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A Study on Drought Tolerance at Chickpea (*Cicer arietinum* L.) with Quantitative Character Locus Analysis

Ufuk KARADAVUT[1]*, Ömer SÖZEN[2]

[1]Karabük Üniversitesi, Temel Bilimler Bölümü, Karabük, Türkiye
[2]Sivas Bilim ve Teknoloji Üniversitesi, Tarım Bilimleri ve Teknoloji Fakültesi Sivas, Türkiye

*Sorumlu Yazar: omers@sivas.edu.tr

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ABSTRACT

The chickpea plant is a very important plant in terms of plant-based protein supply. However, in recent years, the drought problem brought about by climate change has started to limit production. As a result, the necessity of directing breeding programs in this direction has emerged. This study, it was aimed to determine the drought tolerance of the local chickpea genotypes collected from Kırşehir province and the genetically related regions. For this purpose, the KGN-15 genotype obtained by crossing KMNG-27 and KKNG-09 genotype, which is considered drought tolerant, was studied among 67 genotypes collected. The characteristics examined in the study were the number of days until germination, the number of flowering days, plant height, the number of pods per plant, biological yield, 100 seed weight, harvest index, relative leaf water content, membrane permeability index, water uptake index, yield, root length, root is the ratio of bud length, root bud ratio, root fresh weight, fresh shoot weight, root dry weight, bud dry weight and root dry weight to total plant dry weight.As a result, it was seen that Yozgat province is in a better condition in terms of phenotypic and genotypic characteristics due to the more regular precipitation distribution compared to Kırşehir province. While 6 of the 23 QTL used were major effective, 17 were determined to be minor effective. According to the results obtained, QTL, which have a positive effect, have shown that they can contribute to increasing the trait values of donor parent alleles. Those with negative influence showed that the parent who was in the receptive position had higher characteristics. For both locations, the above-ground parts were defined as 6 QTL in Kırşehir and 7 QTL in Yozgat, while root-related features were defined as 11 QTL in Kırşehir and 4 QTL in Yozgat.

Key words: Chickpea, parameter, genotype, locus analysis, quantitative character.

Kantitatif Karakter Lokus Analizi ile Nohutta (*Cicer arietinum* L.) Kuraklık Toleransı Üzerine Bir Çalışma

ÖZ

Nohut bitkisi bitkisel kaynaklı protein temini açısından oldukça önemli bir bitki olup son yıllarda iklim değişikliğinin getirdiği kuraklık sorunu üretimi sınırlamaya başlamıştır. Bunun sonucu olarak ıslah programlarının bu yöne doğru yönlendirilmesi gerekliliği ortaya çıkmıştır. Bu çalışma ile Kırşehir ilinden toplanan yerel nohut genotiplerinin kuraklığa toleransı ile genetik olarak bunun bağlantılı bölgelerin tespit edilmesi amaçlanmıştır. Bunun için toplanan 67 nohut genotipi içinden kuraklığa toleranslı görülen KMNG-27 ile KKNG-09 genotiplerinin çaprazlanması ile elde edilen KGN-15 genotipi üzerinde çalışılmıştır. Çalışmada incelenen özellikler çimlenmeye kadar geçen gün sayısı, çiçeklenme gün sayısı, bitki boyu, bitki başına bakla sayısı, biyolojik verim, 100 tane ağırlığı, hasat indeksi, bağıl yaprak su içeriği, membran geçirgenlik indeksi, su alma indeksi, verim, kök uzunluğu, kök sürgün uzunluğu, kök sürgün oranı, kök taze ağırlığı, taze sürgün ağırlığı, kök kuru ağırlığı, sürgün kuru ağırlığı ve kök kuru ağırlığının toplam bitki kuru ağırlığına oranıdır.

Sonuç olarak Yozgat ilinin Kırşehir iline göre yağış dağılımının daha düzenli olması nedeniyle fenotipik ve genotipik özellikler bakımından daha iyi durumda olduğu görülmüştür. Kullanılan 23 QTL'den 6'sı majör etkili olurken 17'si ise minör etkili olarak belirlenmiştir. Elde edilen sonuçlara göre pozitif bir etkiye sahip olan QTL'lerin donör ebeveyn alellerinin özellik değerlerinin artırılmasına katkıda bulunabileceğini göstermiştir. Negatif etkiye sahip olanlar ise alıcı konumunda bulunan ebeveynin daha yüksek özelliğe sahip olduğunu göstermiştir. Her iki lokasyon için toprak üstü kısımlar için Kırşehir için 6 QTL ve Yozgat için 7 QTL tanımlanırken kök ile ilgili özellikler için incelenen özellikler için Kırşehir için 11 QTL ve Yozgat için 4 QTL tanımlanmıştır.

Anahtar kelimeler: Nohut, parametre, genotip, lokus analiz, kantitatif karakter.

INTRODUCTION

Chickpea is an important basic food source for humans and can be grown successfully especially in regions with arid and semi-arid climates. Also, against cold it is quite tolerant (Düzdemir and Akdağ, 2007; Karaköy et al., 2012). Chickpea which is a self-pollinating plant, has a diploid 2n=16 chromosome and has a genome size of approximately ~738 Mb (Varshney et al., 2013; Dumanoğlu et al., 2022). This plant which has a wide adaptation ability, also has high protein (23%) and carbohydrates (40%) and vitamin A, B and E contents (Kaytan, 2006). The biological value of chickpea protein is quite high and it is distinguished from other legumes due to this feature (Sabaghpour et al., 2018). It is easier to cultivate than other legumes and can be grown in large areas due to its low ecological demand. However, especially some biotic and abiotic adverse conditions limit the cultivation of chickpeas. Although the most important abiotic stress factor in most field crops is drought, chickpea can be grown without irrigation in most of our country. Since chickpea cultivation is carried out depending on precipitation, in case of decrease in precipitation, the plant gets stressed and causes low yield. Hajjapoor et al. (2018) stated that this rate is around 60% on average. Yield loss due to weed is around 50% (ICARDA-FSP, 1986; Kantar et al., 1999; Hassan and Khan, 2007).

The effect of biotic and abiotic conditions has begun to increase, especially due to global warming. For this reason, the necessity of bringing the drought to the fore has emerged as well as the reorganization of the breeding programs. Drought-induced crises can always be the determinant of other factors (Hall and Richard, 2013). Sciarresi et al. (2019) stated that drought stress affects plants negatively and the damage changes depending on whether it is temporary or permanent. However, the drought that is effective here is the drought observed at the time of fertilization and which prevents pollination. Sometimes the drought is so effective that the fertilization activity can stop completely (Şehirali, 1988). Drought is a quantitative trait and is directly affected by the interaction between the genotype and the environment (Van Dijk et al., 2017; Ceyhan et al., 2012b; Kahraman et al. 2016). Especially, high degree of drought observed in breeding studies can significantly limit genotype selection. Because, as a result of large changes in dry matter accumulation, reductions in the total canopy ratio cause a decrease in yield per plant, but wrong selection can be made in single plant selections (Krisnamurty et al., 2010).

Drought has begun to seriously threaten crop production today and is expected to increase its negative effects further in the coming periods. Plants have developed defense mechanisms to protect themselves and survive against water stress (Ceyhan et al., 2012a; Gökmen and Ceyhan, 2015; Örs and Ekinci, 2015). In order to be successful in future studies, it is necessary to fully understand the genetic basis (Yıldız, 2020). A serious evaporation problem has started with the drought due to global climate change (Teuling et al., 2013). Due to the fact that the evaporation amount is much higher than necessary, there may be great losses in yield. Due to the height of evaporation, the growth rate of the plants can be adversely affected by the leaf area index and the amount of dry matter (Purushothaman et al., 2016). Drought in chickpea can shorten the flowering period and also cause a significant decrease in vegetative parts, photosynthetic activity, membrane permeability, chlorophyll, proline and ABA contents (Ceyhan et al., 2012a; Gaur et al., 2012; Gökmen and Ceyhan, 2015; Kushwah et al., 2020).

In order to determine drought tolerance in chickpea plant and to better understand the events, chickpea genetic resources and germplasm should be screened very well. Therefore, it will be possible to select productive genotypes that are drought tolerant and have a very well developed root system (Kashiwagi et al., 2006). It is important to determine the genotypes and to cultivate them in terms of drought resistance. However, it is known that this is very difficult to do. The first thing to do is to change the direction of breeding studies by determining quantitative loci in terms of drought tolerance. DNA markers have been used extensively in breeding studies. Therefore, QTL, which is defined as a quantitative character locus, has been used to determine genetic structures and successful results have been obtained (İşci, 2008; Sivashakthi et al., 2018). QTL analysis can successfully explain variational relationships as well as mapping genes in chickpea plant. With the QTL analysis, genetic characteristics that show drought tolerance in chickpea were determined (Varshney et al., 2014). QTL is a next-generation sequencing technique and can explain many complex features. Puritz et al. (2014) stated that it is possible to determine the optimal number of ideal regions with QTL analysis. Stephens et al. (2014) stated that this is necessary for more effective use of the narrow genetic base in chickpeas. Thudi et al. (2011) stated that they were successful in creating genetic maps of interspecies genes.

The aim of this study is to determine the drought tolerance characteristics of the mapping population among the progeny obtained from the cross between the local chickpea genotypes collected from Kırşehir province and also to determine the regions that are genetically related to them.

MATERIAL and METHOD

In the seed collection studies carried out in Kırşehir and Yozgat provinces, 67 local chickpea populations were collected. Among these populations, one genotype was selected, which was found to be promising in terms of root characteristics, yield, and morpho-physiological characteristics under cultivation conditions without irrigation. The genotype named KNG-15 is a highly drought-tolerantt chickpea genotype and it is a genotype selected from village populations in Kırşehir province and obtained by crossbreeding. One of the parents of this genotype is KMNG-27 collected from the villages of Mucur district and the other is KKNG-09 village population collected from the villages of Kaman district. The KNG-15 chickpea genotype has semi-upright growth. With its plant height in the range of 65-70 cm, its branching ability is less than its other counterparts. At the same time, this genotype has a high drought tolerance. Although this genotype is semi-resistant to Ascochyta blight, it has been observed to be tolerant to Fusarium wilt.

Sowing of parent genotypes with KNG-15 was carried out in the experimental fields of Kırşehir Ahi Evran University, the first of which is located in the Merkez district of Kırşehir province, between 2019-2020 and the second one was included in the experiment in 3 replications according to the randomized plots trial design in the producer's land in the Sarıkaya district of Yozgat province. The plots were arranged with 30 cm row spacing and 10 cm row spacing, and sowing was carried out in 5 meter long parcels. Sowing operations were carried out in both locations in October, and harvesting was completed at the end of June. The ecology of both locations has similar characteristics and there is a distance of 175 km between the two locations. Annual precipitation is between 350-400 mm in both locations. The soil composition of both locations is generally low in terms of organic matter and rich in clay, sand ,and lime. Although soil pH is 7.9 in Kırşehir, it was determined as 7.8 in Yozgat. It can be said that both locations have a slightly alkaline structure. The most important problem here is the irregularity of the precipitation rather than the amount of precipitation.

In order to make the first stages of plant development healthier, weed control was carried out manually on the 20th and 45th days after emergence. In order to support nodule formation, 2 kg of pure nitrogen and 6 kg of pure phosphorus were given to each plot per decare in both locations. Irrigation was not carried out in both locations and the water needs of the plants were met completely from the rains. The reason for the inability to irrigate is the very limited irrigation possibilities in the region and to see how the morphological characteristics such as pod tying and yield, especially the flowering date of the genotypes against drought, change in arid conditions. The field water capacity started with the completion of the emergence of the plants and was measured every 15 days with the help of samples taken from the plot heads. While the field water capacities increased slightly in the days after the rain, they decreased rapidly when the rainless days lasted longer. In some cases, the field water capacity has even decreased to the fading point. In fact, it has been determined that the water holding capacity of the soils is not very bad.

The water holding capacity (WHC) of the soils was calculated with the help of the following equation (Çevik, 2020);

WHC= (MLFC – MLWP) x VVS x SD

WHC: Water holding capacity (mm/m)

MLFC: Moisture level at field capacity (volume percent)

MLWP: Moisture level at wilting point (volume percent)

VVS: Volume value of soil (g cm^{-3})

SD: Soil depth (mm)

In the study, some morphological and physiological properties (the number of days until germination, number of days of flowering, plant height, the number of pods per plant, biological yield, 100 seed weight, harvest index, relative leaf water content, membrane permeability index, water uptake index and yield) that determine plant growth and development were measured.

The membrane permeability index was calculated with the help of the following equation;

MPI=[1-(C1/C2)]×100

Here, MPI is the membrane permeability index; C1 denotes the initial electrical conductivity value at 40 °C and C2 the final electrical conductivity value at 100 °C.

Root structure is considered as an important criterion in drought studies. Knowing plant root characteristics can give us important information in terms of determining drought resistance and tolerance. In the study, the ratio of root length, root shoot length, root shoot ratio, root fresh weight, fresh shoot weight, root dry weight, shoot dry weight and root dry weight to total plant dry weight were determined (Aldemir and Ceyhan, 2015). In the study, 10 plants randomly taken from the plots were selected to determine the morphological and physiological characteristics. In the study of determining root characteristics, cylinders made of PVC (polyvinyl chloride) material were used. These cylinders with a diameter of 20 cm and a length of 120 cm were arranged in three repetitions as in the plots. Vertisol and sand were mixed equally in the rollers and sand was used to facilitate root growth. Plant roots were carefully collected during the flowering period and were carefully immersed in water to purify them from the soil. In order to prevent the soil and root fragments from being lost, sieving was done with the help of a 2 mm sieve. The obtained parts were returned to the trial. While the fresh weights were weighed on a scale with an accuracy of 0.001, the dry weights were weighed after drying at 70 ^{0}C for 72 hours.

The significance of the differences observed in terms of the characteristics examined in the study was determined by performing analysis of variance. Individual means were calculated using mixed model analysis to estimate the contribution of each factor to the total variation. Relationships between the considered features were determined by Pearson's correlation coefficient. QTL analysis was performed using the Compound interval method (CIM) implemented in the Windows QTL Cartographer V2.5 software package (Wang et al., 2007). Compound interval method was performed using stepwise regression analysis. The statistical significance level was determined as 0.05 and the results were evaluated accordingly. The position of the QTL is defined on the basis of the logarithm of the peak of probabilities with a 95% confidence interval. Percentage of phenotypic variance explained by QTLs and additive effect were also estimated. While QTLs that explained >10% of the total phenotypic variance were classified as major-effecting QTLs, those that explained <10% were considered minor-effecting QTLs (Varshney et al., 2014). The phenotypic contribution (R^2) was estimated as the percentage of the variance explained by each QTL proportional to the total phenotypic variance. 56 polymorphic SNPs were used for connectivity maps (Kushwah et al., 2020). BLUP values and drought tolerance values for the investigated traits were used to determine the QTLs. A total of 23 QTLs were used to identify morphological and physiological features. Of the 23 QTLs, 6 were determined to be major effective, while 17 were determined to be minor. In the study, analyzes were performed using the XXX package in MINITAB 17 and R software.

RESEARCH FINDINGS and DISCUSSION

Although the genotype and parents evaluated differed according to the characteristics examined during the two years they were raised, significant differences were observed due to the climate. The results for the obtained values are shown in Table 1. When the table is examined, it is seen that there are differences between the characters according to the provinces. However, it was determined that these differences were not statistically significant (P>0.05). The fact that the differences did not turn out to be significant was evaluated as the ecological similarity of Kırşehir and Yozgat provinces to each other. These results were similar not only for morphological features, but also for root and some physiological features. It has been stated by most researchers who have done research on these issues that there will be no major morphological and physiological changes between genotypes grown under similar ecological conditions (Pundir et al., 1985; Singh et al., 1990; Düzdemir and Akdağ, 2007; Ceyhan et al., 2012a; Ceyhan et al., 2012b; Gökmen and Ceyhan, 2015; Topalak and Ceyhan, 2015; İşlek and Ceyhan, 2016; Kahraman et al. 2016; Güngör and Dumlupınar, 2018).

Shah et al. (1983) stated in their study that there are significant changes in vegetative characteristics as environmental characteristics differ, but there is no significant change in similar climatic conditions. Mart (2000) made a similar assessment too. Accordingly, the results we obtained are similar to the findings of the researchers. Similar ecologies do not cause statistically significant changes in genotypes. However, Karadavut and Sözen (2020) emphasized the importance of having similar soil characteristics as well as ecology in their study. Wood and Hunt (1997) stated that genotypes grown in similar ecological conditions may be affected by periodic changes in ecological conditions.

In the current study, it was observed that there were no major changes in ecological factors periodically. Of course, seasonal factors such as high temperature and drought can negatively affect plant growth and development. At the same time, if all factors are positive, growth and development can occur much above normal. In this case, the evaluations to be made will not be realistic. In this respect, no abnormality was observed in the present study.

According to the results obtained in the study, plants were affected by drought. In particular, this was clearly observed in root-related data and morphological and physiological features. Yozgat province had a better situation than Kırşehir province. While there was no significant difference in precipitation between provinces, the distribution of precipitation in Yozgat province was more regular. Because in the cultivation of field crops, the distribution of precipitation is more important than the amount of precipitation. (Sayılgan and Kocatürk, 2019). Saxena et al. (1983) stated that the distribution of precipitation is important in chickpea cultivation. They stated that there is a great need for water, especially at the beginning of germination and flowering. Rainfall or irrigation in the specified periods has a significant and positive effect on yield (Misra, 1991; Mart et al., 2005).

Table 1. Some descriptive statistics and genetic parameter results of examined characters

Character	Environment	KMNG 27 (Genotype)	KKNG 09 (Genotype)	Contrast Between Parents	Average	Coefficient of Variation	Genotypic Variance	Environment x Genotype Variance	h^2
Number of Germination Days (day)	Kırşehir	11,2±SE	10,6±SE	75,19**	9,6±SE	7,18	19,55**	0,56	47,18±SE
	Yozgat	12,6	11,3	69,06*	10,8	11,03	22,34**	0,62	41,77
Number of Flowering Days (day)	Kırşehir	76,3	80,2	97,35**	77,1	16,98	9,78**	0,54	44,12
	Yozgat	78,1	80,3	103,21**	79,5	13,47	7,79**	0,55	26,89
Plant Height (cm)	Kırşehir	58,6	61,4	37,06*	60,8	4,22	5,12*	2,76	51,66
	Yozgat	61,2	60,5	42,88**	60,7	3,17	6,82*	2,49	62,09
Biological Yield (g plant^{-1})	Kırşehir	82,7	86,1	63,92*	85,1	21,05	12,88**	12,87**	78,92
	Yozgat	78,3	77,4	132,04**	78,0	19,40	16,31**	11,93**	81,27
100 Seed Weight (g)	Kırşehir	52,9	49,3	29,79*	51,8	1,37	31,05**	1,01	87,90
	Yozgat	48,6	49,7	41,07**	49,2	1,51	27,48**	1,12	88,14
Harvest Index (%)	Kırşehir	44,6	47,2	163,45**	45,4	8,83	16,90**	4,52**	89,06
	Yozgat	42,5	44,0	209,31**	43,3	9,19	12,49**	5,01**	91,25
Relative Leaf Water Content (mg)	Kırşehir	58,8	54,8	33,02**	55,6	3,06	23,71**	0,78	88,53
	Yozgat	57,2	55,1	39,77**	56,2	3,27	21,03**	0,72	90,04
Membrane Permeability Index	Kırşehir	41,8	38,7	21,67**	39,9	18,56	4,58**	2,14	87,63
	Yozgat	42,6	39,0	19,93*	40,4	21,77	5,01**	2,26	88,81
Water Uptake Index (%)	Kırşehir	1,108	1,054	38,19**	1,088	2,04	7,28**	3,25	90,77
	Yozgat	1,069	1,018	31,03*	1,036	1,99	6,73**	2,79	91,13
Yield (kg da^{-1})	Kırşehir	98,16	93,12	317,51**	95,2	18,92	30,42**	14,25**	89,67
	Yozgat	103,68	104,59	297,04**	104,1	21,03	28,94**	15,43**	90,92
Root Length (cm)	Kırşehir	85,54	93,17	37,73**	88,46	15,47	17,89**	3,18**	91,12
	Yozgat	89,12	91,05	44,13**	82,19	18,11	21,04**	2,69**	90,56
Root Bud Length (cm)	Kırşehir	37,59	27,58	75,79**	26,14	11,87	6,78**	2,39**	93,27
	Yozgat	28,29	31,14	81,55**	29,06	10,56	7,14**	2,06**	95,15
Root Bud Rate (%)	Kırşehir	5,06	4,51	76,54**	8,12	24,48	5,78**	10,37**	79,05
	Yozgat	3,28	3,92	77,18**	9,04	21,03	6,29**	12,54**	82,13
Root Fresh Weight (g)	Kırşehir	7,68	2,78	65,43**	4,42	17,16	10,02**	6,69**	94,42
	Yozgat	9,04	2,83	74,98**	3,17	17,44	11,65**	7,12**	92,18
Root Dry Weight (g)	Kırşehir	7,93	7,14	105,42**	1,15	13,28	20,87**	4,06**	76,44
	Yozgat	8,15	8,09	97,17**	0,96	14,52	18,93**	9,76**	81,17
Bud Fresh Weight (g)	Kırşehir	3,44	9,77	18,47**	3,78	21,50	4,76**	11,03**	92,36
	Yozgat	2,79	11,12	25,62**	4,12	20,48	6,44**	8,76**	93,31
Bud Dry Weight (g)	Kırşehir	1,28	4,51	143,82**	1,03	12,58	11,58**	5,59**	88,82
	Yozgat	2,26	5,53	135,22**	1,18	15,00	13,62**	6,12**	85,67
Root Dry Weight / Plant Dry Weight Ratio (%)	Kırşehir	1,38	1,48	55,48**	0,33	17,89	16,73**	7,01**	83,94
	Yozgat	1,45	1,25	67,18**	0,31	19,14	18,88**	6,89**	84,68

***P<0,05; **P<0,01) SE: Standard Error**

Considering the coefficients of variation by evaluating both locations together, the lowest was 1.37 and the highest was determined as 24.48. Considering the locations, it is seen that Yozgat is in the range of 1.51-

21.77, and Kırşehir is in the range of 1.37-24.48. Accordingly, it is understood that the spread in Kırşehir province is higher than Yozgat province. Excessive spread may be due to the characteristics of the genotype, but also to the effects of ecological factors (Seber and Wild, 1989; Kaçar et al., 2005). Considering the genotypic variance, it was seen that all the traits examined were important. Since the genotype is the most important determinant of a living thing, living things move within the limits allowed by the genotype. However, it is known that the environment greatly affects the genetic effect and the variation expands as much as possible (Breese, 1969). While plant height was significant according to the statistical significance level of 0.05 in both locations, other characteristics were determined to be significant compared to 0.01. The fact that the genotype variance is important shows that the changes and adaptability of the genotypes are not very high (Becker, 1981).

When examined in terms of genotype x environment interaction, biological yield, harvest index, yield, root length, root bud length, root bud ratio, root fresh weight, root dry weight, bud fresh weight, bud dry weight and root dry weight / total plant dry weight rate was found to be statistically significant in both locations (P<0,05). The interaction of the genotype with the environment is important for the growth and development of the genotype. Although the genotype determines plant growth and development, the environment will determine where it will be within the determined limits. While unfavorable conditions direct growth and development towards the lower limit, positive conditions may carry it to the upper limit in the opposite way. Comstock and Moll (1963) noticed that the genotype showed different responses in different growing environments and started the first studies on genotype x environment interaction. When environmental conditions are considered as a factor, genotype determines phenotypic differences. However, since the differences between genotypes vary from environment to environment, determining the relationships between genotype and environment will increase the success of the studies. (Düzgüneş et al., 1987). The effect of the environment may vary from character to character depending on the characteristics of the genotypes (Altınbaş and Sepetoğulu, 2001; Altınbaş, 2004). This feature constitutes the source of the difference between the interactions seen in the study.

Heritability can determine the level of genetic progress in selection studies. It is also used in breeder selection and in determining how important the effect of the environment is for the trait being examined (Kumlu, 2003). The heritability of the characters examined in the study was determined. Accordingly, in general, the property with the lowest heritability was found in the number of days of flowering with a value of 26.89±SE, while the highest value was determined in root bud length with a value of 95.15±SE. The high heritability of root bud length indicates that the plant will be more resistant to adverse conditions compared to other genotypes. However, the low heritability of the number of flowering days shows that flowering is the most affected character from the environment. According to the locations, while the number of flowering days was the lowest in Kırşehir province with 44.12±SE, the fresh root weight was at the highest level with 94.42±SE. In Yozgat, while the number of flowering days was the lowest with a value of 26.89±SE, the highest value was obtained from root bud length with a value of 91.15±SE. It is seen that the heritability of the root characters is higher than the other characters. This situation has positive and negative aspects. In terms of the good feature, high stability is a desired feature and it does not change much under adverse environmental conditions. However, the high heritability of an undesirable trait will mean that it will not be greatly affected by the environment, no matter how much the environment is improved (Raven and Edwards, 2001; Scotland, 2010). Nakajima et al. (2001) stated that the determinant of this is intercellular relations. Karadavut and Tozluca (2005) stated that environmental effects are the most important determinants of both above-ground and root growth of plants. Plackett et al. (2014), on the other hand, stated that the effect of stability is very high and they said that environmental conditions can affect this variability very little.

The results of the QTL analyzes in the study are given in Table 2. The odds ratio shows the relationship between the probability of a situation occurring and the probability of it not happening, and is obtained by proportioning the two odds ratios. The logarithm is taken to convert the relative risk values obtained by proportioning the two ratios in the study to an approximate normal distribution. Odds ratios were found to be >1 in the study. Accordingly, the effect examined is to increase the probability of the desired event. The results include close values for both locations. The risk ratios vary between 2.78-5.36 and the lowest rate was observed in the root dry weight / total plant dry weight ratio, while the highest rate was observed in the root dry weight. When evaluated according to the locations, the lowest value was obtained from the relative leaf water content with 2.90 in Kırşehir, while the highest value was obtained from the dry root weight with 5.12. In Yozgat, the lowest value was observed in root dry weight / total plant dry weight ratio with 2.78, while the highest value was observed in root dry weight with 5.36. Accordingly, it is seen that root dry weight is the variable most affected by the environment. Rogers et al. (1996) stated in their study that the root/stem ratio in root development is greatly affected by environmental conditions and explained the importance of the change in the amount of carbon dioxide. Salsman et al. (1999) stated that changes in atmospheric conditions can have significant effects. In the study, there was no significant change in the odds ratios according to the locations. The fact that their value is above one (1) is important in terms of showing that they are open to all kinds of influences.

Table 2. QTL results of analyzed characters

Character	Environment	Logarithm of Odds Ratios	Additive Effect	R^2 (%)	Ratio of Total Variance Explained by the Model	Left Side Marker Position (cM)	Right Side Marker Position (cM)
Number of Germination Days (day)	Kırşehir	3,68	0,1278	12,78	0,206	418,25	389,02
	Yozgat	4,17	0,1502	16,57	0,278	322,07	441,48
Number of Flowering Days (day)	Kırşehir	3,28	0,7643	17,42	0,261	291,56	521,65
	Yozgat	3,27	0,5672	17,13	0,302	319,24	388,67
Plant Height (cm)	Kırşehir	4,08	-0,6732	9,04	0,278	364,66	417,44
	Yozgat	4,22	-0,7680	9,45	0,215	499,41	290,13
Biological Yield (g plant^{-1})	Kırşehir	4,72	1,0981	6,68	0,196	277,13	188,56
	Yozgat	3,83	1,1174	6,61	0,205	316,68	201,38
100 Seed Weight (g)	Kırşehir	2,99	2,1344	10,56	0,267	333,77	312,56
	Yozgat	3,54	2,1560	9,60	0,259	345,95	444,20
Harvest Index (%)	Kırşehir	3,56	1,7344	12,36	0,255	198,92	395,38
	Yozgat	3,55	1,7325	11,39	0,269	205,74	366,61
Relative Leaf Water Content (mg)	Kırşehir	2,90	2,6803	8,58	0,329	217,17	217,05
	Yozgat	3,02	2,7917	7,65	0,345	218,55	267,44
Membrane Permeability Index	Kırşehir	3,76	3,8861	7,74	0,296	418,92	512,59
	Yozgat	3,85	2,9041	6,98	0,263	370,99	489,34
Water Uptake Index (%)	Kırşehir	4,12	-1,9803	7,95	0,234	426,29	167,15
	Yozgat	4,03	-2,2026	7,98	0,197	444,51	178,45
Yield (kg da^{-1})	Kırşehir	4,42	1,9995	10,19	0,260	402,27	202,27
	Yozgat	4,36	1,7379	10,83	0,286	487,21	248,91
Root Length (cm)	Kırşehir	3,56	-0,1897	6,77	0,257	382,11	381,56
	Yozgat	3,21	-0,2003	5,47	0,316	402,67	294,29
Root Bud Length (cm)	Kırşehir	3,69	0,2377	11,18	0,254	286,27	441,78
	Yozgat	3,77	0,2190	13,88	0,227	267,09	419,38
Root Bud Rate (%)	Kırşehir	2,89	0,3402	10,03	0,289	198,34	330,02
	Yozgat	3,02	0,5682	9,74	0,274	212,56	378,21
Root Fresh Weight (g)	Kırşehir	4,48	0,4235	3,47	0,210	166,17	167,55
	Yozgat	3,97	0,3990	4,14	0,199	184,23	198,42
Root Dry Weight (g)	Kırşehir	5,12	0,1988	5,60	0,412	381,33	219,68
	Yozgat	5,36	0,2109	5,77	0,481	401,59	266,71
Bud Fresh Weight (g)	Kırşehir	4,51	0,4677	9,34	0,356	146,88	188,03
	Yozgat	4,22	0,5882	10,23	0,302	167,41	210,70
Bud Dry Weight (g)	Kırşehir	3,28	0,2239	4,66	0,288	196,13	308,91
	Yozgat	3,81	0,1783	5,28	0,273	202,78	288,83
Root Dry Weight / Plant Dry Weight Ratio (%)	Kırşehir	2,92	0,5001	3,79	0,455	329,44	249,59
	Yozgat	2,78	0,4677	2,99	0,418	330,51	288,82

The additive effect is considered as part of the total genetic effect and the performance of the offspring can be estimated from the performance of the parents. The environment, which is considered as a non-additive effect, may directly affect the success of this estimation. The effect can be positive as well as negative.

Plant height was adversely affected in both locations. Similarly, water uptake index and root length were similarly negatively affected. All other features were positively affected. However, the number of days of flowering, root length, root bud length, root dry weight and root bud dry weight were very close to zero. Others had values far from zero. Approaching zero indicates that the additive effect is ineffective (İşçi, 2008). Doligez et al. (2002) stated that the plant's response will change depending on the size of the additive effect and it is quite difficult to estimate the size of the response. It is not known what additive effects can do, and the effects of the environment on them are not known enough (Jones and Dolan, 2012).

When the phenotypic contribution (R2) values are examined, it is seen that the contribution margins are not very high proportionally. While the highest phenotypic contribution was determined in the number of days of flowering with 17.42%, the lowest value was revealed in the dry root weight / dry weight ratio per plant (%) with the value of 2.99%. When evaluated according to locations, the highest effect was in the number of days of flowering with 17.42%, while the lowest value was in the fresh root weight with a value of 3.47% in Kırşehir.

In Yozgat, the lowest value was observed in the ratio of root dry weight / total plant dry weight with 2.99%, while the highest value was observed in the number of days of flowering with 17.13%. As it is known, phenotype means external structure and can be defined as the reflection of the genotype and environmental factors on the external appearance of the living thing (Düzgüneş and Akman, 1985). Although the phenotype is determined by the genes, the reflection of the genetic effect is often prevented by the effect of dental factors. For this reason, the influence of the environment can be quite effective, as the phenotype does not have such deterministic and precise boundaries as the genotype (Çancı and Toker, 2009). Variables with the highest phenotypic effect will always have a higher-than-average survival rate than those with the highest genotype effect. This can be seen as an expected result, as non-genetic factors can alter the structure with the permission of genetic expression. Ram et al. (2007) and Moose and Mumm (2008) are in this direction. Knowing the amount of the phenotypic contribution at all times will increase the chances of success in breeding studies (Percy et al., 2006).

When the ratio of the total variance including the covariant used is examined, it is seen that the ratios have values that are not very close to each other. While the lowest value was observed in biological yield with 0.196, the highest rate was observed in root dry weight with 0.481. The observed width of variation value indicates that the variation is not small. The fact that the variation between provinces is also significantly different shows that the model is successful in identification. The variables selected in the study were chosen correctly and the success of the study is explained by the high values of the explained variance rates. Karaman et al. (2017) stated that the high explained variance indicates the success of the study, while Tabachnick and Fidel (2014) stated that the high explained variance was due to the success in the selection of the variable in the study. However, if there is not a wide range of motion when choosing a variable, it will be necessary to use the available variables (Stupak et al., 2006).

In the study, 6 QTL definitions were made for the number of days to germination, the number of days until flowering, harvest index, membrane permeability index and leaf water content for the characters that affect yield and yield. For Kırşehir province, 6 QTL clusters containing QTLs for germination days, number of days until flowering, number of pods per plant, biological yield, hundred-seed weight harvest index, membrane permeability index and yield were defined in link groups. For Yozgat province, 7 QTL clusters were defined for germination days, number of days until flowering, number of pods per plant, harvest index, hundred-seed weight, membrane permeability index and yield. It was noteworthy that the defined QTL link groups did not contain QTLs for any location. For the root-related variables, when the ratio of root to stem, root dry weight and root dry weight to total plant were examined, a total of 5 QTL definitions could be made. One of these QTLs was found to be major and four of them minor.

CONCLUSION and SUGGESTIONS

Besides being the problem of the future, drought has now become the most important problem of today. Kumar et al. (2015) stated that the effect of drought on reducing yield reached 60%. Drought-tolerant or resistant genotypes need to be developed, as the world no longer seems to be able to go back to the way it was. In the tolerance studies to be carried out against drought, the time taken for germination, time for flowering, maturity time and biological yield parameters should be found. These features are affected by drought at a much higher rate than other features. Control of sweating, leaf water permeability, excess root density, root weight and root bud rate are effective in reducing water loss of plants. These properties are controlled by multifactorial and unknown mechanisms. Therefore, in order to determine drought tolerance, besides morphological features, it should be studied on their molecular markers. Thus, the duration of the work to be done will be shortened and the success of the work will be increased.

In the conducted study, drought stress significantly affected all variables except root length and root fresh weight. The amount of impact occurred regardless of locations. Although chickpea genotypes were not statistically significant in terms of yield and properties affecting yield and root-related properties, they were higher in Yozgat province. It was thought that this difference was caused by the fact that the precipitation was more regular compared to Kırşehir province during the years of the study. Among the drought-tolerant properties, it may be beneficial to have as short a flowering day period as possible. Because plants can provide a certain amount of growth and development with spring rains in the first periods. However, in addition to the lack of sufficient precipitation during the flowering period, the effect of drought and a significant increase in temperature generally coincide with the flowering period. Strong flowering also means more pods and seeds per pod. Early flowering can be considered in breeding programs to avoid drought stress. With early flowering, it will be possible to partially get rid of drought or reduce its effects. Although drought tolerance and drought escape mechanisms are different from each other, they should be considered together. Early flowering, early maturing and drought resistant genotypes are needed. Since Turkey is the gene center of chickpea, it has the knowledge and infrastructure to reach these characteristics. However, the primary decision to be made here is to increase the root density depth and root dry weight as much as possible. If the root system is in good condition in terms of specified characteristics, drought escape and increased tolerance can be achieved. An effective root system will be the primary condition for drought avoidance and increasing tolerance. Root structure is required to be strong in order to increase the efficiency of benefiting from soil moisture.

In the study carried out, genotype x environment interaction was found to be important in all measured traits besides root-related traits. Similar results in both locations indicate that the environment has a high level of influence on genotype. However, this interaction can be caused by soil moisture as well as other factors. In order to compare with these differences, a random effect was created in the BLUP values, estimation was made for both locations and high correlation was observed. Obtaining high correlation explained the interaction more clearly. More QTL analyzes were required to find consistent QTLs in both locations. Considering that the studies to be done with traditional methods take a lot of time, the necessity of focusing on these methods will be better understood.

The mechanism of drought tolerance is complex. However, if its components can be determined very well and QTLs can be determined for them, it will be possible to obtain tolerant elite varieties in a much shorter time and successfully. According to the results obtained, QTLs which have a positive effect, have shown that they can contribute to increasing the trait values of donor parent alleles. Those who have a negative influence may have higher characteristics because the parent is in the receiver position. 11 QTLs in Kıreşhir and 4 QTLs in Yozgat were defined for root-related features in both locations. Roots are the most important part of the plant. Because the roots are the first part to be exposed to drought conditions and the plants with weak root structure are also highly affected by drought. It has been observed that root development should be included in the studies to be carried out and the scenarios to be created regarding drought.

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