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EVALUATION OF KABULI CHICKPEA GENOTYPES (*CICER ARIETINUM* L.) COLLECTION UNDER TUNISIAN SEMI ARID CONDITIONS

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Abstract: The enrichment of the tolerant Tunisian chickpea genotypes list to abiotic stresses, particularly drought and heat, depends on the specie water and thermal requirements. Within this framework, 41 chickpea genotypes were conducted in rainfed conditions with supplementary irrigations in the experimental field of the Higher Agronomic Institute of Chott Mariem which belongs to the Tunisian semi arid area. Rainfall and supplementary irrigations amount to 245 mm. Results show that thermal conditions of this bioclimatic zone are favorable for chickpea cropping. Regarding water, the provided amount was found to be lower than the required one by the specie, estimated to 370 mm. Chickpea culture underwent a drought stress during filling pods and seed maturity phases. Among the 41 genotypes, 13 drought stress tolerant accessions were screened. They can be lead in, winter or spring, rainfed culture conditions under Tunisian semi arid zones. However, the other genotypes were sensitive to this abiotic stress. Their cropping area would be the humid and/or sub humid bioclimatic zones. Nevertheless, they can be conducted in winter culture in the Tunisian semi - arid zones.

Key words: Chickpea; Drought; Selection; Stress; Thermal; Tolerance.

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INTRODUCTION

In Tunisia, seed pulses remain marginal cultures compared to cereals. They occupy only 6% of the cereal surfaces. Chickpea (*Cicer arietinum* L.) culture occupies 25.2% of the leguminous plants surfaces with 13 520 tons annual seed production and 700 kg/ha average yield. The national production in this foodstuff covers only 41.6 % of the country internal requirements (DGPA, 2008). To make up the deficit, the Tunisian government makes recourse to imports (Aouani *et al.,* 2001). Spring chickpea culture, most recognized in Tunisia (Slama 1998), was conducted in rainfed culture (Wery, 1990). It was rustic specie, equipped with a powerful root system with mixed development, side and swiveling, which exceeds one meter of depth (Saxena, 1987). Nevertheless, it was exposed to two drought types which explain 30 % of the biotic and abiotic stresses (Singh *et al.,* 1994). The first one was intermittent, caused by the rupture of the precipitations, and the second was final and occurs during the flowering and seeds filling phases. Faris and Gowda, (1990) announced that dryness, expressed by drought stress often associated with thermal stress (Blum *et al.,*1989), represents the most significant physiological constraint which limits chickpea production and productivity. Summerfield *et al.,* (1984) indicated that chickpea was sensitive to high temperatures during the reproductive phase; in particular, filling and maturity seed phases. Exposition of chickpea culture to temperatures higher than 30°C during 3 to 4 days causes a progressive reduction of seed yield. According to Singh *et al.,* (1994), 50 % of plant flowers exposed to temperatures, upper than 30°C, are nearly sterile. However, Ellis *et al.,* (1994) noticed that temperatures higher than 38°C delay considerably the chickpea flowering phase. Slama (1998) indicated that cultivars, whose pods maturated during hot days, underwent reductions of their

seed yield. To surmount these abiotic chickpea constraints, the most effectiveness solution reside in the improvement of the dryness tolerance and the water use efficiency (Boubaker, 1997). According to Sarrafi *et al.* (1992), it was difficult to select directly for resistance to dryness because genetic control of this quantitative trait was very complex. The current approach consists in selecting for several parameters related to resistance to drought and thermal stress. In Tunisia, list of dryness tolerant, including water and thermal, chickpea genotypes, was limited. This work enters within the program framework of seeds leguminous plants improvement, in particular, the development of chickpea genotypes adapted to various Tunisian bioclimatic zones.

EXPERIMENTAL

Vegetable material

The vegetable material was composed of 41 kabuli chickpea genotypes (Table 1), pleasantly provided by the International Center Agronomic Research in the Arid Regions (ICARDA) in the framework of " Legume International Testing Program (LITP)" Aleppo, Syria.

Table 1. Chickpea (*Cicer arietinum* L.) genotypes List

N°.	Genotypes names	Pedigree	Origin
1	FLIP92 - 113C	X89TH 141/ILC1934 X FLIP 85 - 122C	ICARDA/ICRISAT
2	FLIP01 - 24C	X98TH 26/FLIP90 - 2CXS95017	ICARDA/ICRISAT
3	FLIP02 - 04C	X99TH 6/FLIP91 - 14CX FLIP90 - 19C	ICARDA/ICRISAT
4	FLIP02 - 47C	X98TH 118/ (FLIP87 - 83CXILC4339XS95159) XS96114	ICARDA/ICRISAT
5	FLIP03 - 22C	X99TH 62/FLIP93 - 2C X FLIP94 - 115C	ICARDA/ICRISAT
6	FLIP03 - 27C	X98TH 86/[(ILC267XFLIP89 - 4C)XHB - 1]XS95345	ICARDA/ICRISAT
7	FLIP03 - 31C	X98TH 18/S96114XFLIP92 - 148C	ICARDA/ICRISAT
8	FLIP03 - 35C	X98TH 18/S96114XFLIP92 - 148C	ICARDA/ICRISAT
9	FLIP03 - 50C	X99TH 62/FLIP93 - 2C X FLIP94 - 115C	ICARDA/ICRISAT
10	FLIP03 - 99C	X00TH 49/FLIP98 - 52CXFLIP98 - 10C	ICARDA/ICRISAT
11	FLIP03 - 121C	X00TH 51/FLIP98 - 52CXFLIP98 - 47	ICARDA/ICRISAT
12	FLIP03 - 123C	X00TH 51/FLIP98 - 52CXFLIP98 - 47	ICARDA/ICRISAT
13	FLIP03 - 145C	X97TH 54/(FLIP93 - 128CXFLIP92 - 24C)XICC890338 - 53	ICARDA/ICRISAT
14	FLIP03 - 147C	X98TH 3/S96114XS96094	ICARDA/ICRISAT
15	FLIP03 - 152C	X98TH 68/ (FLIP93 - 24CXILC6119) XS96114	ICARDA/ICRISAT
16	FLIP04 - 32C	X00TH 41/FLIP98 - 132CXS99075	ICARDA/ICRISAT
17	FLIP05 - 175C	X2000TH 31/FLIP98 - 29CXS99093	ICARDA/ICRISAT
18	FLIP05 - 183C	X2000TH 39/FLIP98 - 29CXS99001	ICARDA/ICRISAT
19	FLIP05 - 10C	X2000TH 39/FLIP98 - 29CXS99001	ICARDA/ICRISAT
20	FLIP05 - 17C	X2001TH 38/(FLIP98 - 52CXFLIP98 - 7C)XSEL 15042	ICARDA/ICRISAT
21	FLIP05 - 19C	X2001TH 171/UZ - 7332XSEL85314	ICARDA/ICRISAT
22	FLIP05 - 41C	X2000TH 35/FLIP98 - 29CXS99442	ICARDA/ICRISAT
23	FLIP05 - 57C	X2001TH 83/S 15063XFLIP97 - 22C	ICARDA/ICRISAT
24	FLIP05 - 66C	X2001TH 99/S 99515XFLIP97 - 22C	ICARDA/ICRISAT
25	FLIP05 - 82C	X2000TH 17/FLIP97 - 25CXS98588	ICARDA/ICRISAT
26	FLIP05 - 83C	X2000TH 18/FLIP98 - 64CXFLIP98 - 7C	ICARDA/ICRISAT
27	FLIP05 - 88C	X2000TH 31/FLIP98 - 29CXS99093	ICARDA/ICRISAT
28	FLIP05 - 92C	X2000TH 32/FLIP98 - 129CXS99093	ICARDA/ICRISAT
29	FLIP05 - 100C	X2000TH 39/FLIP98 - 29CXS99001	ICARDA/ICRISAT
30	FLIP05 - 102C	X2000TH 69/(FLIP91 - 61CXFLIP85 - 5C)XFLIOP98 - 29C	ICARDA/ICRISAT
31	FLIP05 - 107C	X2000TH 77/(FLIP84 - 145CXILC2398)XFLIP98 - 29C	ICARDA/ICRISAT
32	FLIP05 - 108C	X2000TH 77/(FLIP84 - 145CXILC2398)XFLIP98 - 29C	ICARDA/ICRISAT
33	FLIP05 - 115C	X2000TH 95/(FLIP84 - 182CXFLIP91 - 138C)XS99075	ICARDA/ICRISAT

34	FLIP05 - 122C	X2000TH 156/GLK 95075XFLIP98132C	ICARDA/ICRISAT
35	FLIP05 - 132C	X2000TH 160/GLK 95061XS98588	ICARDA/ICRISAT
36	FLIP05 - 162C	X2001TH 61/(Turkesh2Xselter85530) XFLIP98 - 47C	ICARDA/ICRISAT
37	FLIP05 - 169C	X2001TH 73/ (sozlaniiz - 304Xselter85581)XFLIP98 - 47C	ICARDA/ICRISAT
38	FLIP05 - 170C	X2001TH 73/ (sozlaniiz - 304Xselter85581)XFLIP98 - 47C	ICARDA/ICRISAT
39	FLIP87 - 59C	X85TH 274/ILC3843XFLIP82 - 130C (Resistant check)	ICARDA/ICRISAT
40	FLIP97 - 116C	X94TH 11/FLIP90 - 132CXS91345 (Sensitive check)	ICARDA/ICRISAT
41	ILC 3279	Chétoui (Sensitive check)	Tunisia

Experimental site

The trial was carried out on a parcel of the experimental field of the Higher Agronomic Institute of Chott Mariem which was located in the Tunisian Centre East area. This region belongs to the higher semi arid bioclimatic stage (altitude 6 m; Northern latitude 35°52' and Eastern longitude 10°38'). It was characterized by Mediterranean climate, cold and humid in winter and the spring beginning and heat and dryness at the spring end, summer and autumn (Figure 1). In winter, it was subjected to prevailing wind, cold and humid, whose direction was Northern West and sometimes Northern East. Average annual pluviometry, amount to 330 mm, was irregularly distributed. The average relative hygroscopy was 64 %. The experimental soil was sandy - clay - silt, rich in active limestone, poor in organic matter and without risk of salinity.

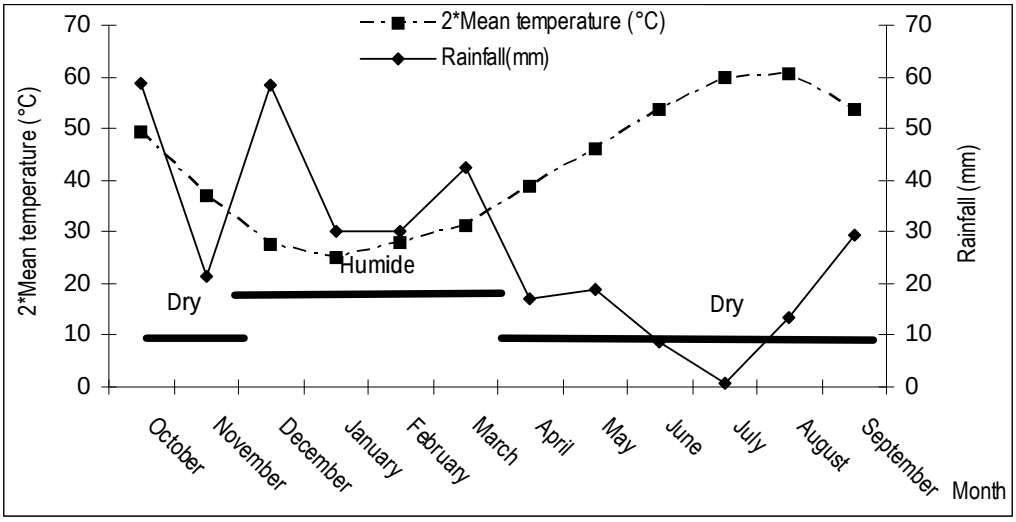

Figure 1. Ombrothermic dendrogram of the Chott Mariem area

Sowing and Harvest

Sowing handbook was carried out on February 26 2012 at 4 to 6 cm depth and 2.2 plants/m^2 density according to randomized block experimental design with three replications. Each elementary parcel was made of one line with 2 m length spacing of (0.1 x 0.45 m^2) between seeds and lines and 1.5 m between blocks. Manual weeding was carried out. Harvest took place at the end of July 2012. In the way of sampling, five plants were, randomly, taken by genotype and replication.

Supplying water irrigation

During the farming cycle, supplying water amounts to 245 mm including 170 mm of rainfall and 75 mm of complementary irrigations. Localized drop irrigation system "Nétaphime" type whose droppers, 0.40 m spaced, are integrated. Dropper nominal debit was 2 $l.h^{-1}$ whereas uniformity test showed that their average real debit amounts to 1.06 $l.h^{-1}$. Ramp carrier were provided with ramps distanced 0.33 m. Water irrigation, coming from Nebhana dam, was characterized by an electric conductivity, measured at 25 °C, evaluated at 1.09 ms/cm^2. It contains 0.70 g/l dry residue including

0.25 g/l sodium chlorides. Culture potential evapotranspiration (ETc) was given according to the formula reported by Ben Mechlia (1998):

$$ETc = ET0 \times Kc$$

Where ET0: reference evapotranspiration was calculated starting from the formula of Blanney - Criddel (Doorenbos and Pruitt, 1977); Kc: farming coefficient. Adopted chickpea farming coefficient (Kc) and physiological duration phases are those used by FAO (Allen *et al.,* 1998).

Studied parameters

- Stomata density (StD; stom. / mm^2): Average number of stomata by mm^2;
- Relative water content in leaves (RWC; in %) was determined by Barrs and Weatherley (1962) method according to the formula:

$$RWC = 100 \times \frac{FW - DW}{TW - DW}$$

Where *FW* Fresh weight, DW Dry weight *and TW:* Turgescent Weight

- Total Chlorophyll Content (TChlC: $mg.g^{-1}$ of Fresh matter: MF): Total quantity of Chlorophylls (a) and (b), determined according to the method indicated by Bounaqba, (1998)
- Emergence date (ED; Days after sowing (DAS)): Days number between sowing and emergence dates of 50 % of plants by elementary parcel;
- Flowering Date (FlD; DAS): Days number from sowing to flowering dates of 50 % plants by elementary parcel;
- Flowering Phase Duration (FlPhDr; Days): Days number between opening of the first and the latter flowers by elementary parcel;
- Maturity Date (MatD; DAS): Days number from sowing to maturity of 50 % pods by elementary parcel;
- Plant Height (PlH; cm): Average height of five representative plants per elementary parcel at the maturity stage;
- Crop Ground Cover Rate (CGCR; %): The percentage of covered soil by the chickpea plants vegetation. It was given using a grid;
- Air biomass (AB; t/ha): Average weight of five representative plants by genotypes and by block. It was given at the maturity stage using a laboratory precision balance (Sartorius) which weighs from 0.01 to 2 kg. It was converted into t/ha;
- Air Biomass Dry Matter Content (ABDMC; %): Air biomass of five representative plants per elementary parcel were weighed in a fresh state and after drying in a ventilated oven 80 °C temperature until obtaining a constant weight. It was expressed by the formula:

$$ABDM = 100 \times \frac{FW}{DW}$$

  Where FW: fresh weight and DW: dry weight.
- Primary Branches Number per seedling (PBrNb, Nb/Pl): Primary branches average number per plant of five representative plants;
- Pods Weight per plant (PW: t/ha): Harvested pods average weight of five representative plants by genotype and block. It was converted into t/ha;
- Pods Number (PNb, Nb/m^2): Average pods number of five representative plants. The obtained number was converted into pods number/m^2;
- Seeds Number (SNb, Nb/m^2): Pods of five representative plants by genotype and block are peeled. The obtained number was converted into seeds number /m^2;
- Seeds Number per pod (SNb/P; Nb): Average ratio of the seeds number by the pods number;
- 100 Seeds Weight (100SW; g): Average weight of 100 seeds of five representatives harvested plants by genotype and block;
- Seed yield (SY; t/ha): Average seeds weight of five representative plants by genotype and block. It was converted into t/ha;

- Harvest Index (HI; %): Average ratio of seed yield by air biomass;
- Dry Matter Water Use Efficiency (DMWUE; kg/ha/mm): Average ratio of air biomass (kg/ha) by the provided amount of water irrigation (pluviometry + complementary Irrigation);
- Seed Yield Water Use Efficiency (SYWUE; kg/ha/mm): Average ratio of seed yield (kg/ha) by the provided amount of water irrigation (pluviometry + complementary Irrigation);

The measured parameters were treated with «SPSS for Windows version 13» and «XLSTAT version 2009.3.02» software. Variance analyses, averages comparisons (LSD test (P = 5 %)), heritability (Nanson, 1970) and binary correlations, Pearson method, were effected. Principal Component Analysis (ACP) (Frontier, 1981) was carried out to identify the agronomic variables which could be used as basic criteria for the discrimination of drought tolerant chickpea genotypes.

RESULTS AND DISCUSSION

Temperature effects on the chickpea culture

Chickpea farming cycle has been lasted 150 days. Annual averages of the relative humidity and the wind speed are respectively of 70 % and 2.3 m/s. Recorded minimum and maximum temperatures varied respectively from 6 to 20.3 °C and 15 to 31.5 °C with respective averages of 14.3 and 24.6 °C (Figure 2). Bamouh, *et al.,* (2002) announced that the chickpea was a spring culture which could be sown in months February and Mars. It grown well at temperatures varying from 20 to 30 °C day and approximately 20 °C night (Mc Vicar *et al.,* 2007).

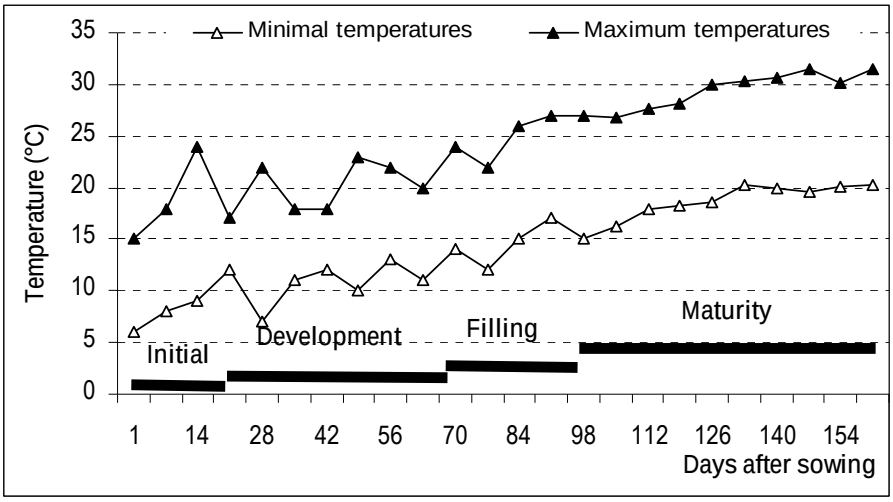

Figure 2. Minimum and maximum temperatures of the chickpea (*Cicer arietinum* L.) farming cycle conducted *in situ*

During the development phase, averages minimum and maximum temperatures were, respectively, 11.1 and 21 °C. At high temperatures, upper than 15 °C and with an optimum between 20 and 24 °C, all chickpea flowers were fertile and false flowers were almost no - existent (Jaiswal and Singh, 2001). Roberts *et al.,* (1980) noticed a linear increase in the chickpea flowering rate at temperatures varying from 11 to 29 °C. Summerfield *et al.,* (1984) remarked that during the flowering period, exposure of chickpea plants, during 3 to 4 days at temperatures higher than 30 °C, caused heavy losses of the grain yield. During filling seeds and maturity phases, recorded averages temperatures, minimum and maximum, were, respectively, 17.2 and 27.8 °C. According to Silim and Saxena (1993) temperatures varied from 30 to 32 °C were maximal and critical which limit the chickpea seed yield potential through the maturity acceleration. Singh, *et al.,* (1994) stated that the chickpea was sensitive to high temperatures during the reproductive phase, in particular, the filling and maturity seeds.

Chickpea culture water requirements

Chickpea culture water requirements were evaluated at 370 mm; whereas the supplying water irrigation, limited to 245 mm, was definitely lower than these requests (Figure 3). The culture cycle was subdivided in two phases. During the first one, which covers the initial and the development periods, culture water requirements are satisfied. The second phase began 54 days after sowing and covered flowering, filling and maturity periods. During this phase the culture undergo more and more accentuated drought stress (Figure 3). Belhassen, *et al.,* (1995) announced that, in the semi - arid zones, drought stress depends on several factors, in particular, the distribution and the frequencies of the precipitations along the culture cycle, the evaporation and the storage of the water capacity in the ground. It generated the most serious damage, in particular, on chickpea spring culture of which seed yield was negatively affected. It seemed feeble and irregular with reduced seed size (Singh, *et al.;* 1994). Saxena, (1987) and Slama, (1998) indicated that, according to the drought stress intensity, seed yield could fell from 40 % to 100 %. Faris and Gowda, (1990) announced that drought stress caused problems in flowering, mineral nutrition, pods filling and plants architecture.

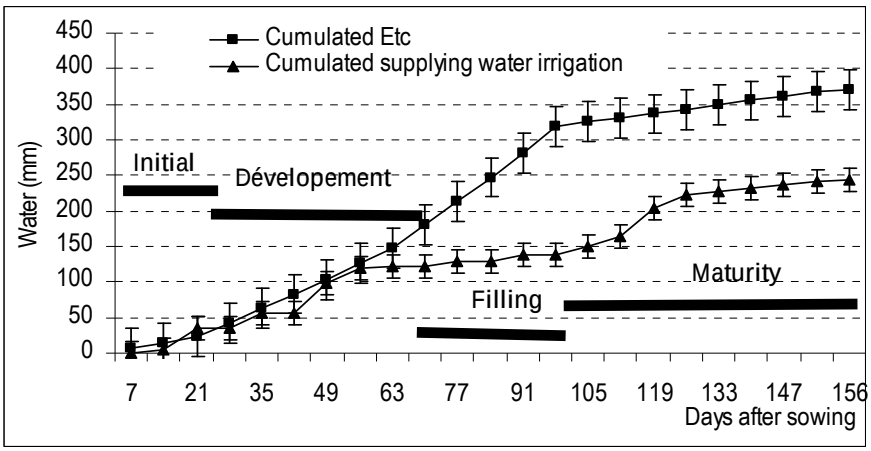

Figure 3. Cumulated crop evapotranspiration (Etc) and water requirements variations according to the chickpea (Cicer arietinum L.) phenologic stages development

Study of the variables

Variance analysis showed very highly significant (P ≤ 1 ‰) genotypic variability for the seed yield and the entire studied agronomic parameters with variation coefficients which varied from 1.21 to 36.6 %. Genotypic heritability was very high (Hallais, 2012) and varied from 44 to 91 % (Table 2). Seed yield was in negative significant correlation (P ≤ 5 %) with the maturity date (r = - 0.379). It was in highly significant correlations (P ≤ 1 %), negative with flowering date (r = - 0.432) and positive with total chlorophyll content (r = 0.514), air biomass (r = 0.934), pods weight (r = 0.948), pods number/m^2 (r = 0.808), seed number/m^2 (r = 0.853), 100 seed weight (r = 0.508), crop ground cover rate (r = 0.548), harvest index (r = 0.731), dry matter water use efficiency (r = 0.934) and seed yield water use efficiency (r = 1.000) (Table 3). Dry matter water use efficiency was in negative significant correlations (P ≤ 0.5 %) with flowering (r = - 0.347) and maturity (r = - 0.363) dates. It was in positive and highly significant correlations (P ≤ 1 %) with total chlorophyll content (r =. 575), crop ground cover rate (r = 0.608), air biomass (r = 1.000), pods weight (r = 0.953), pods (r = 0.853) and seed (r = 0.838) numbers, 100 seed weight (r = 0.431) and harvest index (r = 0.486) (Table 3). Seed yield water use efficiency was in negative and significant correlation (P ≤ 0.5 %) with maturity date (r = - 0.379). It was in highly significant correlations (P ≤ 1 %) negative with flowering date (r = - 0.432) and positive with total chlorophyll content (r = 0.514), crop ground cover rate (r = 0.548), air biomass (r = 0.934), pods weight (r = 0.948), pods (r = 0.808) and seeds (r = 0.853) numbers/m^2, 100 seed weight (r = 0.508), harvest index (r = 0.731) and dry matter water use efficiency (r = 0.934) (Table 3).

Table 2. Average values of chickpea (*Cicer arietinum* L.) Seed yield Genotypes and studied agronomic parameters

N° Genotype	SY (t/ha)	StD (St/mm2)	RWC (%)	TChlC (mg,g - 1MF)	ED (DAS)	FlD(DAS)	FlPhDr (Days)	MatD (DAS)	PlH (cm)	CGCR (%)	AB (t/ha)
1	1.651	154.3	77.1	26.34	21	72.7	9.0	149	38	86.3	3.818
2	1.355	184.7	65.5	35.78	21	76.0	7.3	149	30	73.3	2.895
3	1.920	196.7	60.4	29.15	22	71.0	7.0	146	36	87.8	4.424
4	2.038	172.7	67.1	31.67	21	70.3	5.7	145	30	96.7	4.507
5	1.888	178.0	78.2	23.52	20	70.3	10.1	146	37	88.1	3.877
6	1.151	161.0	70.5	25.22	21	72.7	7.0	146	34	64.8	2.806
7	1.652	178.3	68.4	21.95	21	71.0	7.0	146	33	83.7	3.544
8	1.448	193.7	73.4	33.87	22	72.7	7.0	149	45	78.5	3.694
9	1.728	200.0	78.0	37.34	22	69.0	5.7	141	34	95.9	3.857
10	0.943	200.3	69.1	21.73	21	72.7	7.0	146	27	66.7	2.063
11	1.487	195.0	62.9	25.44	21	69.7	6.6	146	35	91.1	3.643
12	2.405	173.3	67.0	24.81	22	71.0	7.0	147	26	84.8	5.115
13	1.772	217.7	73.1	14.86	21	68.3	5.3	141	34	73.3	4.629
14	1.434	197.7	66.2	16.02	21	74.3	8.7	151	34	78.5	3.363
15	0.846	215.3	68.5	27.43	21	72.7	7.2	150	36	70.4	2.643
16	1.779	178.3	61.5	19.90	21	75.0	7.7	145	38	84.1	4.064
17	0.831	182.3	74.5	24.19	22	75.7	5.9	147	35	77.0	2.908
18	1.553	175.3	69.8	30.07	22	72.7	7.9	146	39	89.6	3.842
19	0.838	200.7	57.7	13.87	20	76.0	7.9	149	32	65.6	2.121
20	0.798	194.0	61.2	22.47	20	72.7	7.6	147	23	42.2	1.925
21	2.036	187.7	64.4	36.01	20	70.3	6.8	147	39	111.5	4.330
22	1.837	213.7	75.6	39.60	21	76.7	7.7	151	49	87.4	4.369
23	1.961	183.0	72.3	26.26	22	74.3	11.0	152	34	84.8	4.017
24	1.522	216.3	64.2	26.72	23	75.0	9.9	154	35	64.4	3.365
25	1.834	191.3	69.1	33.83	20	72.7	7.0	145	35	87.8	4.577
26	0.947	197.0	78.5	40.62	20	74.3	8.1	150	42	82.2	3.682
27	1.396	227.3	55.2	21.49	21	73.3	8.6	155	38	53.0	2.911
28	2.112	190.0	70.0	25.47	22	75.0	6.4	145	38	92.2	4.929
29	2.077	196.0	72.3	23.05	21	74.3	7.0	146	45	85.2	4.848
30	2.019	179.3	65.6	17.57	22	72.7	7.3	148	41	95.2	4.814
31	0.987	184.3	66.9	19.30	22	76.0	7.0	153	35	58.5	2.587
32	0.961	184.7	70.2	16.91	21	77.3	5.9	152	43	63.3	2.989
33	1.061	201.6	69.4	22.53	22	74.3	7.6	147	39	48.5	2.677
34	1.061	173.3	72.1	10.40	21	74.3	7.9	150	36	78.9	2.756
35	1.238	171.3	67.8	13.05	21	76.0	10.1	153	40	77.8	3.406
36	1.787	171.3	62.3	23.99	21	76.0	8.2	150	38	73.3	4.032
37	0.616	185.8	71.7	20.52	23	77.3	6.6	151	26	39.3	1.912
38	2.315	182.7	60.4	30.95	20	76.7	6.8	152	42	78.9	4.994
39	2.250	199.7	68.2	22.36	20	64.7	8.0	141	29	94.1	4.309
40	1.697	180.7	61.7	27.31	23	77.7	8.1	151	34	80.0	3.958
41	0.550	199.0	70.1	17.48	20	77.3	3.7	151	43	73.3	1.851
Means ±	1.507 ±	189.8 ±	68.3 ±	24.90 ±	21.1 ±	73.5 ±	7.4 ±	148 ±	36 ±	77.8 ±	3.59 ±
Standard Error	0.661	20.1	6.5	8.68	1.1	3.4	1.7	4	6	21.3	1.27
Genotypic variability	***	***	***	***	***	***	***	***	***	***	***
VC (%)	35.61	7.94	5.74	22.1	2.84	3.1	16.84	1.25	11.3	23.86	30.10
LSD (P ≤ 5%)	0.675	19	4.8	6.92	0.754	2.8	1.6	2.3	5.1	23.3	1.357
h^2G (%)	62	70	84	83	87	79	72	91	82	50	55

Numbers in fat represent the minimum and maximum values. ***: Very highly significant; CV: Variation coefficient; LSD: Last significant difference; H^2G: Heritability.

Table 2. (Suite) Average values of the chickpea (*Cicer arietinum* L.) Seed yield genotypes and of the studied agronomic parameters.

N° Genotype	ABDMC (%)	PBrNb/ Pl	PW (q/ha)	PNb/m 2	SNb/m 2	SNb/P	100 SW (g)	HI (%)	DMWUE (kg/ha/mm)	SYWUE (kg/ha/mm)
1	21.1	2.3	2.181	562	488	0.85	35.5	43.2	11.4	26.4
2	24.7	3.1	1.717	349	302	0.85	45.2	46.5	9.4	20.0
3	21.6	2.3	2.591	712	625	1.00	32.6	44.1	13.3	30.6
4	23.0	2.9	2.717	674	636	0.94	32.5	44.2	14.1	31.1
5	19.7	2.3	2.564	533	482	0.89	38.6	48.5	13.0	26.8
6	20.9	2.5	1.510	370	348	0.89	29.6	39.3	7.9	19.4
7	21.9	2.6	2.158	533	443	0.87	36.8	46.4	11.4	24.5
8	20.2	2.2	1.972	575	496	0.78	31.9	39.7	10.0	25.5
9	21.2	2.8	2.313	592	400	0.54	49.3	40.8	11.9	26.6
10	22.1	2.4	1.118	282	233	0.81	39.3	46.2	6.5	14.2
11	20.7	2.2	2.071	556	482	0.85	32.0	39.8	10.3	25.2
12	22.4	1.9	3.207	569	555	0.95	43.3	46.3	16.6	35.3
13	23.9	2.5	2.393	602	546	0.85	33.2	38.3	12.2	32.0
14	21.1	2.0	1.936	516	467	0.90	30.2	43.4	9.9	23.2
15	24.3	2.4	1.523	341	232	0.97	33.8	30.5	5.8	18.3
16	23.5	1.7	2.393	499	477	0.95	37.3	43.6	12.3	28.1
17	23.4	3.4	1.140	234	223	0.98	37.0	27.0	5.7	20.1
18	22.6	2.0	2.087	476	439	0.80	39.8	41.8	10.7	26.5
19	24.3	2.1	1.127	314	296	0.80	28.7	39.5	5.8	14.6
20	22.1	2.3	1.034	331	293	0.86	29.8	39.6	5.5	13.3
21	24.8	1.4	2.649	504	490	0.97	45.2	47.0	14.1	29.9
22	20.5	2.1	2.496	472	520	1.16	34.1	41.2	12.7	30.2
23	21.5	2.9	3.103	603	560	0.87	46.4	50.2	13.5	27.7
24	23.8	2.3	1.934	499	450	0.94	29.6	43.6	10.5	23.2
25	22.3	2.6	2.450	702	468	0.54	51.6	40.8	12.7	31.6
26	22.3	1.8	2.302	508	316	0.69	30.3	28.3	6.5	25.4
27	25.1	2.7	1.301	353	373	1.13	37.0	47.9	9.6	20.1
28	21.3	2.6	2.849	679	669	0.96	32.5	40.1	14.6	34.0
29	21.3	1.8	2.845	578	383	0.92	51.4	41.6	14.3	33.5
30	22.9	2.5	2.846	875	754	0.88	27.6	40.9	13.9	33.2
31	22.6	2.4	1.234	365	330	0.80	28.2	38.4	6.8	17.9
32	24.2	1.9	1.312	397	353	0.92	24.7	31.0	6.6	20.6
33	23.4	2.0	1.447	356	309	0.81	32.2	33.6	7.3	18.5
34	20.0	2.5	1.501	432	394	0.90	27.1	36.5	7.3	19.0
35	23.7	2.1	1.749	503	420	0.83	29.3	36.4	8.6	23.5
36	22.5	1.7	2.406	389	363	0.89	48.4	44.4	12.3	27.8
37	22.2	2.0	0.856	209	179	0.80	34.6	24.1	4.3	13.2
38	25.3	2.5	3.047	606	541	0.93	39.3	45.7	16.0	34.5
39	20.3	3.2	2.852	659	628	0.95	36.4	52.7	15.5	29.8
40	25.3	2.2	2.316	486	441	0.81	43.8	42.9	11.7	27.3
41	20.9	2.0	0.839	282	206	0.80	25.1	27.2	3.8	12.8
Means ± Standard Error	22.5 ± 1.7	2.3 ± 0.5	2.051 ± 0.894	490 ± 200	429 ± 180	0.87± 0.15	35.9 ± 10.2	40.6 ± 8.6	10.4 ± 4.6	24.8 ± 8.8
Genotypic variability	***	***	***	***	***	***	***	***	***	***
VC (%)	4.31	17.85	35.61	35	34.7	13.8	25.69	17.03	36.61	30.1
LSD (P ≤ 5%)	1.22	0.52	0.918	213	187	0.152	11.5	8.7	4.659	9.374
h^2G (%)	87	67	61	55	59	64	44	63	62	55

- Numbers in fat represent the minimum and maximum values.
- ***: Very highly significant; CV: Variation coefficient; LSD: Last significant difference; H^2G: Heritability.

Table 3. Binary Pearson correlations of the studied parameters

Variables	StD (St/mm2)	RWC (%)	TChlC (mg,g - 1MF)	ED (DAS)	FlD (DAS)	FlPhDr (Days)	MatD (DAS)	PlH (cm)	CGCR (%)	AB (t/ha)	ABDMC (%)	PBrNb/Pl	PW (q/ha)	PNb/m2	SNb/m2	SNb/P	100SW (g)	SY (q/ha)	HI (%)	DMWUE (kg/ha/mm)	SYWUE (kg/ha/mm)
StD (St/mm2)	1	0.027	- 0.119	- 0.105	0.028	0.067	0.075	0.087	- 0.22	- 0.225	0.246	0.09	- 0.255	- 0.223	- 0.242	0.095	- 0.066	- 0.215	- 0.113	- 0.225	- 0.215
RWC (%)		1	0.224	- 0.24	- .431**	- 0.281	- 0.276	0.189	.378*	0.186	- 0.288	0.256	0.165	0.238	0.156	- 0.148	0.018	0.153	- 0.02	0.186	0.153
TChlC (mg,g - 1MF)			1	- 0.092	- 0.287	- 0.166	- 0.306	0.093	.560**	.575**	- 0.003	0.163	.555**	.417**	.392*	0.07	.374*	.514**	.309*	.575**	.514**
ED(DAS)				1	0.074	0.302	0.175	- 0.19	0	- 0.018	- 0.021	0.149	- 0.005	- 0.002	0.068	0.04	0.081	0.033	0.039	- 0.018	0.033
FlD(DAS)					1	0.1	.737**	.314*	- .492**	- .347*	.326*	- 0.255	- .391*	- .480**	- .444**	0.054	- 0.158	- .432**	- .447**	- .347*	- .432**
FlPhDr(Days)						1	0.172	0.044	- 0.056	0.119	0.111	- 0.006	0.242	0.158	0.185	0.063	0.138	0.185	.348*	0.119	0.185
MatD (DAS)							1	0.19	- .369*	- .363*	0.281	- 0.207	- .357*	- .395*	- .322*	0.216	- 0.267	- .379*	- 0.281	- .363*	- .379*
PlH (cm)								1	0.063	0.292	- 0.048	- .344*	0.188	0.201	0.15	0.162	- 0.1	0.117	- 0.181	0.292	0.118
CGCR (%)									1	.608**	0.021	0.142	.551**	.561**	.546**	0.009	0.209	.548**	0.305	.608**	.548**
AB (t/ha)										1	- 0.041	- 0.022	.953**	.853**	.838**	0.147	.431**	.934**	.486**	1.000**	.934**
ABDMC (%)											1	- 0.062	- 0.114	- 0.202	- 0.165	0.116	0.095	- 0.067	- 0.049	- 0.041	- 0.067
PBrNb/Pl												1	- 0.009	0.109	0.125	0.004	0.045	0.054	0.165	- 0.022	0.054
PW (q/ha)													1	.843**	.831**	0.124	.475**	.948**	.595**	.953**	.948**
PNb/m2														1	.919**	- 0.052	0.172	.808**	.473**	.853**	.808**
SNb/m2															1	0.236	0.066	.853**	.584**	.838**	.853**
SNb/P																1	- 0.2	0.223	0.235	0.146	0.223
100SW (g)																	1	.508**	.453**	.431**	.508**
SY (q/ha)																		1	.731**	.934**	1.000**
HI (%)																			1	.486**	.731**
DMWUE (kg/ha/mm)																				1	.934**
SYWUE (kg/ha/mm)																					1

- *: Significant (P≤ 5 %); - **: Highly significant (P≤ 1 %);

Ben Mbarek (2011) found that water use efficiency was proportional to seed yield, air biomass, seed number/m^2, pod weight/m^2, seed number per pod, 100 seed weight and harvest index and inversely proportional to total chlorophyll content and flowering and maturity dates. Serraj, *et al.,* (2003) reported that, under dryness conditions, empirical selection of water stress tolerant genotypes was based on the seeds yield and its components. They underlined that all components adopted for this screening should be characterized by highly significant correlations with elevate and stable seed yield, high level of heritability and a repetitive and easily measurable expression of water stress tolerance. According to Singh, *et al.;* (1994), some parameters, such as early maturity, good plant vigor, fast crop ground cover and high seed weight were significantly associated to drought tolerance.

According to Silim and Saxena (1993), at the lens, dryness tolerance was dependent on the plant growth and vigor, the crop ground cover rate and the air biomass; whereas at chickpea, it was associated to the harvest index, pods number per unit area and high seed weight. Other works indicated that, at these same species, resistance by escape, early flowering (Malhotra and Saxena, 2002) and seed yield potential represents two principal components for drought stress tolerance selection (Silim and Saxena, 1993). Bonfil and Pinthus, (1995) announced that by reason of undetermined chickpea growth, its flowering period was a determining factor of its seed yield. Indeed, early flowering involved a long period of seed filling and a high yield potential; whereas a late flowering induced a short reproductive period and poor seed yield (Abernethy, 1987). Singh *et al.,* (1991) concluded that, under water stress conditions, 75 % of the seed yield variations are allotted to the flowering and maturity dates and to the 100 seed weight. According to Jain *et al.,* (1991), combination between seed yield components, was the best mean for the seed yield improvement. On the other hand, Omar and Singh (1994) indicated that the increase in the seed yield requires the increase in the air biomass and the harvest index. Ofori, (1996) noticed that, at groundnut, the highest seed yield was foreseeable if all its components are on their maximum levels and the seed yield variations, expressed by negative correlations between some of its components, can be attenuated by compensation phenomena. Yousaf and Tahir (1999) recommended that the seed yield was a complex character which results from multitude interactions of highly sensitive factors to the environmental variations. It could be estimated on the basis of the performance of some components such as the plant height, the branches and pods numbers per plant and the 100 seed weight. The air biomass, the pods number per plant, the 100 seed weight (Singh *et al.,* 1995) and the flowering period duration have raised direct effects on the seed yield (Jahangiri *et al.,* 2006).

Berger *et al.,* (2005) found that the seed yield was positively correlated with the air biomass, the harvest index, the flowering phase duration and the productivity by plant and negatively correlated with flowering and pods formation dates and with the filling pods phase duration. Singh (1977) reported that it was positively correlated with the primary branches number, the pods per plant number and the seeds number per pod and negatively correlated with the flowering date and the plant height. According to Ciftçi, *et al.,* (2004), seed yield was in significant relationships, negative with the 100 seed weight and positive with the air biomass, the pods number per plant and the harvest index. Water stress induced a reduction in the stomata density (Erchidi, *et al.,* 2000) which does not, always, result in reduction of water losses because of compensation phenomenon which involves increase in the stomata size (Wang and Clarke, 1993). On the other hand, Mougou, *et al.,* (1986) noticed that, at pepper, the stomata density was proportional to the water deficit intensity. They concluded that the increase in the stomata density presented an adaptive particularity at the dryness.

Principal Component Analysis

The principal component analysis, Pearson type (n), of the chickpea genotypes collection showed that the studied variables have different contributions to the construction of the three first axes that have the highest values. It accounted alone for 60.09 % of the total variability (Table 4).

Table 4. Eigenvalues and variability of the principal factors of the ACP analysis.

Axes	Eigenvalue	Variability (%)	% cumulated
F1	8.36	39.83	39.83
F2	2.40	11.45	51.28
F3	1.85	8.81	60.09
F4	1.37	6.53	66.62
F5	1.30	6.19	72.81
F6	1.06	5.03	77.84
F7	1.00	4.78	82.62
F8	0.80	3.79	86.41
F9	0.65	3.07	89.48
F10	0.59	2.82	92.30
F11	0.49	2.31	94.61
F12	0.39	1.86	96.47
F13	0.27	1.29	97.77
F14	0.24	1.13	98.89
F15	0.13	0.60	99.50
F16	0.04	0.21	99.71
F17	0.03	0.14	99.84
F18	0.02	0.09	99.94
F19	0.01	0.06	100.00

The first axis absorbs 39.83 % of the observed variability (Table 4). It was primarily composed of harvest index (11.14 %), seed water use efficiency (11.14 %), pods number/m^2 (10.87 %), branches number per plant (10.74 %), air biomass dry matter content (10.74 %), seed number per pod (9.27 %) and seed number/m^2 (9.25 %) (Table 5).

Table 5. Variables contributions in the edification of the axes 1 and 2 of the ACP analysis

Variables	F1	F2	F3
StD (St/mm2)	0.762	0.020	0.001
RWC (%)	0.76	0.02	0.00
TChlC(mg.g - 1MF)	0.83	14.93	7.59
ED(DAS)	4.45	0.92	0.93
FlD(DAS)	0.00	3.13	13.58
FlPhDr(Days)	3.63	16.77	2.82
MatD (DAS)	0.24	12.27	9.79
PlH (cm)	2.89	16.25	1.03
CGCR (%)	0.20	5.42	30.99
AB (t/ha)	5.45	2.22	0.73
PBrNb/Pl.	10.74	1.18	1.60
PW (q/ha)	0.15	6.59	9.19
PNb/m2	10.87	1.19	0.08
SNb/m2	9.25	0.00	0.65
SNb/P	9.27	0.55	0.12
100SW (g)	0.20	7.10	0.37
SY (q/ha)	2.46	0.10	6.52
HI (%)	11.14	1.14	0.19
DMWUE(kg/ha/mm)	5.34	0.62	11.54
SYWUE(kg/ha/mm)	11.14	1.14	0.19
ABDMC (%)	10.74	1.18	1.60
Total	100	100	100

There was in positive correlations, particularly with seed yield, dry matter and seeds yield water use efficiency, pods weight, air biomass, seeds and pods numbers/m^2, crop ground cover rate,

harvest index and total chlorophyll content. It was in negative correlations, especially, with stomata density, maturity and flowering dates (Table 6).

Table 6. Variables correlations with the first three axes of the ACP analysis;

Variables	F1	F2	F3
StD (St/mm2)	- 0.252	0.022	0.003
RWC (%)	0.264	- 0.599	0.375
TChlC(mg.g - 1MF)	0.610	- 0.149	0.131
ED(DAS)	- 0.004	0.274	- 0.501
FlD(DAS)	- 0.551	0.635	0.229
FlPhDr(Days)	0.141	0.543	- 0.425
MatD (DAS)	- 0.492	0.625	0.138
PlH (cm)	0.131	0.361	0.757
CGCR (%)	0.675	- 0.231	0.116
AB (t/ha)	0.948	0.168	0.172
PBrNb/Pl	0.114	- 0.398	- 0.412
PW (q/ha)	0.954	0.169	0.038
PNb/m2	0.880	- 0.008	0.110
SNb/m2	0.881	0.115	0.048
SNb/P	0.130	0.413	0.083
100SW (g)	0.454	0.049	- 0.347
SY (q/ha)	0.965	0.165	- 0.060
HI (%)	0.668	0.122	- 0.462
DMWUE(kg/ha/mm)	0.965	0.165	- 0.060
SYWUE(kg/ha/mm)	0.948	0.168	0.172
ABDMC (%)	- 0.143	0.419	- 0.094

This was an axis of vegetative growth and seed production. It allows subdividing chickpea genotypes according to the importance of their air biomass, crop ground cover rate and their seed production. The second axis explains 11.45 % of the observed variability (Table 4). It was especially composed of flowering phase duration (16.77 %), plant height (16.25 %), total chlorophyll content (14.93 %), maturity date (12.27 %), 100 seed weight (7.1 %) and pods weight (6.59 %) (Table 5). It was in correlations, positive with flowering and maturity dates, flowering phase duration, air biomass dry matter content, seed number per pod and plant height and negative with crop ground cover rate, primary branches number per plant and relative water content (Table 6). This was an architecture axis and seed formation. It discriminated chickpea genotypes according to the flowering and maturity precocity and the plant vigor. The third axis explains 8.81 % of the observed variability (Table 4). It was notably composed of crop ground cover rate (30.99 %), flowering date (13.58 %), dry matter water use efficiency (11.54 %), maturity date (9.79 %), pod weight (9.19 %) and total chlorophyll content (7.59 %) (Table 5). There are correlations, positive with the plant height, the relative water content and the flowering date and negative with the 100 seeds weight, the primary branches number per plant, the flowering phase duration, the harvest index and the emergence date (Table 6). This axis distributes chickpea genotypes, particularly, according to their germination energy defined by the emergence rapidity, plant vigor and water turgescences.

Each of the first three axes of the ACP analysis distributed the chickpea genotypes in two groups. The first one of the first axis was composed of 23 genotypes (1; 3; 4; 5; 7; 8; 9; 11; 12; 13; 16; 18; 21; 22; 23; 25; 28; 29; 30; 36; 38; 39; 40) which appears characterized by strong vegetative development, vigorous plants, high seed yield and water use efficiency and large seed size. The second group of this axis was composed of 18 genotypes (2; 6; 10; 14; 15; 17; 19; 20; 24; 26; 27; 31; 32; 33; 34; 35; 37; 41). They ware characterized by slow emergence and quite long vegetative cycle development (Figure 4 a, b). The first group of the second axis was composed of 21 genotypes (3; 12; 14; 16; 18; 19; 21; 22; 23; 24; 27; 28; 29; 30; 31; 32; 33; 35; 36; 38; 40). They ware discriminated by vegetation height and rich in dry matter, late and spread flowering and maturity phases and high seeds number per pod. The second group was composed of 20 genotypes

(1; 2; 4; 5; 6; 7; 8; 9; 10; 11; 13; 15; 17; 20; 25; 26; 34; 37; 39; 41). They are characterized by abundant vegetation, high water turgescence, ramification and pods production (Figure 4 a, c).

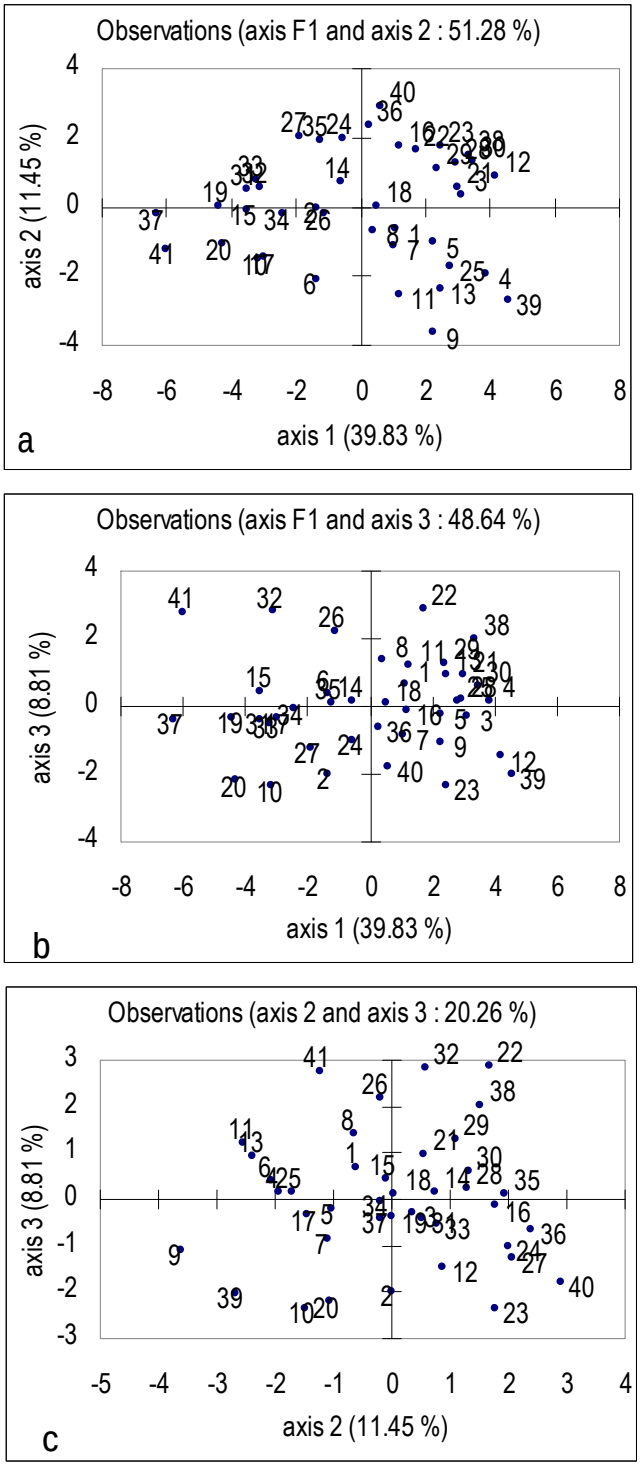

Figure 4. Chickpea (*Cicer arietinum* L.) genotypes dispersion in the plans generated by a: axes 1 and 2; b: axes 1 and 3 and c: axes 2 and 3

The first group of the third axis was composed of 20 genotypes (1; 4; 6; 8; 11; 13; 14; 15; 18; 21; 22; 25; 26; 28; 29; 30; 32; 35; 38; 41). They appear characterized by high seed size,

raised water turgescence, late flowering date and high dry matter water use efficiency. The second group of the this axis was composed of 21 genotypes (2; 3; 5; 7; 9; 10; 12; 16; 17; 19; 20; 23; 24; 27; 31; 33; 34; 36; 37; 39; 40) which appear productive and endow with high seed yield water use efficiency. They showed a delayed emergence, high primary branches number and air biomass dry matter, spread flowering phase and large seeds size (Figure 4 b, c). Considering the first two axes, we find that chickpea genotypes could be divided into four groups. The first group consists of 13 genotypes (3; 12; 16; 18; 21; 22; 23; 28; 29; 30; 36; 38 and 40) which appear characterized by a long flowering phase duration, abundant and elevated air biomass, elevated reserves accumulation resulted in the formation of high seeds number per pod, large seeds size, important seed yield and seeds and dry matter water use efficiency.

The second group was composed of 10 genotypes (1; 4; 5; 7; 8; 9; 11; 13; 25 and 39) which are characterized by vigorous, turgescent and high primary branches number. They produced fairly high pods number/m^2. The third group was formed by eight genotypes (14; 19; 24; 27; 31; 32; 33 and 35). They showed a slow emergence, rather long vegetative development cycle, high stomata density, late flowering date and high dry matter accumulation. The last group consists of 10 genotypes (2; 6; 10; 15; 17; 20; 26; 34; 37 and 41). They are quite rich in chlorophyll and turgescent water vegetation, late flowering and high primary branches number that caused the increase in crop ground cover. In sum, it seems that genotypes 3; 12; 16; 18; 21; 22; 23; 28; 29; 30; 36; 38 and 40 are tolerant to water stress. They can be conducted under rainfed conditions in Tunisian semi - arid zones. However, the rest of the genotypes were sensitive to water stress. Their cultivation area was delimited to the humid and sub humid zones.

CONCLUSION

It appears that thermal conditions of Tunisian semi - arid zones are favorable for chickpea culture. In contrast, the contribution of water irrigation were significantly lower than the water crop requirements, which amounted to 370 mm. Collection of chickpea genotypes underwent an increasingly intense water stress during the seeds filling and maturity phases. Highly significant genotypic variability and high heritability were detected for seed yield and the studied agronomic parameters. The principal component analysis revealed that among the 41 genotypes, 13 of them, namely: 3; 12; 16; 18; 21; 22; 23; 28; 29; 30; 36; 38 and 40 ware drought tolerant. They can be conducted under rainfed conditions in Tunisian semi - arid zones. On the other hand, the others, 28 genotypes, were sensitive to water stress. Their cultivation area was delimited to the humid and sub humid zones. However, they can be conducted in winter crop in the Tunisian semi - arid zones with supplementary irrigation. Other research in other Tunisian semi - arid regions will be conducted to confirm these results.

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CONFLICT OF INTEREST : Nothing