by the application of distilled water.
PEG application was increased the number of the plants/m^2, plant height, number of the tillers/plant, spike length, spikelets per pike, number of the grain/spike, grain yield/spike and number of the spike/m^2.

According to laboratory and field experiments, PEG application to the seeds of bread wheat could increase some germination properties and some yield components of bread wheat. However, further studies are needed to get clearer picture in order to make final conclusion.