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CHICKPEA PERFORMANCE COMPARED TO PEA, BARLEY AND OAT IN CENTRAL EUROPE: GROWTH ANALYSIS AND YIELD

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ABSTRACT

An increase of grain legume production is essential for meeting feed protein need in Europe. Warming climates offer the opportunity for adapting crops with a more warm-season growth habit such as chickpea (*Cicer arietinum* L.) in cool, northern latitude areas. Therefore, yield and growth analysis of chickpea were assessed in a two-year field experiment in Central Europe (Raasdorf, Austria) and compared to pea, barley and oat, which are well adapted crops in that region. Chickpea had a lower above-ground biomass and grain yield compared to pea, barley and oat in 2006, whereas only pea was more productive than chickpea in the dry year of 2007. The relative good performance of chickpea regarding crop growth rate and relative growth rate compared to pea, barley and oat under severe drought in 2007 indicated that chickpea may be an interesting crop in the Central European production area in the face of possible climate change.

Keywords: Biomass production, Central Europe , chickpea, *Cicer arietinum*, growth rate

INTRODUCTION

The European Union has a deficit of protein sources for livestock relying therefore to a large extent on soybean meal imports. Increasing grain legume production in Europe could provide an alternative. Furthermore, grain legumes contribute to the diversification and long-term productivity of sustainable agricultural systems as they can satisfy a bulk of their N demand from atmospheric nitrogen through symbiosis with nitrogen fixing soil bacteria (*Rhizobium* spp.) thus minimizing the demand for N fertilizer inputs within crop rotations (van Kessel and Hartley, 2000). Positive yield effects on subsequent non-legume crops result from the soil-N sparing of the legumes and the transfer of biologically fixed N via crop residues (Chalk, 1998; Kaul, 2004).

Warming climates are prolonging growing seasons in northern latitudes and thus causing an impact on agricultural systems (Menzel et al., 2006). Under these conditions, promising opportunities may arise for adapting crops with a more warm-season growth habit such as chickpea (*Cicer arietinum* L.) in comparatively cool, northern latitude areas (Gan et al., 2009). Currently, pea (*Pisum sativum* L.) and soybean (*Glycine max* (L.) Merr.) are the most important grain legumes in Eastern Austria. Alternative crops like chickpea could become of interest for this region due to the forecasted change in climatic conditions with presumably longer periods of drought stress. Chickpea genotypes can effectively cope with drought conditions due to several morphological and physiological advantages of the crop (Serraj et al., 2004; Toker et al., 2007; Cutforth et al., 2009; Zaman-Allah et al., 2011). A former experiment showed that chickpea could compete on an average grain yield level of 3 t ha^{-1} with pea and soybean in Central Europe (Wichmann et al., 2005).

Chickpea is on the fourth position among grain legumes in the world regarding grain production after soybean, bean (*Phaseolus vulgaris* L.) and pea. It is mainly produced in areas classified as arid or semiarid environments (Canci and Toker, 2009ab). Chickpea is of high importance in human diets in many areas of the world. Additionally, chickpea grains can be used as energy and protein-rich feed in animal diets and chickpea straw as alternative forage for ruminants (Bampidis and Christodoulou, 2011). Although chickpea is not a common crop in Central Europe, it could provide an alternative for food and feed protein production in Central Europe in the face of possible climate change.

The objective of this study was to evaluate chickpea suitability in Central Europe, focussing on grain yield and growth analysis as compared to the legume pea and the non-legumes barley (*Hordeum vulgare* L.) and oat (*Avena sativa* L.), which are common crops in that region.

MATERIALS AND METHODS

Experimental factors

Chickpea genotypes were tested under different treatments of nitrogen fertilization in comparison to common varieties of pea and the non-legumes barley and oat. The experiment was set up in a randomized complete block design with two replications. The *Cicer arietinum* variety "Kompolti" and commercial seeds of a *C. arietinum* genotype of unknown origin (named by us after the trade company "Hirschhofer") (both are Kabuli type chickpeas) were planted. The seeds had been multiplied on-farm by our own. *Pisum sativum* cv. "Attika" and "Rosalie", *Hordeum vulgare* cv. "Xanadu" and *Avena sativa* cv. "Jumbo" were used as standards of comparison. The nitrogen fertilizer calcium ammonium nitrate (CAN) (27% N, 10% Ca) and the depot fertilizer Basacote® Plus 6M (16% N, 3.5% P, 10% K, 1.2% Mg, 5% S and micronutrients) were applied at two fertilization levels (10 and 20 g N g^{-2}) supplemented by an unfertilized control. Fertilizers were applied right after sowing.

Environmental conditions

The experiment was carried out in Raasdorf (48° 14' N, 16° 33' E) in Eastern Austria on the experimental farm Gross-Enzersdorf of BOKU University. The soil is classified as a chernosem of alluvial origin and rich in calcareous sediments (pH 7.6). The texture is silty loam; the content of organic substance is at 2.2-2.3%.

The mean annual temperature is 10.6°C, the mean annual precipitation is 538 mm (1980-2009). Table 1 shows the long-term average monthly temperature and precipitation (1980-2009) from February to July and the deviations during the 2006 and 2007 growing season. The temperature was considerable higher in 2007 than in 2006 (except for the month July). Monthly precipitation was highly above average in March and April in 2006. Contrary to that, the growing season 2007 was characterized by severe spring drought without rainfall from end of March to beginning of May.

Table 1. Long-term average monthly temperature and precipitation (1980-2009) and deviations during the 2006 and 2007 growing seasons

	Temperature (°C)			**Precipitation (mm)**		
	Mean (1980-2009)	**2006 (±)**	**2007 (±)**	**Mean (1980-2009)**	**2006 (±)**	**2007 (±)**
February	1.7	-1.9	3.8	26.4	-7.7	17.7
March	5.8	-2.1	2.3	38.5	7.7	28.0
April	10.7	1.3	2.1	35.3	30.3	-34.4
May	15.6	-0.5	1.6	56.1	16.7	-9.8
June	18.5	0.6	2.8	72.3	-9.9	-3.9
July	20.8	2.8	1.9	59.1	-52.3	-6.2

Experimental treatments and measurements

Seeds were sown with an Oyjard plot drill at a row distance of 12 cm on plots of 30 m^2. Seeds of chickpea were inoculated with *Mesorhizobium ciceri* (Jost GmbH), seeds of pea with *Rhizobium leguminosarum* (Radicin No4, Jost GmbH) according to product specifications before sowing. Table 2 gives detailed information on the experimental conditions and crop management practices. The development of above-ground dry matter was determined by harvesting (0.24 m² per plot) at intervals of about 14 days until end of June and drying (100°C, 24 h). For grain and straw yield assessment, the final harvest was performed at full ripeness of the plants on 0.96 m² per plot.

Table 2. Field experiment and crop management practices

		2006	**2007**
Sowing date		14 April	11 April
Row distance		12 cm	
Sowing rate (seeds m^{-2})	Chickpea	90	
	Pea	90	
	Barley	350	
	Oat	350	
Weeding		Mechanical hand weeding	
Harvest date 1		5 May	14 May
Harvest date 2		22 May	31 May
Harvest date 3		9 June	14 June
Harvest date 4		27 June	26 June
Harvest date 5	Chickpea	1 August	23 July
	Pea	20 July	9 July
	Barley	18 July	23 July
	Oat	24 July	23 July

Growth analysis

Crop growth rate (CGR) and relative growth rate (RGR) were calculated for each period between subsequent harvest dates according to Hunt (1982) as follows:

$CGR = (W_2 - W_1)/(t_2 - t_1)$

$RGR = (\ln W_2 - \ln W_1)/(t_2 - t_1)$

where W_2 and W_1 indicate the final and initial above-ground plant dry weight and t_2 and t_1 indicate the end and the start day of each period. Growth analysis is one way to verify ecological adaptation of crops to new environments (Namvar et al., 2011).

Statistics

Statistical analyses were performed using software SAS version 9.2. Analysis of variance (PROC GLM) with subsequent multiple comparisons of means were performed. Means were separated by least significant differences (LSD), when the F-test indicated factorial effects on the significance level of $p<0.05$. Genotype differences of chickpea and pea were not significant, so data were pooled for analysis.

RESULTS AND DISCUSSION

Above-ground biomass, final yield and harvest index

Grain yield of chickpea and the other crops was not affected in both years by N fertilization. Straw yield and consequently above-ground biomass (AGB) were increased by N fertilization in the more humid year 2006, whereas no effects of fertilization were found in the dry year 2007. No interactions of crop×fertilization were observed for the yield parameters (data not shown). Obviously the experimental site had a very fertile soil that supplied enough plant available N even in the unfertilized control plots. Farzaneh et al. (2009) found similar results with chickpea and barley in pot experiments.

A significant interaction of crop×year was observed for above-ground biomass (AGB), grain yield, straw yield and harvest index (Fig. 1). The AGB of chickpea was significantly lower than that of the other crops in 2006 whereas it was slightly lower than the AGB of pea and slightly higher than the AGB of barley and oat in 2007 (Fig. 1a). Drought occurring at the end of the growing period of the plants in 2006 might not have affected plant growth and yield substantially. Generally, the water restrictions limited AGB productions of all plants in the dry year of 2007. Precipitation in the late growing period in 2007 could not compensate for the drought damages that occurred earlier that season. Kurdali et al. (2002) reported that drought highly reduced dry matter production as well as nodulation and N_2 fixation of chickpea. Reduced N_2 fixation may additionally impair yields as reported for soybean (Salvagiotti et al., 2008). However, negative effects of drought on chickpea´s AGB productions were less pronounced compared to other crops.

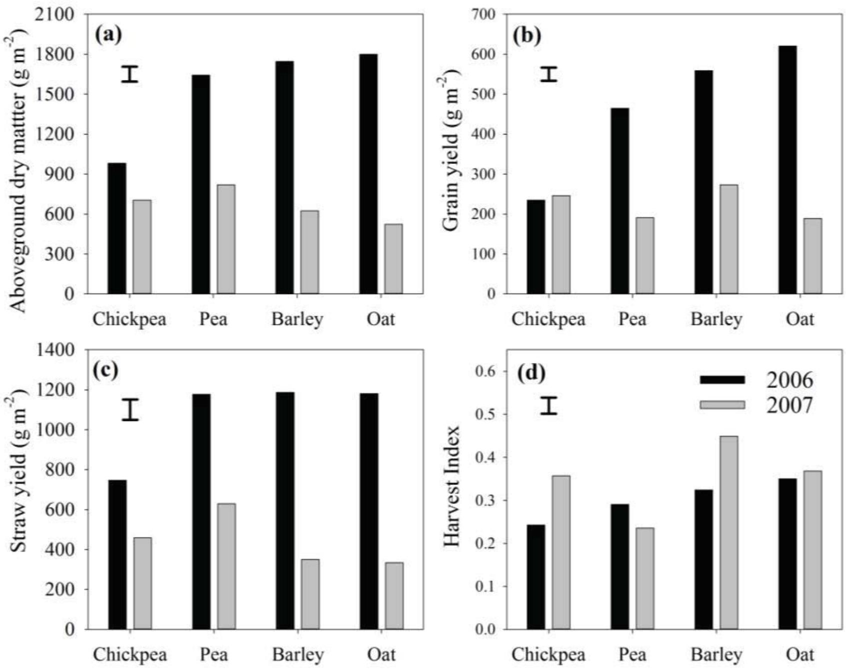

Figure 1. (a) Above-ground biomass, (b) grain yield, (c) straw yield and (d) harvest index depending on crop and year, error bars are LSD

Chickpea had the lowest grain yield among the four crops in 2006, while it had performed better in terms of grain yield than pea and oat in the dry year of 2007 (Fig. 1b). Barley had the highest grain yield among the studied crops in 2007 since it is one of the important drought resistant crops (Toker et al., 2009). Similar to our observations, Angadi et al. (2008) reported that chickpea grown in semiarid conditions in the Canadian prairie produced under mid- to late-season drought stress a higher grain yield compared to the crops canola (*Brassica napus* L. and *B. rapa* L.), mustard (*Brassica juncea* L.), pea and spring wheat (*Triticum aestivum* L.). Chickpea is better adapted to moderate to severe water stress due to its ability to maintain a positive turgor over a wide range of water potentials (Cutforth et al., 2009), a deep and prolific root system (Serraj et al., 2004) and a conservative pattern of water use (Zaman-Allah et al., 2011). Chickpea grain yields (2006: 235 g m^{-2}, 2007: 246 g m^{-2}) in Central Europe seem to be satisfying in face of grain yield reported in experiments conducted in Turkey, one of the main chickpea producing countries, which were at 186 g m^{-2} (Özalkan et al., 2010).

The straw yield of chickpea was lower than that of the other crops in 2006 but it was higher than those of barley and oat in 2007 (Fig. 1c). Chickpea had the lowest harvest index in 2006, while its harvest index was in a similar range to that of oat, higher compared to pea and lower compared to barley in 2007 (Fig. 1d). Under the dry conditions of 2007, chickpea´s harvest index was considerably higher than in 2006. Chickpea has an indeterminate growth habit (Yildirim et al., 2013), thus under favourable growing conditions the plant continues the vegetative growth and delays pod setting, seed filling and maturity (Liu et al., 2003; Gan et al., 2009). Sinha et al. (1982) reported that sufficient water availability after flowering is used by chickpea for a prolonged vegetative growth resulting thereby in further increase of total above-ground biomass but not necessarily in a grain yield gain. Consequently, chickpea can achieve a good harvest index under drought conditions. Angadi et al. (2008) reported that the harvest index of chickpea was not so severely impaired by drought conditions in the Canadian Prairie as compared to that of pea, wheat and oilseed crops. Our results are also in accordance with Fulkai (1995) who reported an increased harvest index under water stress at two of three experimental sites. A crop's ability to maintain a high harvest index is important for its adaption to semiarid conditions (Ludlow and Muchow, 1990). An increased biomass partitioning into seed contributes especially under dry conditions to the relatively large seed yield of the lower biomass producing pulse crops, like chickpea, compared with other crops (Angadi et al., 2008).

Growth analysis

The crop growth rates (CGR) of chickpea, pea, barley and oat are shown in Fig. 2. Crop growth rate is a function of canopy gross photosynthesis and crop respiration (Evans, 1993). These processes are influenced by environmental conditions such as temperature, solar radiation, water and nutrient supply (Connor et al., 2011). Fertilization positively influenced the crop growth rates of all tested crops until middle of June, i. e. until harvest date 3, which was set in accordance with flowering of pea and chickpea (data not shown).

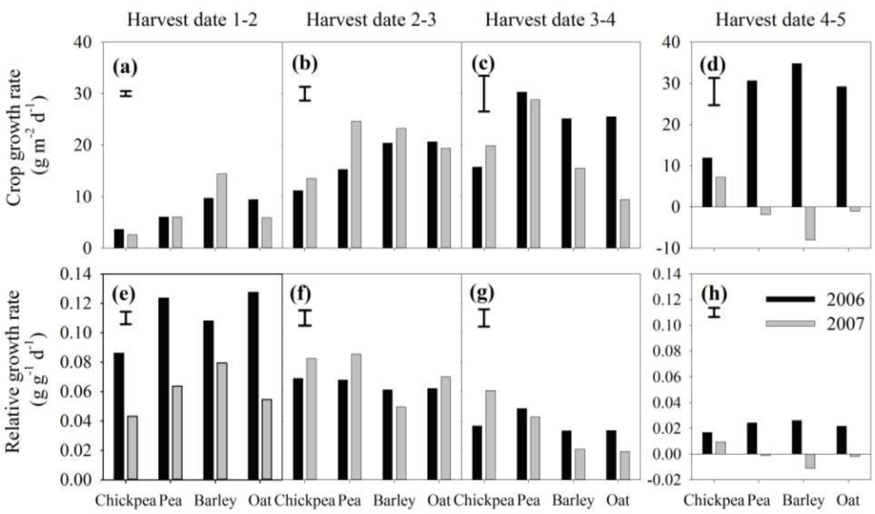

Figure 2. Crop growth rate (a-d) and relative growth rate (e-h) depending on crop and year, error bars are LSD

The CGR was lowest at early growth. There was a significant crop×year interaction in all observation periods (Figs. 2a-d). The crop growth rate of chickpea was consistently lower than that of the other crops in 2006 whereas chickpea´s CGR remained lower until middle of June (harvest date 3) in 2007 (Fig. 2a, b), subsequently exceeding the CGR of barley and oat but staying below that of pea (Fig. 2c). After end of June (harvest date 4-5), the CGR of chickpea was the highest one among the four crops (Fig. 2d). Obviously, chickpea performed better compared to the other crops in the dry conditions of 2007. Although rainfall (below the long-term average) occurred in June and July 2007, water limitations due to severe spring drought with absent rainfall for some weeks may have strongly impaired CGR of pea, barley and oat at the end of the growth period (harvest date 4-5) while the slower development of chickpea allowed to profit from this late water supply. Koutroubas et al. (2009) reported that different weather conditions were among the main causes of seasonal variation in rainfed chickpea growth and productivity under Mediterranean conditions. Our results showed generally lower variations of chickpea´s CGR between the two years indicating that the crop growth of chickpea may have been less affected by environmental conditions compared to that of pea, barley and oat.

The relative growth rate (RGR) was the highest at early growth and decreased with time (Figs. 2e-h). This is due to the increase of the share of non-assimilatory tissues with time (Nogueira et al., 1994). The RGR was only affected by fertilization in 2006, when RGR of all fertilized treatments was higher than that of the unfertilized control (data not shown). The RGR of chickpea was lower than that of the other crops in the first growth period in 2006, whereas it remained in the other periods on a similar level as with pea, barley and oat. In 2007, chickpea´s RGR was the lowest again in the first period (Fig. 2e). In the second period the RGR of the legumes was higher than that of the cereals (Fig. 2f). Starting with sampling date 3 the RGR of chickpea was the highest among the tested crops being the only one with positive values after end of June (date 4) (Fig. 2g, h) until harvest. Consequently, chickpea had the highest biomass increase per unit of biomass and per unit of time among the tested crops after mid of June 2007.

CONCLUSION

Yield and growth analysis assessment of chickpea compared with pea and cereals was performed in a two-year experiment in Central Europe. Chickpea had a lower above-ground biomass and grain yield compared to pea, barley and oat in the humid year 2006, whereas only pea was more productive than chickpea in the dry year of 2007. This and the good performance of chickpea regarding the crop growth rate and the relative growth rate during late crop development under severe drought in 2007 indicate that chickpea may be an interesting crop for the Central European production area in the face of possible climate change.

LITERATURE CITED

Angadi, S.V., McConkey, B.G., Cutforth, H.W., Miller, P.R., Ulrich, D., Selles, F., Volkmar, K.M., Entz, M.H. and S.A. Brandt. 2008. Adaptation of alternative pulse and oilseed crops to the semiarid Canadian Prairie: Seed yield and water use efficiency. Can J Plant Sci 88:425-438.

Bampidis, V.A. and V. Christodoulou. 2011. Chickpeas (*Cicer arietinum* L.) in animal nutrition: A review. Anim Feed Sci Technol 168:1-20.

Canci, H. and C. Toker. 2009a. Evaluation of annual wild *Cicer* species for drought and heat resistance under field conditions. Genet Resour Crop Ev 56:1-6.

Canci, H. and C. Toker. 2009b. Evaluation of yield criteria for drought and heat resistance in chickpea (*Cicer arietinum* L.). J Agron Crop Sci 195:47-54.

Chalk, P.M. 1998. Dynamics of biologically fixed N in legume-cereal rotation: a review. Aust J Agric Res 49:303-316.

Connor, D.J., Loomis, R.S. and K.G Cassman. 2011. Crop Ecology: Productivity and Management in Agricultural Systems. 2. ed. Cambridge, UK: Cambridge University Press.

Cutforth, H.W., Angadi, S.V., McConkey, B.G., Entz, M.H., Ulrich, D. Volkmar, K.M., Miller, P.R. and S.A. Brandt. 2009. Comparing plant water relations for wheat with alternative pulse and oilseed crops grown in the semiarid Canadian prairie. Can J Plant Sci 89:823-835.

Evans, J. 1982. Symbiosis, nitrogen and dry matter distribution in chickpea (*Cicer arietinum* L.). Exp Agr 18:339-351.

Farzaneh, M., Wichmann, S., Vierheilig, H. and H.-P. Kaul. 2009. The effects of arbuscular mycorrhiza and nitrogen nutrition on growth of chickpea and barley. Pflanzenbauwiss 13:15-22.

Fulkai, T.S. 1995. Growth and yield response of barley and chickpea to water stress under three environments in southeast Queensland. I. Light interception, crop growth and grain yield. Aust J Agric Res 46:17-33.

Gan, Y.T., Warkentin, T.D., McDonald, C.L., Zentner, R.P. and A. Vandenberg. 2009. Seed yield and yield stability of chickpea in response to cropping systems and soil fertility in northern latitudes. Agron J 101:1113-1122.

Hunt, R. 1982. Plant Growth Curves. Functional Approach to Plant Growth Analyses. London: Edward Arnold.

Liu, P.H., Gan, Y.T., Warkentin, T. and C.L. McDonald. 2003. Morphological plasticity of chickpea in a semiarid environment. Crop Sci 43:426-429.

Ludlow, M.M. and R.C. Muchow. 1990. A critical evaluation of the traits for improving crop yields in water limited environments. Adv Agron 43:107-153.

Kaul, H.-P. 2004. Pre-crop effects of grain legumes and linseed on soil mineral N and productivity of subsequent winter rape and winter wheat crops. Bodenkultur 55:95-102.

Koutroubas, S.D., Papageorgiou, M. and S. Fotiadis. 2009. Growth and nitrogen dynamics of spring chickpea genotypes in a mediterranean-type climate. J Agr Sci 147:445-458.

Kurdali, F., Al-Ain, F. and M. Al-Shamma. 2002. Nodulation, dry matter production, and N_2 fixation by fababean and chickpea as affected by soil moisture and potassium fertilizer. J Plant Nutr 25:355-368.

Menzel, A., Sparks, T.H. and N. Estrella. 2006. European phenological response to climate change matches the warming pattern. Glob Change Biol 12:1969-1976.

Namvar, A., Sharifi, R.S. and T. Khandan. 2011. Growth analysis and yield of chickpea (*Cicer arietinum* L.) in relation to organic and inorganic nitrogen fertilization. Ekologija 57:97-108.

Nogueira, S.S.S., Nagai, V., Braga, N.R., Do, M., Novo, C.S.S. and M.B.P. Camargo. 1994. Growth analysis of chickpea (*Cicer arietinum* L.). Sci Agr 51:430-435.

Özalkan, C., Sepetoğlu, H.T., Daur, I. and O.F. Şen. 2010. Relationship between some plant growth parameters and grain yield of chickpea (*Cicer arietinum* L.) during different growth stages. Turk J Field Crops 15:79-83.

Salvagiotti, F., Cassman, K.G., Specht, J.E., Walters, D.T., Weiss, A. and A. Dobermann. 2008. Nitrogen uptake, fixation and response to fertilizer N in soybeans: A review. Field Crops Res 108:1-13.

Serraj, R., Krishnamurthy, L., Kashiwagi, J., Kumar, J., Chandra, S. and J.H. Crouch. 2004. Variation in root traits of chickpea (*Cicer arietinum* L.) grown under terminal drought. Field Crops Res 88:115-127.

Sinha, S.K., Khanna-Chopra, R., Aggarwal, P.K., Chaturvedi, S. and K.R. Koundal. 1982. Effect of drought on shoot growth: significance of metabolism to growth and yield. In: Drought resistance in crops with emphasis on rice. ed. International Rice Research Institute, 153-170, International Rice Research Institute, Los Baños, Laguna, Philippines.

Toker, C., Lluch, C., Tejera, N.A., Serraj, R. and K.H.M. Siddique. 2007. Abiotic stresses. In: Yadav, S.S., Redden, R., Chen, W. and Sharma, B. (eds) Chickpea breeding and management. CAB Int., Wallingford, UK, pp. 474-496.

Toker, C., Gorham, J. and M.I. Çagirgan. 2009. Certain ion accumulations in barley mutants exposed drought and salinity. Turk J Field Crops 14:162-169.

van Kessel, C. and C. Hartley. 2000. Agricultural management of grain legumes: has it led to an increase in nitrogen fixation? Field Crops Res 65:165-181.

Wichmann, S., Wagentristl, H. and H.-P. Kaul. 2005. Der Anbau von Kichererbsen in Vergleich zu Körnererbsen und Sojabohnen, Mitt Ges Pflanzenbauwiss 17:28-29.

Zaman-Allah, M., Jenkinson, D.M. and V. Vadez. 2011. A conservative pattern of water use, rather than deep or profuse rooting, is critical for the terminal drought tolerance of chickpea. J Exp Bot 62:4239-4252.

Yildirim, T., Canci, H., Inci, N.E., Baloglu, F.O.C., Ikten, C. and C. Toker. 2013. Inheritance of female sterility in induced *Cicer* species. Turk J Field Crops 18:78-81.