ROMANIAN AGRICULTURAL RESEARCH, NO. 38, 2021
First Online: September, 2020. DII 2067-5720 RAR 2021-27

YIELD AND WATER USE EFFICIENCY OF WINTER AND SPRING-SOWN CHICKPEA TO VARIOUS IRRIGATION REGIMES UNDER MEDITERRANEAN ENVIRONMENT

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ABSTRACT

The effects of various irrigation strategies applied with drip system and different planting dates on yield, components and water use efficiency of chickpea (*Cicer arietinum* L.; var. Inci), were evaluated during 2010 and 2011 under Mediterranean conditions. The treatments included full irrigation (FI), mild deficit irrigation (DI-75), severe deficit irrigation (DI-25), partial root-zone drying (PRD-50), and non-irrigated (DRY) for winter and spring planting times. DI-75, PRD-50, and DI-25 received irrigation water 75, 50, and 25% of full irrigation, respectively. Both irrigation regimes and sowing dates had significantly different effect on grain yields. Interaction of irrigation and sowing dates was also significant in 2011. Water stress reduced significantly yield of spring-planted chickpea as compared to winter-planted chickpea. The greatest yields of 4.40 and 2.85 t ha^{-1} were recorded, respectively, for winter- and spring-planted chickpeas under FI. The greatest water use efficiency was 0.70 kg m^{-3} for winter-planted and 1.03 kg m^{-3} for spring-planted chickpeas in DRY treatment. WUE increased with decreasing irrigation amounts for both planting times. Winter planting performed better than spring planting for the yield and yield attributes. However, in dry years, deficit irrigations DI-75 and PRD-50 can be practiced to obtain higher yields with winter sowing.

Keywords: chickpea, sowing time, deficit irrigation, partial root-zone drying, water use efficiency.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third most important pulse crop in the world, with a total production of 12.09 million tons and a harvested area of 12.7 million hectares in 2016 (FAOSTAT, 2016). It is cultivated on a wide range of environments, from the subtropics to arid and semi-arid environments of Mediterranean climatic regions (Silva et al., 2014). Chickpea is considered one of the most drought tolerant food legumes, and plays an important role in the production of sustainable agriculture mainly in the traditionally semiarid areas of Mediterranean basin where water resources keep decreasing (Singh and Ocampo, 1997; Oweis et al., 2004). In semiarid environments, chickpea is traditionally sowing in window of the spring (March-April) after the rainy season. In this case yield is greatly dependent on the remaining soil moisture, and by drought and heat stress during vegetative season (Soltani et al., 2001). However, in the semi-arid regions where mild winters prevail such as the Southeast of Anatolia, Mediterranean, Aegean, and other regions could make winter chickpea sowing possible aiming to maximum benefit from winter precipitations. Chickpea suffers by drought and high temperatures during reproductive development, resulting fewer pods and seeds which reduced yields (Behboudian et al., 2001; Leport et al., 1999; Fang et al., 2010). Therefore, supplemental irrigation has been shown to significantly increase chickpea seed yield (Anwar et al., 2003; Oweis et al., 2004; Silva et al., 2014). Apart from improving yield, supplemental irrigation has the potential of stabilizing crop yield, reducing the risk of crop failure in dry years (Soltani et al., 2001; Oweis et al., 2004). Saxena et al. (1990) reported that winter

Received 3 September 2020; accepted 21 September 2020.

sowing was superior to spring planting, and irrigation increased yield 56% over rain-fed, and greater water use efficiency was found for winter-sown chickpea. However, there are some constrains in winter-sown chickpeas that affect the quality and productivity of the crop, such as the incidence of Ascochyta blight, and low temperatures and radiation during the vegetative period of crop growth. On the other hand, drought stress during the reproductive period of spring-sown chickpeas is considered a constraint for late sowing (Singh and Virmani, 1996). Limited supplemental irrigation can, however, play a major role in raising and stabilizing the productivity of winter-sown chickpeas (Zhang et al., 2000). Improving water use efficiency can be a strategy to save water, especially in regions where the main consumer of freshwater is agriculture (Fereres and Soriano, 2007).

The Mediterranean climate is characterized by high inter annual variability, especially in the case of rainfall, with dry and wet years, that can have considerable amounts of precipitation in the spring (Silva et al., 2014). This variability increases the difficulty in forecasting sowing dates, with either early or late sowing dates, and also in the management of supplemental irrigation. Therefore, the main objectives of this study are to evaluate the effects of various irrigation strategies (full, deficit and partial root-zone drying) applied with a drip system and different planting dates (winter- and spring-sowing) on vegetative growth of chickpea (*Cicer arietinum* L. Inci), grain yield and yield components as well as water use efficiency under the Mediterranean climatic conditions in Turkey.

MATERIAL AND METHODS

Experimental site and soil description

The chickpea experiment was set up at the Çukurova Agricultural Research Institute (36º48’ N and 35º17’ E, 7 m msl), in Adana, Turkey in two consecutive growing seasons (2009/2010 and 2010/2011). Typical Mediterranean climate prevails in the experimental area. Mean annual rainfall is 650 mm, and about 65% of total falls during the winter months.

The soil texture at the site varies from silty-clay in the upper layers to sandy loam in the lower layer. Some soil physical and chemical properties of the experimental soil are given in Table 1. Available soil water content in the effective root-zone depth of 60 cm is 98 mm.

Table 1. Some properties of soil in the experimental area

Depth cm	Texture (%)			Texture class	Organic matter (%)	ECe (dS m^{-1})	Bulk density (g cm^{-1})	Field capacity (g g^{-1}, %)	Wilting point (g g^{-1}, %)
	Sand	Silt	Clay						
0-30	15.5	40.4	44.1	SiC	1.36	1.18	1.26	30.2	17.1
30-60	10.1	46.1	43.8	SiC	0.96	1.02	1.28	29.8	17.2
60-90	18.1	50.0	31.9	SiCL	0.56	0.94	1.25	26.0	13.7
90-120	54.7	28.4	16.9	SL	0.15	0.68	1.54	13.6	7.2

Experimental design and treatments

Experiment was designed as split-plots with four replications. In the study, four different irrigation treatments (sub-plots) and two planting times (winter and spring) (main-plots) were tested under the Mediterranean climatic conditions. These treatments are: full irrigation (FI), deficit irrigations (DI-75 and DI-25), partial root-zone drying (PRD-50) and non-irrigated (DRY). Full irrigation (FI) treatment plots was irrigated at weekly interval throughout the growing season and weekly soil water deficit in the effective root zone depth (60 cm) was replenished to field capacity. DI-75, DI-25 and PRD-50 treatment plots received respectively 75, 25, and 50% of the water applied to FI plots. Irrigation was started when approximately 50% of available water in the 60 cm effective root-zone depth was used.

Drip laterals of 16 mm in diameter, with discharge of 2 L h^{-1} inline emitters spaced at 20 cm apart (Betaplast Corp, Adana Turkey) were laid in the center of adjacent crop rows. In PRD-50 treatment plots, drip laterals laid out at the center of adjacent crop rows supplied water in an alternate manner. One lateral provided water during and irrigation, the other lateral supplied water in the next irrigation. Thus, half of the root-zone remained dry.

Agronomic practices and observations

A local chickpea (*Cicer arietinum* L.) variety Inci was used. Winter sown was on December 12, 2009 and the spring planting was on February 12, 2010. In the second year, chickpea was planted on December 8, 2010 and on March 3, 2011 at 45 cm row spacing and 6 cm apart in the row with a four-row planter. Experimental plots were 6 rows wide and 5 m long. At planting 120 kg ha^{-1} ammonium nitrate (26% N; 31.2 kg ha^{-1}) and 120 kg triple super phosphate (50 kg ha^{-1} P_2O_5) was applied broadcast and incorporated into the soil.

Weather data was collected from an automatic recording meteorological station located at the experimental site. Precipitation, maximum and minimum air temperatures, air humidity and wind speed measured on a daily basis for each growing season.

Biomass samples were collected by cutting all the plants in the 50 cm row section in all plots at the ground level, and dry matter yield was determined at two-week intervals.

Soil water was measured with a profile probe (Delta-T Devices PR2/6 model, Cambridge, England) at weekly intervals in the plots. For this purpose, access tubes were installed at the center of each plot. The profile meter used in the study measures soil water at 6 depths down to 100 cm.

Crop water use (ET) was estimated based on water balance equation using soil water measured by the profile probe and gravimetric sampling methods. Water use is the total of seasonal water depletion (planting to harvest) plus rainfall and irrigations during the same period. The water balance equation is as following:

$$ET = I + P \pm \Delta S - D \quad (1)$$

where
- ET is evapotranspiration (mm);
- I is irrigation (mm);
- P is precipitation (mm);
- D is deep percolation (i.e., drainage, mm);
- ΔS is change of soil water storage in a given time period Δt (days) within plant rooting zone.

Chickpea was harvested by a mechanical harvester on June 26, 2010 and July 8, 2010 for winter and spring planted chickpeas, respectively. In the second year, chickpea was harvested on July 4, 2011 and 12 July 2011 for winter and spring chickpeas, respectively. Grain yield per hectare, grain yield per plant, 100-grain weight, main branch numbers, first pod height, were determined on the plant samples. Water use efficiency (WUE) was calculated as seed yield divided by seasonal ET and total seasonal irrigation water applied.

Statistics

Data were analyzed for a split-plot design using the MSTAT-C (MSTAT-C is a computer based Statistical software packages developed by the Crop and Soil Sciences Department of Michigan State University, USA).

RESULTS AND DISCUSSION

Mean monthly climatological data of the experimental years are presented in Table 2. The 2009/2010 season was relatively drier as compared to the second year. In general, mean temperatures during both growing seasons were similar. However, higher relative humidity values were recorded during the second year due to greater amount of rainfall received.

Table 2. Mean monthly climatological data of the experimental years

Climatological parameters	2009/2010						
	December	January	February	March	April	May	June
Mean temperature, ºC	10.1	8.0	10.5	11.9	15.0	19.9	22.8
Minimum temperature, ºC	5.8	3.2	3.2	3.7	9.0	12.1	18.8
Maximum temperature, ºC	15.4	13.9	16.1	20.1	20.1	24.8	30.8
Mean wind speed, m s^{-1}	0.3	0.3	0.4	0.4	0.6	0.5	0.8
Mean Relative Humidity, %	81.3	78.3	78.2	77.9	80.1	78.5	79.3
Rainfall, mm	91.0	105.0	54.0	2.6	38.6	0.4	3.1
	2010/2011						
Mean temperature, ºC	10.8	8.4	9.5	11.3	14.9	19.6	23.8
Minimum temperature, ºC	6.0	3.7	4.1	4.1	8.5	13.1	17.8
Maximum temperature, ºC	18.4	14.9	17.1	19.8	22.1	26.9	29.8
Mean wind speed, m s^{-1}	0.2	0.4	0.4	0.4	0.6	0.5	0.8
Mean Relative Humidity, %	86.1	80.8	81.3	82.9	85.5	81.5	83.7
Rainfall, mm	210.8	96.8	86.4	104.8	109.0	67.2	36.6

Irrigation water applied and evapotranspiration

Total amount of water applied to different treatments varied from 79 mm in DI-25 to 315 mm in FI winter-sown chickpea; and from 56 to 225 mm in spring-sown chickpea in 2010 (Table 3). The first irrigation application was on 105 days after sowing (DAS) for winter sowing and 56 DAS for the spring sowing in 2010; and 101 DAS for winter-sown and 67 DAS for spring-sown chickpea in 2011 (Figure 1 and Figure 2). Full irrigated winter-sown chickpea received 29% more irrigation water than the spring sowing. In 2011 growing season, less irrigation water was applied to both winter and spring-planted chickpea due to sufficient rainfall received during growing season as compared to 2010 (Table 4).

Seasonal crop water use values ranged from 446 to 734 mm for winter-planted chickpea, and from 239 to 488 mm in spring-planted chickpea in 2010 (Table 3). Thus, seasonal ET of the winter-planted chickpea was 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. Actual crop evapotranspiration (ET) values in 2011 ranged between 456 mm in DRY treatment and 630 mm in FI treatment in winter planted chickpea; on the other hand, ET values ranged between 379 mm in DRY and 588 mm in FI treatment in spring planted chickpeas (Table 4).

Table 3. Total irrigation water applied, evapotranspiration (ET), grain yield, water use efficiency (WUE) and biomass yield for winter and spring planted chickpea in 2010

Planting time	Irrigation treatment	Irrigation (mm)	ET (mm)	Grain yield (kg ha^{-1})	WUE (kg ha^{-1})	Biomass (g m^{-2})
Winter Chickpea	FI	315	734	4399a*	0.60d	2272a
	PRD-50	158	575	3636b	0.63c	1904ab
	DI-75	236	661	4379a	0.66bc	1911ab
	DI-25	79	497	3337b	0.67bc	1706b
	DRY	0	446	3115b	0.70bc	1736b
Spring Chickpea	FI	225	488	2849cd	0.58d	1184c
	PRD-50	113	363	2691d	0.74bc	1002c
	DI-75	169	430	2812cd	0.65c	1048c
	DI-25	56	327	2763d	0.84b	846dc
	DRY	0	239	2460d	1.03a	751d
LSD				591.9	0.16	256.6

**Any two values within a column are significantly different at the 5% level if they have no letters in common.*

Table 4. Total irrigation water applied, evapotranspiration (ET), grain yield, water use efficiency (WUE) and biomass yield for winter and spring planted chickpea in 2011

Planting time	Irrigation treatment	Irrigation (mm)	ET (mm)	Grain yield (kg ha^{-1})	WUE (kg ha^{-1})	Biomass (g m^{-2})
Winter Chickpea	FI	180	630	1086c*	0.17f	1387ab
	PRD-50	90	552	1272c	0.23e	1212b
	DI-75	135	595	1201c	0.20e	1365ab
	DI-25	45	477	1140c	0.24e	1009b
	DRY	0	456	444d	0.97a	890bc
Spring Chickpea	FI	215	588	1159c	0.20f	1627a
	PRD-50	108	463	1046c	0.23e	1114b
	DI-75	161	503	1710b	0.34d	1528a
	DI-25	54	424	2340ab	0.55c	1595a
	DRY	0	379	2623a	0.69b	1409ab
LSD				598	0.210	196.4

**Any two values within a column are significantly different at the 5% level if they have no letters in common.*

Water use efficiency (WUE)

Water use efficiency (WUE) values varied from 0.60 kg m^{-3} in FI to 0.70 kg m^{-3} in DRY treatment in winter planting; and from 0.58 kg m^{-3} in FI to 1.03 kg m^{-3} in DRY treatment in spring planting in 2010 (Table 3); and WUE values varied from 0.17 kg m^{-3} in FI to 0.10 kg m^{-3} in DRY treatment for winter-sown chickpea, and 0.17 kg m^{-3} in FI to 0.69 kg m^{-3} in DRY treatment for spring-sown chickpea in 2011 (Table 4). Both planting times and irrigation treatments resulted in significantly different effect on WUE values. In the favourable growing season of 2009-2010, WUE values were higher in all treatments than in 2010-2011 growin season. In general, DRY treatment had the greatest WUE values for both planting times except the spring planting time in the second year, and FI treatment had the lowest WUE values. WUE increased with decreasing ET in both planting times. From the Table 3 and 4, it is evident that irrigation supply increased seasonal ET at a greater rate than yield increase rate. As a result, the WUE in irrigated treatments decreased. Sowing times and irrigation treatments had significant effect on WUE values. WUE in general increased with decreasing crop water use in both planting times. Studies to compare the crop growth and WUE of winter and spring sown chickpea have shown that the WUE increases by more than 100 % in the winter sown crop over the spring sown one (Keatinge and Cooper, 1983). Silva et al. (2014) reported that the rainfed treatment had the highest WUE value. Amiri et al. (2016) found much higher WUE under supplementary irrigation than under rainfed conditions in Iran. The results of the current study are in line with a study on chickpea by Oweis et al. (2004), who observed an increase in yield and WUE when winter sowing was implemented with supplementary irrigation as compared with spring sown crop.

Dry matter yield (Biomass)

Irrigation treatments ($P<0.019$) and sowing dates ($P<0.007$) resulted in significantly different biomass production in 2010. FI treatment resulted in greatest biomass yield for both planting times, followed by PRD-50 and DI-75 treatments in 2010. Rain-fed treatment (DRY) produced the lowest biomass yield (Table 3). Winter planting resulted in more biomass yield as compared to spring planting due to longer growing season and cooler temperatures during winter planting season promoted vigorous vegetative growth. Biomass yields in 2011 were significantly lower than those in 2010 because of the occurrence of *Ascochyta blight*. Spring planting resulted in greater biomass yields in comparison to winter planting in 2011 (Table 4). Winter planting resulted in more biomass yield as compared to spring planting due to longer growing season and cooler temperatures during winter planting season promoted vigorous vegetative growth. Rainfall during the growing season had a strong effect on biomass production and grain yield for the two planting dates.

Variation of soil water content

The variation of soil water content (SWC) in the 100 cm soil profile depth for the different treatments for winter- and spring-sown chickpea in the experimental years are depicted in Figure 1 and Figure 2, respectively. SWC values remained above 50% available water (AW) level until 105 DAP when first treatment irrigation was applied in winter-sown chickpea in 2010. Then SWC values started to differ among the treatments. SWC in FI treatment prior to irrigations remained close to 50% AW until maturity stage then SWC decreased to near wilting point (WP) during harvest time SWC in other treatments remained below FI treatment depending on the irrigation amounts (Figure 1a). In spring-sown treatments SWC remained above 50% AW after the first irrigation application on 60 DAP then SWC decreased in all treatments towards the maturity stage (Figure 1b). Therefore, plants in PRD, DI25 and RF treatment plots exposed to severe water stress during the rest of the growing season.

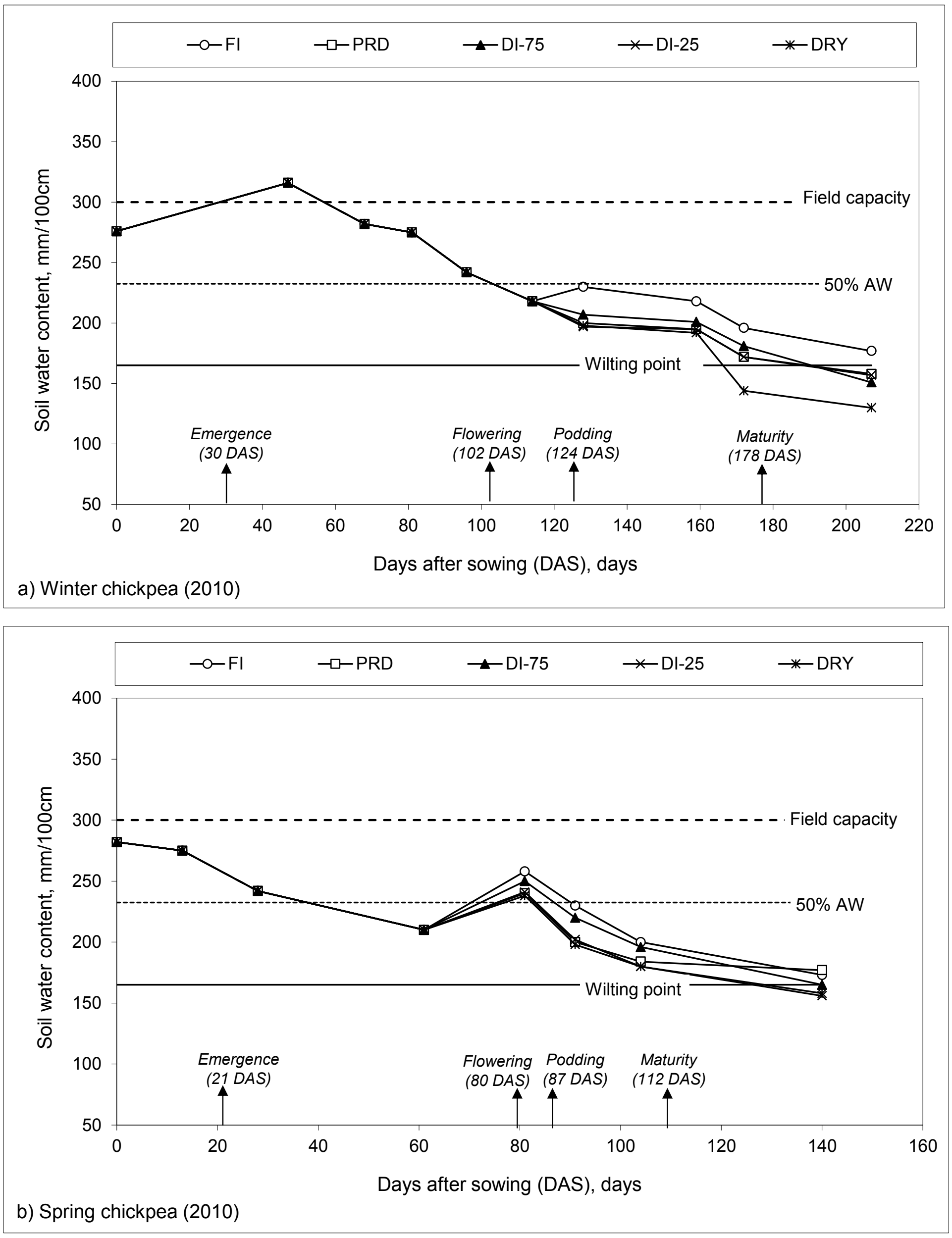

Figure 1. Soil water storage variation during growing season of winter chickpea in all treatments (a) and soil water storage variation during growing season of spring chickpea in all treatments (b) in 2010

During the 2011 growing season, SWC remained above field capacity (FC) until 101 DAP when first treatment irrigation was applied in winter-sown chickpea and SWC remained above 50% AW level almost during the rest of the season for FI and DI75 treatments. For the PRD and DI25 treatment plots SWC remained between the FC and WP during the rest of the season (Figure 2a). For spring-sown treatments SWC in FI, DI75 and PRD treatment plots remained above 50% AW level throughout the growing season. In D25 and RF treatment plots, SWC remained just below 50% AW level (Figure 2b). Thus, all treatments plots including RF, plants did not suffer from soil water deficit.

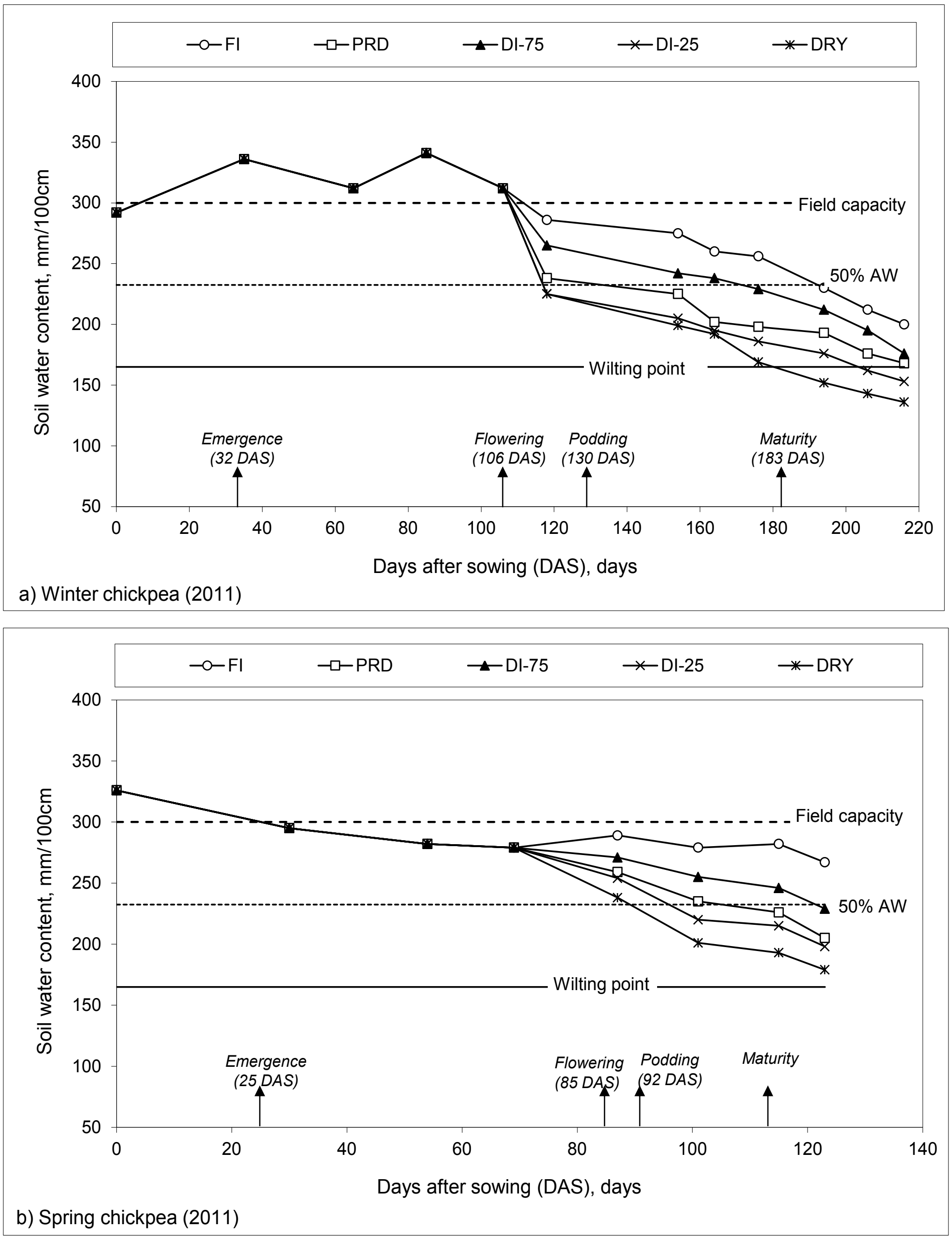

Figure 2. Soil water storage variation during growing season of winter chickpea in all treatments (a) and soil water storage variation during growing season of spring chickpea in all treatments (b) in 2011

Grain yield

During of 2010 and 2011 growing seasons, both irrigation treatments ($P < 0.037$; $P < 0.041$) and sowing dates ($P < 0.005$; $P < 0.008$) had significantly different effect on grain yields. Interaction of irrigation and sowing dates was also significant effect ($P < 0.049$; $P < 0.036$). Winter planting resulted in significantly higher yields than spring planted chickpeas in the first year. FI (4399 kg ha^{-1})

and DI-75 (4379 kg ha^{-1}) treatments resulted in higher yields as compared to PRD-50 (3636 kg ha^{-1}), DI-25 (3337 kg ha^{-1}) and DRY (3115 kg ha^{-1}) treatments in winter planting. Average grain yield values for spring-sown chickpea ranged from 2460 kg ha^{-1} in DRY treatment to 2849 kg ha^{-1} in the FI treatment in the first year (Table 3). Full irrigation in winter-sown chickpea produced 29% more yield than DRY treatment; the corresponding increase for the spring-sown chickpea was only 14% in the first year. In spring planting, yields increased with increasing irrigation water, however the effect was less pronounced. In general, as the amount of irrigation water increased, grain yield also increased both for spring- and winter-sown chickpea.

Grain yields in all treatments were lower in 2011 growing season due to widespread occurrence of a fungal disease called *Ascochyta blight*. Occurrence of *Ascochyta blight* was more severe in winter planted chickpea plots than in the spring planted ones. Average grain yields in 2011 ranged from a low of 444 kg ha^{-1} in DRY treatment and to maximum of 1271 kg ha^{-1} in DI-25 treatment in winter-sown chickpea while it ranged between 1046 kg ha^{-1} in DI-25 and 2623 kg ha^{-1} in DRY in the spring-planted chickpea (Table 4).

The research results revealed that the highest yields for local cultivar and winter sowing date (November-December) were achieved when drought stress was completely eliminated by irrigating throughout the growing season. Seed yield was almost 50% greater in November-sown chickpea as compared to spring planted chickpeas. Thus, winter-sown chickpea under full irrigation produced 54% more grain yield than the spring-sown chickpea in 2010. One possible reason for higher yield with winter sowing is the longer growing season and better utilization of soil water. In the rain-fed farming systems of the Mediterranean region, winter-sown chickpea utilizes rainwater falling during the wet season (autumn and winter) and transpires more than spring-sown chickpea. This study confirms previous results showing that winter sowing improves the productivity of chickpea, as compared with spring sowing. With spring sowing time (March), the plants were more developed and the yield components (number of pods per plant, number of seeds per pod and seed weight) were improved, with an increase of grain yield up to 45%. These results show that the best season, in terms of grain yield, was the 2010, because it had the highest rainfall and because that rainfall was favourably distributed throughout the growing season. The highest yields for both grain and biomass were obtained in this season. By contrast, the 2011 season was the worst in terms of *Ascochyta blight*, which resulted in the lowest yields being obtained due to heavy rainfall received during this growing season. In winter-sown chickpea, growth coincided with more favorable climatic conditions and increased biomass and grain yields as compared with spring-sown crop. For instance, for winter sowing, the flowering stage did not coincide with rising temperatures that often decreases chickpea grain yield. The yield results from the current study are in line with the results from ICARDA (Keatinge and Cooper, 1983; Saxena et al., 1990) and results from Iran (Khourgami and Rafiee, 2009).

Yield components

Both irrigation treatments and sowing dates had significant effect on plant height, first pod height (FPH), grain number per plant (GNP), filled pod per plant (FPP) and number of pods per plant in 2010. FI, DI-75 and PRD-50 treatments resulted in greater plant heights (>100 cm) than DRY and DI-25 treatments. Plant height values in winter-sown chickpeas were significantly greater than those in spring-sown. Irrigation treatments resulted in similar plant height values in the spring-sown chickpea. Winter-sown chickpeas had greater first pod heights as compared with spring-sown chickpea. Irrigation treatments resulted in higher FPH values in comparison to DRY treatment (Table 5 and Table 6).

Winter sowing produced more main branch than spring sowing, and irrigation treatments had significantly different effect on main branch number. PRD-50 produced the greatest main brunch number in the winter-sown chickpea. Filled pod per plant was also greater for winter-sown chickpea than spring-sown. Irrigation treatments had significant effect on filled pod number. FI and DI-75 treatments resulted in greater number of filled pods in winter-sown chickpea; all irrigated treatments produced significantly greater number of filled pods per plant than DRY treatment in spring-sown chickpea. The greater grain yield in the first year was associated with a higher number of pods per plant, but not a higher number of seeds per pod or a difference in seed size (100-seed weight) compared with the second year. Winter-sown chickpea resulted in significantly greater 100-seed weight than spring-sown chickpea in the first year. PRD-50 and DI-75 treatments resulted in greater 100-seed weights than the other treatments in winter-sown chickpea. In general, winter sown-chickpea was superior to spring-sown chickpea in many yield components mentioned.

Table 5. Yield components in winter-sown chickpea under different treatments in 2010

Planting time	Irrigation treatment	Plant height (cm)	1st pod height (cm)	Main branch number	Grain number/plant	Filled pod number	Number of pods plant	100 seed weight (g)
Winter Chickpea	FI	106a	39.3a	4b	128a*	80.4a	140.7a	32.0b
	PRD-50	84b	35.5ab	5a	96b	65.1c	106.2c	34.5a
	DI-75	107a	39.0a	4b	121a	79.3a	137a	34.5a
	DI-25	102ab	38.3a	4b	102b	67.0b	112.8bc	33.2ab
	DRY	68d	31.5b	4b	100b	49.5d	120.8b	32.3b
Spring Chickpea	FI	71cd*	33.8ab	2d	71a	50.4c	78a	32.1b
	PRD-50	73cd	34.5ab	2d	73a	55.1c	77.4a	31.4b
	DI-75	71cd	33.0b	3c	72a	71.3a	71.3ab	32.5b
	DI-25	73cd	33.3b	3c	71a	64.0b	71.9ab	31.8b
	DRY	68d	29.5b	3c	58b	40.5d	59b	31.7b
LSD		8.36	5.24	0.83	14.85	9.64	14.08	2.16

**Any two values within a column are significantly different at the 5% level if they have no letters in common.*

In 2011 growing season, both sowing dates and irrigation treatments had significant effect on yield components such as plant height, first pod height, main brunch number, pod per plant, however the effect was not significant on 100 seed weight (Table 6). Winter-sown chickpeas had greater plant height than spring-sown chickpea, and as the irrigation amount applied increased plant height increased. Number of pods per plant was significantly greater for spring-sown chickpea than the winter-sown chickpea.

In contrary to 2010 growing season, spring-sown chickpea resulted in significantly greater 100 seed weight than winter-sown chickpea in 2011. Deficit irrigation treatments had greater 100 seed weight values than the full irrigation treatment. Due to occurrence of *Ascochyta blight* disease in 2011 growing season negatively affected almost all yield components. Singh et al. (2016) reported that the 100-seed weight increased significantly with irrigation. Behboudian et al. (2001) found that water stress reduced seed dry mass and seed number per plant significantly. Davies et al. (2000) showed water deficit markedly reduced pod numbers and reduced them to such a degree that seed size was increased.

Table 6. Yield components in winter-sown chickpea under different treatments in 2011

Planting time	Irrigation treatment	Plant height (cm)	1st pod height (cm)	Main branch number	Grain number/plant	Filled pod number	Number of pods plant	100 seed weight (g)
Winter Chickpea	FI	106a	39.3a	4b	128a*	80.4a	140.7a	32.0b
	PRD-50	84b	35.5ab	5a	96b	65.1c	106.2c	34.5a
	DI-75	107a	39.0a	4b	121a	79.3a	137a	34.5a
	DI-25	102ab	38.3a	4b	102b	67.0b	112.8bc	33.2ab
	DRY	68d	31.5b	4b	100b	49.5d	120.8b	32.3b
Spring Chickpea	FI	71cd*	33.8ab	2d	71a	50.4c	78a	32.1b
	PRD-50	73cd	34.5ab	2d	73a	55.1c	77.4a	31.4b
	DI-75	71cd	33.0b	3c	72a	71.3a	71.3ab	32.5b
	DI-25	73cd	33.3b	3c	71a	64.0b	71.9ab	31.8b
	DRY	68d	29.5b	3c	58b	40.5d	59b	31.7b
LSD		8.36	5.24	0.83	14.85	9.64	14.08	2.16

**Any two values within a column are significantly different at the 5% level if they have no letters in common.*

CONCLUSIONS

The first year research results demonstrated that the highest yields for local chickpea cultivar were achieved with winter sowing (November-December) when drought stress was completely eliminated by irrigating throughout the growing season. Seed yield was 54% greater for November-sown chickpea as compared to spring-planted chickpeas under full irrigation in the Mediterranean region. This study confirms that winter sowing improves the productivity of chickpea, as compared with spring sowing in years with rainfall favourably distributed during the growing season. However, in the second year with heavy rainfalls, higher relative humidity during vegetative and flowering growth stages caused severe *Ascochyta blight* disease in chickpea in both sowing times in irrigated treatments. Rain-fed (DRY) treatment resulted in greater yield under the heavy rainfall conditions in spring planting.

The results also revealed that winter planting performed better than spring planting with regard to yield and yield components such as seed weight, first pod height, grain number per plant, number of pods per plant. In years with rainfall lower than the long-term average, deficit irrigations (DI-75) and PRD can be practiced to obtain higher yields with winter sowing.

Winter planting resulted in more biomass yield as compared to spring planting due to longer growing season and cooler temperatures during winter planting season promoted vigorous vegetative growth in year with sufficient rainfall and distributed favourably during the growing season. In general, rain-fed (DRY) treatment had the greatest WUE values for both sowing dates, on the other hand FI treatment had the lowest WUE values for both planting times. WUE in general increased with decreasing crop water use in both planting times. Higher WUE of the winter-sown over the spring-sown crop is due to the seed yield advantage. The research findings also suggest that in the semiarid environment of the Mediterranean region deficit irrigation can save water and increase chickpea WUE.

ACKNOWLEDGEMENTS

The authors would like to thank the financial support of the EU project ref. KBBE-2008-212337 (SWUP-MED) Sustainable Water Use Securing Food Production in Dry Areas of the Mediterranean Region, which allowed carrying out these experiments.

REFERENCES

Amiri, S.R., Deihimfard, R., Soltani, A., 2016. *A single supplementary irrigation can boost chickpea grain yield and water use efficiency in arid and semiarid conditions: A modeling study.* Journal of Agronomy, 108(6): 2406-2416.

Anwar, M.R., Mckenzie, B.A., Hill, G.D., 2003. *The effect of irrigation and sowing date on crop yield and yield components of kabuli chickpea* (*Cicer arietinum L.) in a cool-temperate subhumid climate*. The Journal of Agricultural Science, 141: 259-271.

Behboudian, M.H., Ma, Q., Turner, N.C., Palta, J.A., 2001. *Reactions of chickpea to water stress: yield and seed composition*. Journal of the Science of Food and Agriculture, 81(13): 1288-1291.

Davies, S.L., Turner, N.C., Palta, J.A., Siddique, K.H.M., Plummer, J.A., 2000. *Remobilisation of carbon and nitrogen supports seed filling in chickpea subjected to water deficit.* Australian Journal of Agricultural Research, 51(7): 855-866.

Fang, X., Turner, N.C., Yan, G., Li, F., Siddique, K.H.M., 2010. *Flower and pod production, pollen viability, and pistil function are reduced and flower and pod abortion increased in chickpea* (*Cicer arietinum L.) under terminal drought*. Journal of Experimental Botany, 61: 335-345.

FAOSTAT, 2016. *Food and agriculture data*. http://faostat.fao.org, accessed 18 September, 2018.

Fereres, E. and Soriano, A., 2007. *Deficit irrigation for reducing agricultural water use*. Journal of Experimental Botany, 58(2): 147-159.

Keatinge, J.D.H. and Cooper, P.J.M., 1983. *Kabuli chickpea as a winter-sown crop in Northern Syria: Moisture relations and crop poductivity*. The Journal of Agricultural Science (Cambridge core), 100: 667-680.

Khourgami, A. and Rafiee, M., 2009. *Drought stress, supplemental irrigation and plant densities in chickpea cultivars*. African Crop Sci. Conf. Proceed., 9: 141-143.

Leport, L., Turner, N.C., French, R.J., Barr, M.D., Duda, R., Davies, S.L., Tennant, D., Siddique, K.H.M., 1999. *Physiological responses of chickpea genotypes to terminal drought in a Mediterranean-type environment*. European Journal of Agronomy, 11: 279-291.

Oweis, T., Hachum, A., Pala, M., 2004. *Water use efficiency of winter-sown chickpea under supplemental irrigation in a mediterranean environment.* Agricultural Water Management, 66: 163-179.

Saxena, M.C., Silim, S.N., Singh, K.B., 1990. *Effect of supplementary irrigation during reproductive growth on winter and spring chickpea in a mediterranean environment.* The Journal of Agricultural Science (Cambridge core), 114: 285-293.

Silva, L.L., Duarte, I., Lourenço, E., Simões, N., Chaves, M.M., 2014. *Yield and water productivity of five chickpea varieties under supplemental irrigation in contrasting years*. Irrigation Science, 32: 393-403.

Singh, P. and Virmani, S.M., 1996. *Modeling growth and yield of chickpea* (*Cicer arietinum L.)*. Field Crops Research, 46: 41-59.

Singh, K.B. and Ocampo, B., 1997. *Exploitation of wild cicer species for yield improvement in chickpea*. Theoretical and Applied Genetics, 95: 418-423.

Singh, G., Ram, H., Aggarwal, N., Turner, N.C., 2016. *Irrigation of chickpea* (*Cicer arietinum L.) increases yield but not water productivity.* Experimental Agriculture, 52(1): 1-13.

Soltani, A., Khooie, F.R., Ghassemi-Golezani, K., Moghaddam, M., 2001. *A simulation study of chickpea crop response to limited irrigation in a semiarid an environment.* Agricultural Water Management, 49: 225-237.

Zhang, H., Pala, M., Oweis, T., Harris, H., 2000. *Water use and water use efficiency of chickpea and lentil in a Mediterranean environment.* Australian Journal of Agricultural Research, 51: 259-304.