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NUTRITIONAL VARIATION AND DROUGHT TOLERANCE IN CHICKPEAS (*CICER ARIETINUM* L.)

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Abstract

Pulses are an important dietary constituent in human and animal diets. As well as being a source of income and livestock feed, pulses satisfy 33% of the dietary protein nitrogen (N) needs of humans. Pulses are often exposed to environmental stresses (biotic and abiotic) that decrease their productivity throughout the world. Abiotic stresses (drought, salt, temperature, UV, nutrient deficiency) alone are responsible for more than 50% yield reductions of some major crops. The following examination of drought stress types (no irrigation, early period stress, late period stress, control) of 10 chickpea genotypes from Turkey was carried out for two years (2010 and 2011) in a field experiment set up accoding to a randomized complete block design with three replications and conducted under the ecological conditions prevalent in Konya, Turkey. The investigated nutrition-related parameters were the seed concentrations of protein, fat, ash, fiber, moisture, non-nitrogenous pith substances and minerals. Means achieved under the particular stress types showed that the protein percentage ranged from 19.71% to 19.80%, fat – 4.640 to 4.690%, ash – 2.810 to 2.860%, fiber – 7.360 to 7.400%, moisture – 9.150 to 9.180%, non-nitrogenous pith substances – 56.16 to 56.25%, while the mineral content (mg kg^{-1}) corresponded to the following ranges: 9.700 to 9.980 B, 68.32 to 79.44 for Fe, 8866.3 to 8912.4 for K, 1383.1 to 1410.3 for Mg, 21.99 to 23.85 Mn, 3148.0 to 3192.6 P, 1815.6 to 1835.4 for S and from 25.81 to 28.43 for Zn. In general, the content of protein, magnesium and sulfur showed the lowest values under no irrigation conditions, while the content of ash, non-nitrogenous pith substances, boron, potassium, phosphorus and zinc showed the highest values under no irrigation conditions. Additionally, the nutritional value of chickpea seeds showed significant differences for all of the investigated characteristics viewed in terms of triple interactions (year x stress factor x genotype). The present research results can be useful for farmers, plant breeders, food companies etc., interested in chickpea. Finally, responses of the genotypes to different levels of drought stress were modified by the investigated quality characteristics.

Key words: mineral, nutrition, quality, seed composition, stress.

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INTRODUCTION

Pulses have been extremely important in human diet since the early age of agriculture. Most of the pulse species remain an irreplaceable source of dietary proteins and other nutrients for humans, especially in vegetarian diets of developing countries (Wang et al. 2009). Seeds of pulses contain from 16 to 50% protein and provide one third of all dietary protein nitrogen (Graham, Vance 2003). For this reason, pulses are used as a supplementary plant to cereals; their cultivation is one of the best solutions for combating protein and calorie malnutrition, particularly in developing countries. Pulses constitute the main component of traditional dishes in various parts of the world where maize and beans, rice and lentils, barley and peas, wheat and chickpeas are eaten together. The supply of carbon energy, which is required by plants at germination, is stored in pulse seeds either in the form of oil (soybean, groundnut) or as starch (common bean, pea, faba bean, lentil, chickpea, cowpea, mung bean). Additionally, pulse seeds are also an important source of 15 essential minerals required by the human body (Wang et al. 2009), complex carbohydrates, soluble fibers and other compounds, which are alternately considered anti-nutritional or health-promoting ones, e.g. trypsin inhibitors, tannins, phytate, saponins and oligosaccharides, recently associated with various health benefits, such as protective effects against cardiovascular diseases, cancers and diabetes (Champ 2002, Clemente et al. 2009). There is an urgent need to develop new references for the health-promoting and nutritional values of grain legumes. Determination of the value of a particular fraction in nutraceutic applications may open up new markets with higher added value. Attempts to modify the content of minor bioactive compounds will involve an appraisal of their consequences on plant behavior in regard to biotic or abiotic stresses (Burstin et al. 2007).

Chickpea yields are low and unstable due to the diminishing soil moisture at sowing time or terminal drought. Under the conditions of semiarid tropics, drought (rainfall deficit) is often aggravated by erratic and unpredictable rainfall, heat waves, prolonged solar radiation and poor soil characteristics. Plant responses to drought stress are affected by the time of occurrence, duration and intensity. There are different technical solutions for irrigation of chickpea, but water management or efficient water use are always very important. Therefore, it is essential to integrate water management for achieving higher productivity (Sekhon, Singh 2007). In the present study, effects of the drought tolerance of chickpea (*Cicer arietinum* L.) were investigated in terms of the crop’s nutritional characteristics.

MATERIAL AND METHODS

Several chickpea genotypes nos 22103, 22124, 22142, 22213, 22227, 22243 22261 (provided by the ICARDA), as well as two commercial varieties (Akcin, Gokce) and a local population (Cumra) were chosen for the study based on their reputed differences in drought performance. The study was conducted at the research and implementation area of the Konya Directorate of Research Station of Soil Water and Combating Desertification in Konya, Turkey, during the plant growing seasons in two consecutive years (2010 and 2011). Konya (1020 m above sea level) has the long-term average temperature of 11.4°C, 281 mm annual rainfall and 52.5% relative humidity, although the actual values during the research years were different (Table 1).

The soil in the trial area had a clay loamy structure, a low level of organic matter (1.49%), a high level of lime (17.14%) and an alkaline reaction (pH = 8.40). The soil salinity was low (0.05%), the available potassium content was high (516.0 kg ha^{-1}) but the phosphorus level was low (40.1 kg ha^{-1}). Table 2 shows the soil characteristics.

The trials were set up according to a randomized complete block design with three replications. The plots consisted of 2-meter-long rows spaced at 20 cm, with seeds planted at a 5-cm distance from one another. Fertilizer was applied before sowing (150 kg ha^{-1} DAP: 18% N and 46% P) in both

Table 1

Meteorological data for the research station

Months	Monthly average temperature (°C)			Monthly total rainfall (mm)			Monthly average relative humidity (%)		
	1980-2010	2010	2011	1980-2010	2010	2011	1980-2010	2010	2011
January	-0.3	4.0	2.7	30.8	38.4	47.8	76.0	76.7	81.4
February	0.6	6.6	3.7	23.2	31.1	38.4	70.3	65.6	64.6
March	5.2	9.8	6.4	25.5	12.5	30.4	62.7	52.1	58.6
April	10.9	12.4	10.6	35.9	31.8	57.0	57.7	57.8	58.9
May	15.5	18.7	15.2	38.6	22.8	62.8	55.4	44.9	55.9
June	20.1	21.2	20.3	20.5	108.0	27.8	47.2	53.8	45.1
July	23.4	26.5	26.4	7.8	7.4	0.0	42.3	39.5	27.4
August	23.0	27.7	24.3	5.6	0.0	1.0	42.7	30.2	28.1
September	18.6	19.3	20.6	11.3	7.6	0.2	46.1	32.4	28.2
October	12.4	13.2	11.7	29.7	76.8	37.6	58.5	73.2	51.7
November	5.5	11.2	3.4	39.0	4.0	9.4	70.1	63.6	63.0
December	1.3	6.1	3.3	43.9	79.8	25.4	76.5	83.4	64.1
Total/ Average	11.4	14.4	12.2	281.0	420.2	337.0	52.5	49.7	45.5

years. Chickenpea was sown on 1st of April 2010 and 4th of April 2011. Seeds were planted manually to the soil depth of 4-5 cm. Hoeing was made twice and harvest was carried out by hand after all the pods matured.

Four stress types were applied:

1st trial (Stress 1) – no irrigation during the vegetation period (Toker, Cagirgan 1998);

2nd trial (Stress 2) – an early period stress: no irrigation during the flowering period (Leport et al. 1999, 2006);

3rd trial (Stress 3) – a late period stress: plants irrigated during the flowering period to the field capacity (the available moisture of soil determined by the gravimetric method) but no irrigation applied during the pod setting period (Leport et al. 1999, 2006);

4th trial – control: none of the above stresses applied, irrigation carried out before the flowering period and during the pod setting period (Leport et al. 2006).

Stress induction, total irrigation and total water consumption values are given in Table 3. Naturally, the water consumption increased when plants were irrigated.

Protein, fat, ash, fiber, moisture and non-nitrogenous pith substances in chickpea seeds were determined according to the standard methods of analy-

Table 2

Soil characteristics of the experiment field

Features	Depth of soil (cm)					
	0–30		30–60		60–90	
Sand (%)	40		40		52	
Silt (%)	16		16		16	
Clay (%)	14		44		32	
Texture	clay		clay		clay	
Volume weight (g cm^{-3})	1.40		1.47		1.50	
Saturation (%)	52	loamy	54	loamy	54	loamy
Salinity (%)	0.050	saltless	0.040	saltless	0.040	saltless
pH	8.400	alkaline	8.420	alkaline	8.430	alkali
Lime (%)	17.14	very high	17.14	very high	17.14	very high
Organic matter (%)	1.490	low	0.950	low	0.640	low
Phosphorus (kg ha^{-1})	40.10	low	11.50	low	5.700	low
Potassium (kg ha^{-1})	516.0	very high	324.0	high	237.0	high
Iron (mg kg^{-1})	3.900	medium	3.300	medium	3.630	medium
Copper (mg kg^{-1})	0.980	medium	1.390	medium	1.110	medium
Manganese (mg kg^{-1})	6.480	medium	5.350	medium	4.750	medium
Zinc (mg kg^{-1})	0.420	low	0.590	medium	0.470	low

sis (AOAC 1984). The mineral composition was determined with an ICP-AES device (Varian Vista Model) according to Burt (2004).

Table 3

Irrigation dates, amount of irrigation and water consumption

Years	Stress applications	17^{th} of June	08^{th} of July	Total irrigation (mm)	Total water consumption (mm)
2010	normal (Stress 1)	-	-	-	270
	early period (Stress 2)	-	-	-	270
	late period (Stress 3)	-	73	73	343
	control	-	73	73	343
2011	normal (Stress 1)	-	-	-	251
	early period (Stress 2)	50	-	50	301
	late period (Stress 3)	-	75	75	326
	control	50	75	125	376

The analysis of variance for all the investigated characteristics was run using a software program called Jump

RESULTS

The statistical results of the determinations of protein, fat, ash, fiber, moisture, non-nitrogenous pith substances, boron, iron, potassium, magnesium, manganese, phosphorus, sulfur and zinc in seeds of the chickpea genotypes are presented in Table 4, whereas Table 5 contains the values of the above nutrients.

Table 4

Variance analyses of the investigated characteristics

SOV	DF	Nutritional characteristics													
General	239	pro-tein	fat	ash	fiber	moi-sture	non-nit.	B	Fe	K	Mg	Mn	P	S	Zn
Year (Y)	1	**	**	ns	**	**	**	ns	**	**	**	**	**	**	**
Stress (S)	3	ns	ns	ns	ns	ns	ns	ns	**	**	**	**	**	**	**
YxS	3	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Genotype G)	9	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Y x G	9	**	**	**	**	**	**	**	**	**	**	**	**	**	**
S x G	27	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Y x S x G	27	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Key: ns – not significant, ** $p < 0.01$

Table 5

Content of the investigated nutritional characteristics

Years	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Moisture (%)	Non-nit. (%)	B	Fe	K	Mg	Mn	P	S	Zn
							(mg kg^{-1})							
2010	19.60	4.620	2.820	7.340	9.130	56.51	9.150	61.89	8649.8	1288.9	19.29	3281.7	1861.3	28.62
2011	19.93	4.710	2.860	7.410	9.200	55.90	10.44	85.08	9143.1	1502.7	26.40	3051.2	1789.9	26.33
Stress														
1	19.71	4.650	2.860	7.370	9.160	56.25	9.980	71.40	8912.4	1383.1	22.48	3192.6	1815.6	28.43
2	19.76	4.690	2.810	7.400	9.180	56.17	9.700	74.78	8900.5	1410.3	21.99	3162.9	1826.3	25.81
3	19.79	4.640	2.830	7.360	9.150	56.24	9.790	68.32	8906.6	1405.6	23.85	3148.0	1825.1	27.53
4	19.80	4.660	2.860	7.360	9.160	56.16	9.720	79.44	8866.3	1384.1	23.08	3162.3	1835.4	28.12
Genotypes														
22103	18.08	3.780	2.230	6.800	8.570	60.06	9.490	83.74	8711.5	1350.6	20.15	3204.1	1817.7	26.93
22124	18.59	4.740	2.610	7.750	9.610	56.75	9.440	66.87	8967.8	1338.8	19.33	3379.9	1811.2	26.01
22142	20.87	5.330	3.240	7.350	8.820	54.39	9.830	58.90	8995.2	1356.0	20.03	3239.9	1845.0	26.97
22213	21.67	5.340	3.370	7.360	8.830	53.63	9.540	66.70	8893.7	1363.4	22.28	3328.2	1848.6	29.03
22227	19.76	3.650	2.970	6.670	9.590	57.68	9.800	79.70	8954.3	1451.6	25.16	2970.1	1830.0	27.78
22243	18.84	5.570	2.570	7.590	9.340	55.72	10.01	87.88	9014.6	1376.2	21.89	3375.4	1821.0	25.46
22261	20.50	4.520	2.350	7.540	9.320	55.72	10.19	80.26	8890.5	1494.1	29.35	2912.4	1813.5	28.51
Akcin	19.95	4.590	2.130	7.610	9.370	56.34	10.16	88.36	8748.3	1447.1	24.16	2923.7	1837.8	26.74
Gokce	18.88	4.390	3.360	7.410	8.860	57.02	9.860	62.90	8961.4	1415.7	24.55	3168.1	1808.6	26.83
Cumra	19.94	4.710	3.520	7.660	9.330	54.73	9.630	59.52	8827.4	1364.4	21.58	3162.6	1822.7	30.47

The protein content ranged from 18.08% to 21.67% in seeds of the chickpea genotypes. Genotype 22103 had the minimum, whereas genotype 22213 had the maximum protein percentage. Seeds of genotype 22213 accumulated the highest protein content (21.67%) under stress 1 conditions.

Genotype 22227 showed the lowest fat percentage (3.650%) while genotype 22243 contained the highest fat ratio (5.570%). Seeds of genotype 22243 accumulated the highest fat percentage (5.630%) under stress 2 conditions. The ash percentage varied significantly among the genotypes in a similar manner as fiber. The variety Akcin had the lowest ash content (2.130%) whereas Cumra had the highest ash percentage in seeds (3.520%). Cumra also had the highest ash content in seeds (3.670%) under stress 3 conditions. The fiber content (in %) ranged from 6.670 (22227) to 7.750 (22124) in seeds of the different chickpea genotypes. Genotype 22124 showed the highest fiber ratio (7.880%) under stress 1 conditions. The moisture content in seeds of the chickpea genotypes varied from 8.570% to 9.610%, with the lowest one observed in genotype 22103 and the highest one found in genotype 22124. Genotype 22227 showed the highest moisture ratio (9.990%) under stress 1 conditions. The share of non-nitrogenous pith substances in the chickpea genotypes varied from 53.63% (22213) to 60.06% (22103). Genotype 22103 showed the highest nitrogenous pith substance ratio (60.72%) under stress 1 conditions.

Significant differences (p<0.01) were observed in the content of the investigated nutrients among all the chickpea genotypes. The content of minerals (mg kg^{-1}) varied from 9.44 (22124) to 10.19 (22261) for B, from 58.90 (22142) to 88.36 (Akcin) for Fe, from 8711.5 (22103) to 9014.6 (22243) for K, from 1338.8 (22124) to 1494.1 (22261) for Mg, from 19.33 (22124) to 29.35 (22261) for Mn, from 2912.4 (22261) to 3379.9 (22124) for P, from 1808.6 (Gokce) to 1848.6 (22113) for S, from 25.46 (22243) to 30.47 (Cumra) for Zn, respectively.

DISCUSSION

The chickpea seed composition differs depending on a variety, the environment and agricultural practices. Values similar to the ones obtained in the present study have been reported in many earlier research experiments, as discussed below.

The protein share (%) in chickpea seeds was reported to be: 17.90-30.80 (Wang, Daun 2004), 20.83-23.98 (Kacar et al. 2004), 22.48-23.63 (Gomez et al. 2007), 17.42-21.10 (Ceyhan et al. 2007), 19.60-22.50 (Singh et al. 2008). These findings are similar to the current ones.

Former reports also found that the fat ratio (%) in chickpea seeds equalled 3.700-8.000 (Khan et al. 1995), 6.600 (Cai et al. 2002), 6.900 (Costa et al.

2004), 5.200 (Iqbal et al. 2004), 5.500-6.900 (Wang, Daun 2004), 6.000 (Patane 2006), 6.870 (Gomez et al. 2007), 5.750 (Nassar et al. 2008).

Similarly to the present results, the ash ratio (%) in chickpea seeds was determined to be 1.200-5.900 (Khan et al. 1995), 2.000-4.000 (Ak 2001), 2.900-3.800 (Wang, Daun 2004), 2.500-3.500 (Aslam et al. 2006), 3.000-3.400 (Singh et al. 2008).

Similar values were established for fiber (%) in chickpea seeds, namely 3.900-11.20 (Khan et al. 1995), 4.820-7.020 (Isik, Guler 2004), 4.200-7.700 (Wang, Daun 2004), 6.490-10.10 (Maheri et al. 2008).

The moisture ratio (%) in chickpea seeds was found out to be 10.90-11.50 (Aslam et al. 2006) and 8.100-8.900 (Singh et al. 2008). Those findings are in parallel with the present results.

Similar observations were made about the percentage of non-nitrogenous pith substances in the composition of chickpea seeds: 59.90 (Iqbal et al. 2004), 55.56 (Gomez et al. 2007), 60.96 (Maheri et al. 2008), 57.80% (Singh et al. 2008).

Investigations on the iron content revealed the following concentrations (mg kg^{-1}): 12.00-59.00 (Khan et al. 1995), 20.00-40.00 (Ak 2001), 29.00-38.00 (Wang, Daun 2004), 25.00-35.00 (Aslam et al. 2006), 30.00-34.00 (Singh et al. 2008) in chickpeas, and 65.00-84.10 (Ceyhan et al. 2008), 38.40-84.10 (Harmankaya et al. 2009) in dry bean. Herein, we report higher values than some of the previous findings. Those discrepancies could have been due to the stress types, genetic variation among the genotypes and the climatic conditions.

In some earlier research, the potassium content (mg kg^{-1}) in chickpeas was 8780.0-9050.0 (Ibanez et al. 1997), 5390.0-6210.0 (Saglam 2001), 5719.0-15184.0 (Poniedziałek et al. 2002), 2200.0-15800.0 (Wang, Daun 2004), 9290.0-9680.0 (Mut, Gulumser 2005), 11090.0-12720.0 (Haq et al. 2007), which resembles our findings.

Furthermore, similar values for the magnesium content (mg kg^{-1}) were given, e.g. 1680.0 (Mccarthy et al. 1977), 1220.0-1280.0 (Ibanez et al. 1997), 1942.0 (Ahmad et al. 2002), 1412.0 (Poniedziaek et al. 2002), 1890.0 (Patane 2006) in chickpeas, and 1745.0-1979.0 (Ceyhan et al. 2008), 902.0-1059.0 (Harmankaya et al. 2009) in dry bean.

Some analyses of the manganese content (mg kg^{-1}) in chickpea seeds yielded the value of 41.80 in wet conditions and 35.60 in dry conditions (Bagci 2010), which are in parallel with other, previously reported results. The lower values of our determinations may be due to the induction of stress, genetic structure and environmental conditions.

Elsewhere, the phosphorus content (mg kg^{-1}) in chikpea seeds was similar to our findings: 1260.0-3150.0 (Khan et al. 1995), 2100.0-2800.0 (Saglam 2001), 2400.0-8300.0 (Wang, Daun 2004), 3770.0-3960.0 (Mut, Gulumser, 2005), 2460.0-2590.0 (Haq et al. 2007).

Experiments that dealt with the zinc content (mg kg^{-1}) also produced similar results, e.g. 50.00 (Anonymous 1989), 18.00-54.00 (Khan et al. 1995), 35.00 - 35.70 (Ibanez et al. 1997), 27.20 (Ahmad et al. 2002), 68.00 (Iqbal et al. 2004), 21.00-56.00 (Wang, Daun 2004), 32.00-42.00 (Mut, Gulumser 2005), 35.00 - 57.00 (Haq et al. 2007) in chickpeas as well as 16.90-22.70 (Ceyhan et al. 2008), 20.90-28.50 (Harmankaya et al. 2009), 15.30-28.20 mg kg^{-1} (Shimelis, Rakshit 2005) in dry bean genotypes.

Former research reports contained similar results regarding the nutritional diversity among chickpea genotypes. Many researchers have demonstrated similar concentrations of nutritional components in seeds. Consequently, the current results are either similar to or only slightly different from previous reports. Those differences may be attributable to some differences between the genotypes, environment, agricultural practice, duration and intensity of drought.

CONCLUSIONS

The values obtained in the present research are similar to the ones achieved under dry conditions and reported by others. In general, responses of the genotypes to different levels of drought stress were modified by the investigated quality traits. Further research into the nutritional characteristics of these chickpea genotypes will be necessary to select the best genotypes with a high quality of the nutritional composition. Such investigations on the nutritional composition of seeds from chickpea genotypes as affected by drought stress should continue for the sake of improved food quality.

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