Effect of Supplementary Irrigation on Yield of Chickpea Genotypes in a Mediterranean Climate

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ABSTRACT

Chickpea (*Cicer arietinum* L.) grown across a wide range of environments, is considered one of the most drought tolerant food legume, 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. Objective of this study was to evaluate the influence of supplementary irrigation on ten genotypes of chickpea crop, in order to select the most suitable ones for a sustainable agriculture in the context of scarcity of water resources. A split-plot experiment was carried out at Policoro, Southern Italy, on a sub-alkaline, silt-clay alluvial soil. The supplementary irrigation was compared with non-irrigated cultivation. The climatic conditions during the crop growing season were characterized by average temperatures higher than the normal ones during the winter months, and a remarkable drought, except in January. Three genotypes (Pa 34 and cultivars Sultano and Pascià) showed a higher yielding potential in these environmental conditions reaching values from 436 to 492 g m^{-2}. Supplementary irrigation increased the yield of three genotypes only (Pa 3, Pa 21 and cv. Crema) and this result can be explained with the excessive drought during the two months after the last supplementary irrigation (shrivelled seeds).

Keywords: Chickpea, supplementary irrigation, genotype, grain yield, Mediterranean climate.

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is cultivated on a large scale across a wide range of environments, from the subtropics (India and North-eastern Australia) to arid and semiarid environments of Mediterranean climatic regions (Mediterranean basin and Southern Australia), and has considerable importance as food, feed and fodder (Siddique *et al*., 1999; Singh, 1997). In these environments it is sown in autumn or spring and is exposed to drought during pod set and seed filling (terminal drought) that limit yields (Buddenhagen, I.W. and Richards, R.A., 1988; Ludlow and Muchow, 1990; Loomis and Connor, 1992). The chickpea is considered one of the most drought tolerant food legume, but the basis of its tolerance is unknown (Singh, 1993). Methodologies for a better understanding of yield improvement under drought conditions have been reviewed by Turner (1997), and some of the key characteristics for improved yield and yield maintenance under drought conditions can be high production of dry matter and early vigour.

In Italy, chickpea is one of the most important grain legume crops, both biological value of seeds (high protein content) and its role in cropping system as nitrogen fixing (Saccardo *et al.*, 2001). Actually farmers are becoming increasingly aware of the value of grain legumes to sustainable agricultural systems (Saccardo *et al.*, 2001), and chickpea can play an important role in the traditionally semiarid areas of Mediterranean basin, where water resources keep decreasing. Anyway, it is necessary to have both improved varieties that are suitable for these environments, and agronomic techniques that enable these varieties to emphasize their yielding potential (Leport, *et al.*, 1999; Lombardo and Leonardi 1993).

In the environments of Southern Italy, characterized by high temperatures and low rainfall during spring and early summer period, it is preferable anticipate the sowing in November-December. With this sowing time, respect to that made in spring (march), the plants are more developed and the yield components (number of pods per plant, number of seeds per pod and seed weight) are improved, with an increase of grain yield up to 45% (Abbate *et al.*, 1994; Calcagno *et al.*, 1987; Poma *et al.*, 1990; De Falco *et al.*, 1992). Even though the chickpea is considered a drought tolerant crop (in Italy the cultivation is predominantly rainfed), its seed yield can increase also with a supplementary irrigation, applied between flowering and beginning seed growth, mainly in environments and years with very low amounts of rainfall during the reproductive stage (Soltani *et al.*, 2001; Abbate *et al.*, 1994; Milia, 1993; Lombardo *et al.*, 1993; Gristina *et al.*, 1993).

Objective of this study was to evaluate the influence of supplementary irrigation on ten genotypes and cultivars of chickpea crop, in order to select the most suitable ones for a sustainable agriculture in the contest of scarcity of water resources.

2. MATERIALS AND METHODS

The research was carried out in 2000-01 at the experimental farm “E. Pantanelli” of Faculty of Agriculture, Bari University, located in Policoro (40° 13’ N, 16° 45’ E; elevation 15 m.s.l.) in Southern Italy. The soil of research location is sub-alkaline, silt-clay, alluvial, deep, well supplied with organic matter, nitrogen, potassium and phosphorus as shown in Table 1.

Table 1. Soil properties of research location.

Organic matter (%) (Walkley Black meth.)	4.34	Sand (%)	39.66
pH	7.82	Clay (%)	22.91
Electrical conductivity (mmhos cm^{-1})	1.97	Silt (%)	37.43
Field capacity (DW %)	31.50	Total N (°/$_{00}$)	1.67
Wilting point (-1.5 Mpa) (DW %)	16.00	Available P (ppm, Olsen meth.)	22.67
Soil specific weight	1.30	Exch. K (ppm, ammonium acetate meth.)	227.03

Climatic data related to the research location and growing period are shown in Figure 1 and 2. Ten chickpea genotypes (three lines under selection named Pa 3, Pa 21 and Pa 34, provided from Institute of Agronomy, University of Palermo, Italy, and seven cultivars: Athenas, Bianca, Cairo, Crema, Nero, Pascià and Sultano) were grown under rainfed and supplementary irrigation conditions.

The experimental design was the split-plot with four replications, with rainfed and supplementary irrigation in the main plots, and the genotypes in the plots. The supplementary irrigation (as sprinkler irrigation with an efficiency of 90%) was applied two times: at flowering (110 DAS, Days After Sowing) and beginning of seed formation (140 DAS), giving 25 mm of water each time. Sowing was made on 21 December in plots 3 m wide (ten rows, 30 cm apart) and 7 m long at a seeding rate that gave established plant populations of 32-36 plants m^{-2} .

The plots received 80 kg ha^{-1} of P_2O_5 with the seed at sowing; weeds were controlled chemically. In Figure 1 are reported the climatic conditions observed at Policoro in 2000-2001 and as 40 years average. Minimum and maximum air temperatures, rainfall, and evapotranspiration were recorded on a daily basis using an automatic weather station at the site (Figure 2). The eavapotranspiration (Eto) was calculated from a class A pan evaporimeter. The soil water, content before irrigation was around 24-25%, and was calculated by evapotranspirometric method (Doorenbos and Pruitt, 1977) utilizing the crop coefficients determined for Policoro field. The amount of supplementary irrigation was determined considering a soil depth of 30 cm explored by most root system and to reach the field capacity.
Plant samples from both irrigation treatments (rainfed and supplementary irrigation) were harvested at ground level on 75, 97, 120, 154 and 190 (maturity) DAS, 10 plants for each replication were collected for the first four harvests, and 20 plants at maturity, randomly chosen in the middle-rows of each plot. All sampled plants were dried to constant weight and weighted. Leaf area was determined for the first four harvests using a Li-Cor-3100 area meter on a soil surface of 1500 cm^2.

The following other measurements were also made: time to flowering and beginning of pods formation (days); number of pods per plant, number of seeds per plant and 100 seed weight (g). From these measurements the seed yield and the number of pods and seeds per unit area were calculated according to the measured plant density for the corresponding plot. Harvest index (HI) was calculated at maturity as the ratio of seed dry weight to total crop dry weight.

Data were analysed using analysis of variance; where significant differences occurred, genotypes means were separated by Duncan test.

3. RESULTS AND DISCUSSION

In 2000-01 at Policoro the climatic conditions, compared to those of 40 years average values (Figure 1A), were characterized by temperatures higher than the normal ones during the winter months, and a remarkable drought, except January, during the crop growing season. If we consider that on January 13 fell 148 mm of rainfall (very exceptional event), and that of this rainfall amount only 1/3 was effective (we measured the soil humidity two days after for a depth of 20 cm), the drought was really remarkable (Figure 2B).

Daily maximum air temperatures were around 15.5 °C from sowing to 100 DAS, around 19.5 °C for the next 50 days and around 26.5 °C from hereafter until maturity (Figure 2A), while relative humidity and wind speed, in the same periods, were 74.3, 73.1 and 67.7%, and 95.6, 125.1 and 139.2 m sec^{-1} respectively. Daily minimum air temperatures below 0° C were observed only in one day (65 DAS), while values close to 0°C (0-2 °C) were observed on seven occasions near the onset of flowering (Figure 1A).

The evapotranspiration was around 2.17 mm day^{-1} from sowing to 90 DAS, around 4.38 mm day^{-1} for the next 60 days (pod set), and increased constantly to a maximum of 11-13 mm day^{-1} at maturity (Figure 2C), increasing rapidly the evaporative demand.

Flowering commenced on 90 DAS for early types Pa 3, Pa 21 and Pa 34 selections and for Crema and Athenas cultivars and 95 to 100 DAS for the medium-late types (Nero, Sultano,

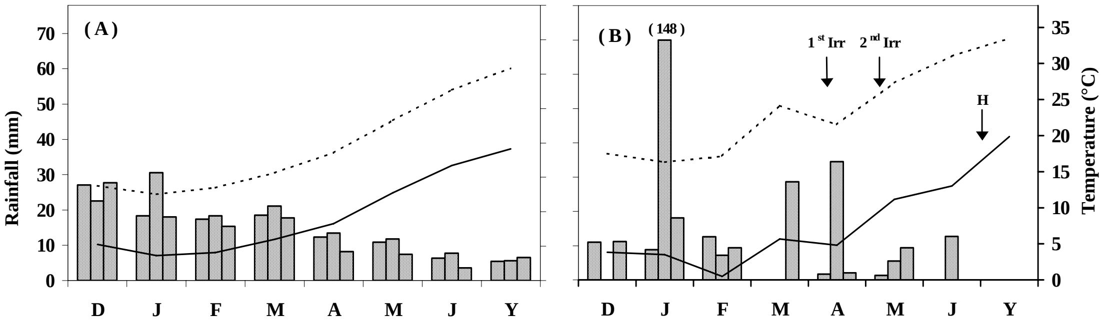

Figure 1. Ten days rainfall ( ), minimum (—) and maximum (---) air temperatures during the growing season at Policoro, Southern Italy, as 40 years average (A) and 2000-2001 experiment (B).

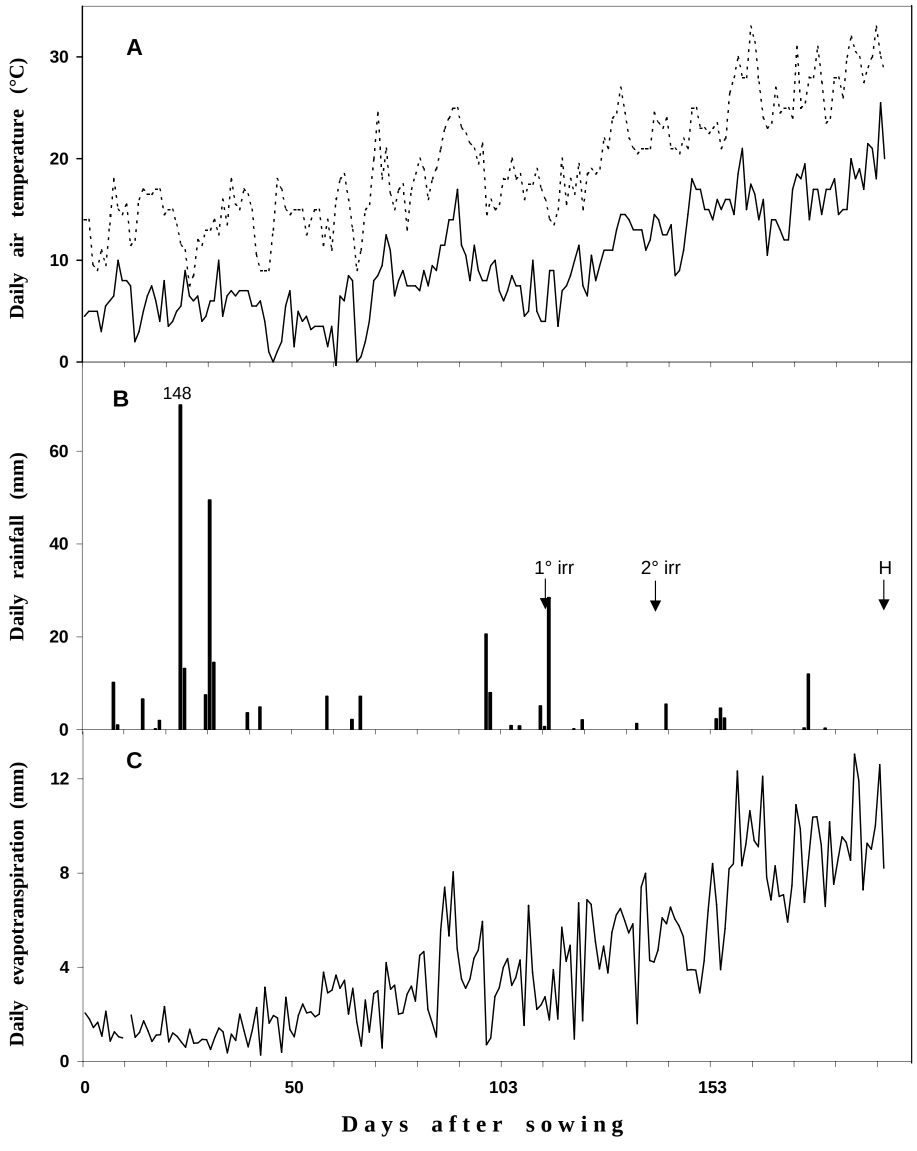

Figure 2. (A) Daily minimum (––) and maximum (- - -) air temperature, (B) rainfall, and (C) evapotranspiration during the growing season recorded at Policoro, Southern Italy, in 2000-01. The arrows denote the dates of first and second irrigation, and that of the harvest (H).

Pascià, Bianca and Cairo cultivars). The first pods were observed four weeks later, on 120 DAS in the early types and 125 DAS in the medium-late ones.

The supplementary irrigation, as average, not influenced significantly respect to rainfed agriculture all the studied characters, while shoved significant interactions with genotypes for some of them.

The supplementary irrigation influenced positively only three genotypes (Pa 3, Pa 21 and Cairo) that showed an increase in dry matter (DM) (from 17 to 24%), seed yield (from 13 to 24 %), pod number (from 15 to 32%) and seed number (from 14 to 27%); in the other genotypes was observed, for the same characters, either a negative (reductions from 10 to 21%) or no influence of supplementary irrigation. All the other studied characters were influenced slightly by supplementary irrigation (reductions up to 7%) (Table 2). These results confirm those obtained in Sicily (Gristina *et al.*, 1993; Lombardo *et al.*, 1993). The total DM in the irrigated plants at maturity was significantly higher in Pascià (1227 g m^{-2}), followed by Pa 21,

Table 2. Dry matter, seed yield, harvest index (HI) , pod (PN), seed numbers (SN) and seed weights (SW) at maturity of ten genotypes of chickpea grown under irrigated and rainfed conditions at Policoro, Southern Italy, in 2000-2001.

Genotypes	Dry matter (g m^{-2})	Seed yield (g m^{-2})	H I	P N (m^{-2})	S N (m^{-2})	S N (pod $^{-1}$)	S W (mg)
				Irrigated			
Pa 3	980 B	412 a	0.42 bc	1462 B	1488 ab	1.07 a	283 bcd
Pa 34	818 CD	406 a	0.50 a	1300 B	1561 a	1.15 a	260 cd
Sultano	959 BC	404 a	0.42 bc	1738 A	1502 a	0.88 cd	275 cd
Pascià	1227 A	434 a	0.35 cd	1262 BC	1059 c	0.84 d	405 a
Pa 21	1028 B	438 a	0.42 bc	1666 A	1570 a	0.96 bc	283 bcd
Bianca	648 E	290 bc	0.43 bc	1206 BC	942 c	0.81 d	319 b
Nero	741 DE	335 b	0.45 ab	1234 BC	1364 b	1.06 ab	241 d
Cairo	892 CD	338 b	0.38 bc	1074 CD	1028 c	0.90 cd	323 b
Athenas	795 D	300 bc	0.37 c	1087 CD	969 c	0.84 d	303 bc
Crema	816 CD	234 c	0.29 d	938 D	616 d	0.66 e	388 a
Mean	890	359	0.40	1296	1209	0.91	308
				Rainfed			
Pa 3	791 DE	364 cd	0.46 b	1266 C	1302 cd	1.02 ab	280 cd
Pa 34	901 BC	492 a	0.54 a	1700 A	1790 a	1.05 a	280 cd
Sultano	985 B	436 b	0.44 bc	1656 A	1498 bc	0.90 c	282 cd
Pascià	1176 A	443 ab	0.38 cd	1264 C	1100 ef	0.86 cd	408 a
Pa 21	876 CD	353 d	0.40 bcd	1436 B	1240 de	0.87 cd	286 cd
Bianca	760 EF	304 d	0.40 bcd	1193 C	946 f	0.82 de	322 bc
Nero	939 BC	421 bc	0.45 b	1481 B	1588 b	1.07 a	260 d
Cairo	894 CD	387 c	0.43 bc	1156 C	1109 ef	0.94 bc	351 b
Athenas	968 BC	340 d	0.35 de	1173 C	1130 e	0.94 bc	300 c
Crema	664 F	190 e	0.29 e	710 D	494 g	0.70 e	400 a
Mean	895	373	0.414	1303	1219	0.92	316

A separate ANOVA was performed for each parameter and for irrigated and rainfed plants. Values with the same letter within a column are not significantly different (P > .05 small letters; P > .01 capital letters).

Pa 3 and Sultano (around 1000 g m^{-2}), while in the other genotypes was around 780 g m^{-2}. Also in rainfed conditions the DM of Pascià was significantly higher (1176 g m^{-2}), followed by Sultano, Nero and Pa 3 (around 940 g m^{-2}); in the cv. Crema was observed the lower value (664 g m^{-2}) (Table 2).

Under rainfed conditions the highest seed yield was observed in Pa 34 selection (492 g m^{-2}) followed by Sultano, Pascià and Nero (around 430 g m^{-2}), that gave also the higher DM values, while Crema had the lowest values of seed yield (190 g m^{-2}), DM and harvest index (HI = 0.29). In the irrigated conditions only Pa 3, Pa 21 and Crema showed an increase of 13-24 % of seed yield, while in the other genotypes there was a decrease that reached a maximum of 26% in Nero (Table 2). These results can be explained with the excessive drought during the two months after the last supplementary irrigation (shrivelled seeds) (Abbate *et al.,* 1994).

The lower HI was observed, both rainfed and irrigated conditions, in Crema (HI = 0.29) followed by Cairo, Athenas and Pascià (HI around 0.37); the higher values (0.50 – 0.54 respectively) were observed in the line under selection Pa 34 (Table 2).

The pod and seed number per unit area (Table 2) have the same trend of DM and seed yield. The genotypes Pa 3, Pa 34 and Nero had a number of seeds per pod greater than 1, both in rainfed and irrigated conditions, while in Crema was observed the lowest one (0.66 – 0.70 respectively); in the other genotypes varied from 0.81 to 0.94 (Table 2). The largest seeds occurred in Pascià and Crema (around 400 mg) followed by Bianca and Cairo (around 320 mg), in the other genotypes varied from 280 to 300 mg (Table 2).

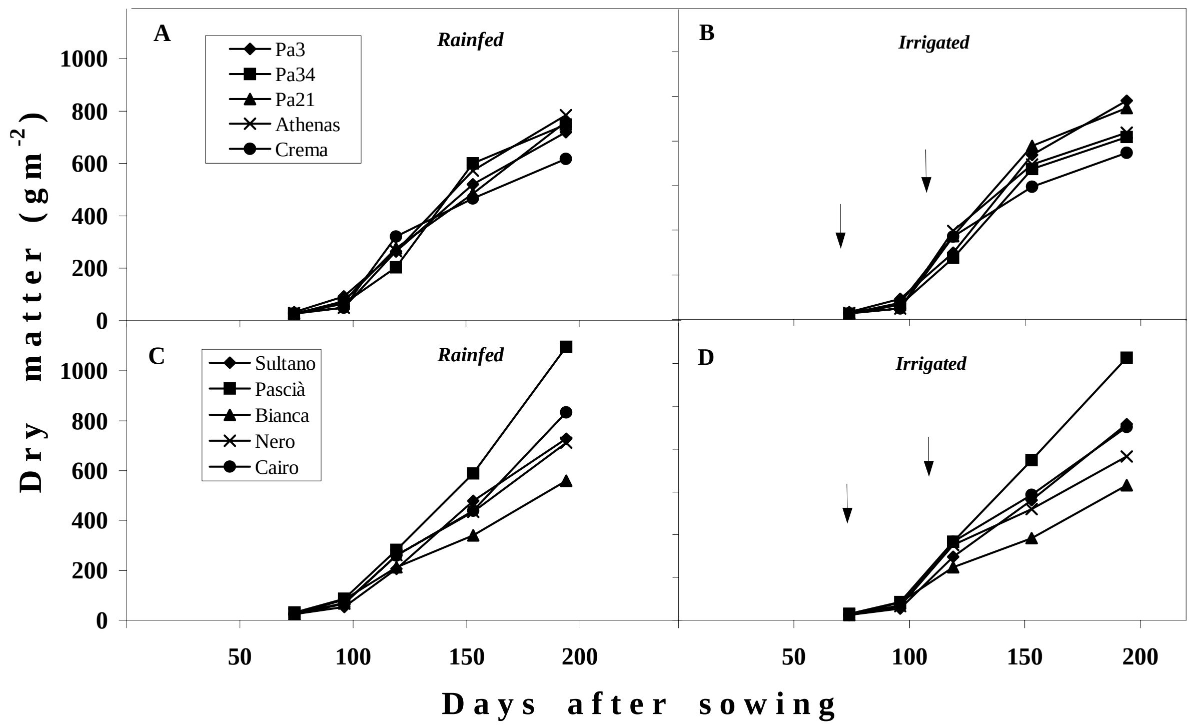

Figure 3. Change with time in dry matter in early (A) and in medium-late genotypes (B) of chickpea grown under rainfed and irrigated conditions. The arrows show the date of first and second supplementary irrigation.

All genotypes achieved their maximum dry weight at seed harvest. After supplementary irrigation, the increase of DM was less in early genotypes respect to the medium-late ones (Figure 3).

In the rainfed conditions the leaf area index (LAI) achieved the maximum value 120 DAS in all genotypes except Pascià (154 DAS), then the LAI decreased in early genotypes (40 % in Pa 21 and Crema, and 10-20% in Pa 34, Pa 3 and Athenas) while in the medium-late ones, except Pascià, the LAI remained practically constant (Figure 4). With supplementary irrigation the LAI achieved the maximum value 154 DAS, except Pa 21, Crema and Nero. (Figure 4).

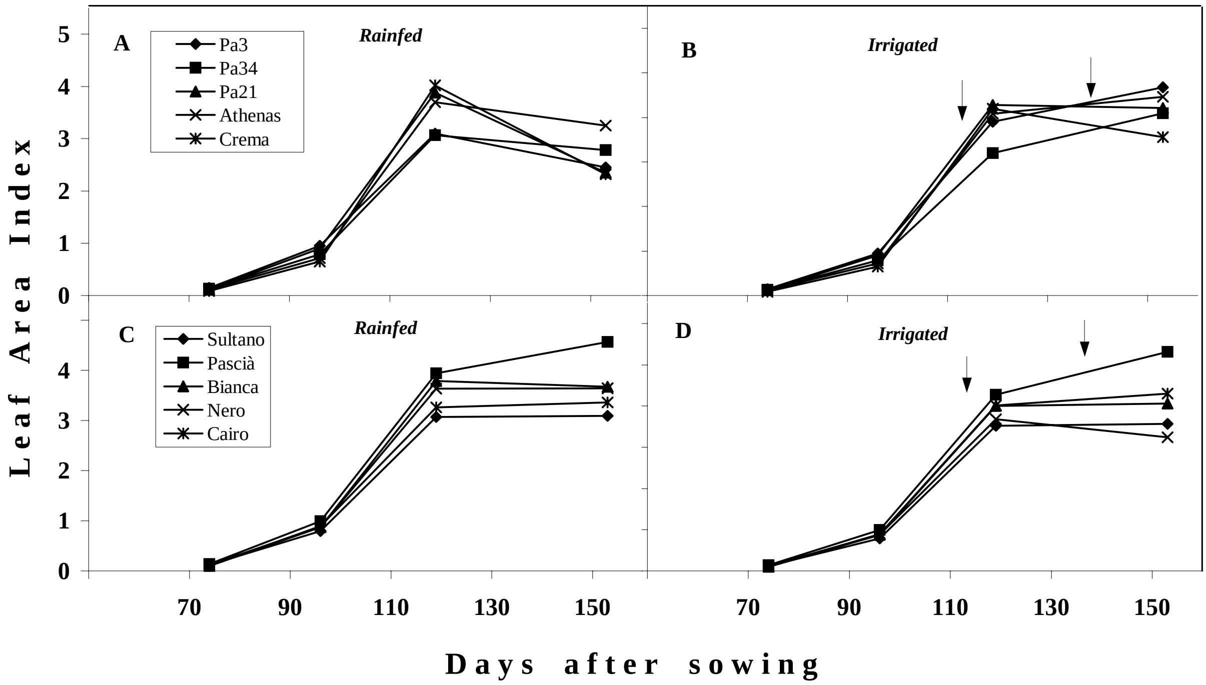

Figure 4. Change with time in LAI in early (A) and medium-late genotypes (B) of chickpea grown under rainfed and irrigated condition. The arrows show the dates of first and second supplementary irrigation.

Correlation coefficients among the studied characters are reported in Tab. 3. Significant positive correlations were observed with seed yield, for almost all characters except seed weight that is correlated negatively.

Table 3. Correlation coefficients and significance level found among the studied characters.

Character	SY	H I	P N	S N m	S N p	S W (1)
Dry matter (g m^{-2})(DM)	0.755**	- 0.029	0.449*	0.343	0.140	0.228
Seed yield (g m^{-2})(SY)		0.670**	0.827**	0.853**	0.654**	- 0.333
Harvest Index (H I)			0.679**	0.849**	0.817**	- 0.720**
Pod number m^{-2} (PN)				0.894**	0.533*	- 0.598**
Seed number m^{-2} (SN m)					0.845**	- 0.754**
Seed number pod^{-1} (SN p)						- 0.742**

(1) SW = Seed weight (mg); *, ** = Significance level p≤ 0.05 and p≤ 0.01 respectively

The positive correlation between seed yield and dry matter suggest to select genotypes or cultivars with high dry matter production, in agreement with Turner (1997), Leport *et al.* (1998) and Siddique *et al* (1999).

4. CONCLUSIONS

The supplementary irrigation applied at flowering and pod set influenced in different ways the genotypes under study. Only in three genotypes (early types that avoid drought by early pod development) was observed an increase in DM and seed yield while in the others there was a decrease or no influence of supplementary irrigation.

Positive correlations have been observed between seed yield and the studied characters except the seed weight that is correlated negatively. Under rainfed conditions the genotypes Pa 34, Pascià, and Sultano were the more productive, while with supplementary irrigation the higher seed yield were obtained from the above mentioned genotypes and Pa 3, and Pa 21.

These results show that in low rainfall Mediterranean-type environments and with water scarcity it is possible obtain good seed yields choosing the most suitable cultivars to be grown.

5. ACKNOWLEDGEMENTS

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