



## Association of some ISSR markers with some agronomic traits in Durum wheat

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### Abstract

The research was conducted during two seasons, at both of Izraa research center- GCSAR (rainfed) and Karahta research station- GCSAR (irrigated). Six durum wheat varieties were studied. The research aimed to study the genetic compatibility relationships of some genetic loci with some important agronomic and morpho-physiological traits related to drought tolerance. Results showed significant differences within varieties, locations, and interactions for most of the studied traits. Results also revealed positive and negative significant correlations within yield and its components, in addition to the positive and negative significant correlations observed between yield and its components on one side, and plant height, peduncle length, relative water content and leaf color on the other side. Regarding the molecular study, the 21 markers resulted out of 8 studied ISSR primers, were tested for their association with the 8 studied traits resulting 336 associations, only 75 of them were significant. Associations ranged from 2 associations for relative water content to 18 associations for number of grains per spike. Our results are to be used in selection the promising genotypes under drought stress by using marker assisted selection (MAS).

**Keywords:** Durum wheat, Drought tolerance, Morpho-physiological traits, Molecular markers, ISSR.

### Introduction

Wheat is one of the most important strategic crops in the world, and durum wheat is one of the most common crops in the Mediterranean region, and the most used in food products, as it is used to make pasta, Moroccan, burgul, freekeh, bread, and others (Elouafi and Nachit, 2004). The area planted with durum wheat in Syria in 2013 was about 690 thousand hectares, of which 330 thousand hectares were rainfed, and the productivity of durum wheat was about 2323 kg/hectare, while the productivity of the rainfed area was 1396 kg /ha (Annual Agricultural Statistical Book, 2013). Durum wheat is subjected to many stresses (Moragues *et al.*, 2006; Nachit *et al.*, 2000) such as drought which is the main abiotic stress determining its production (Mangini *et al.*, 2005; Royo *et al.*, 1998; Nachit, 1998).

Researchers emphasized on the need to find plant types that have morphological characteristics that help plants tolerate drought, whether these traits are specific to the vegetative or root system (Bazzaz *et al.*, 2000). Plant breeders aim to develop genotypes that are more tolerant to drought stress through Identifying key indicators or traits that

contribute effectively to improving grain yield and which are the main objective of breeding programs (Slafer *et al.*, 1996), in addition to developing appropriate screening technology (Araus, 1996). Breeding programs used to improve productivity during last century proved to be very successful as they relied on morphological traits, but they may be insufficient due to the influence of the environment on these traits (Tatikonda *et al.*, 2009). These programs can be more effective, depending on the contributions of biotechnology to improving the potential for production. Molecular markers are increasingly used as means of genetic improvement, as all of the physiological and morphological traits that help plants tolerate drought possess a molecular genetic base. Breeding with the help of molecular markers overcomes the need for a large number of test sites, which are necessary for the selection of superior genotypes by conventional breeding programs based on phenotypic expression. There are many technique based on the polymerase chain reaction (PCR), including Simple Sequence Repeats (SSR) method, Inter- Simple Sequence Repeats (ISSR), Random Amplification of Polymorphic DNA (RAPD), ISSR is one of the most important techniques to study genetic fingerprint,

diversity of different plant species including wheat (Motawei *et al.*, 2007; Aliyev *et al.*, 2007; Joshi and Nguyen, 1993 (a, b)). This technique combines the benefits of ALFP and SSR, and it is generic as RAPD (Carvalho *et al.*, 2009; Vaillancourt *et al.*, 2008); Pradeep Reddy *et al.*, 2002). Ratnaparkhe *et al.* (1998) indicated that ISSR can be used as parameters related to the desired gene, as it helps in the selection in breeding programs and this is called Marker Assisted Selection. Deshmukh *et al.* (2012) found that some genetic markers resulting from the use of ISSR and RAPD are associated with traits responsible for drought tolerance in some varieties of wheat, which are easy, simple and effective methods for identifying the locations of the genes responsible for the drought tolerance traits. These techniques help the breeder to improve these traits. Many studies have been conducted to determine Genetic association of these traits in many crops (wheat, rice, barley, and maize). The importance of this study comes from the fact that durum wheat is one of the most important crops on which many studies have been conducted.

Objectives aimed the study of genetic association between some morphophysiological traits associated with drought tolerance and some molecular markers in durum wheat yield.

### Materials and Methods

**Six varieties of durum wheat were studied:** Duma1, Cham3, Cham5, Hourani, Duma3, Cham9. It is worth mentioning that Duma3 and Cham9 are new varieties, while the other four varieties are considered as old durum wheat varieties. The research was carried out during two agricultural seasons.

Studied varieties were planted in both of Karahta Research Station (irrigated conditions) and Ezraa Research Center (rainfed conditions with 284 mm annual precipitation), the amount of rainfall reached 327.9 and 299.3 mm during the first and second study seasons, respectively.

Varieties were planted on lines, the length of the line was 7 m, the distance between the lines was 25 cm, and the number of lines was 6 in each experimental plot. The plant density is 300 grains/m<sup>2</sup>.

The following eight field traits were studied: plant height, peduncle length, grains per spike, spikes per square meter, grain yield, 1000 kernels weight, chlorophyll content, and relative water content.

Molecular study was carried out in the laboratories of the Biotechnology Department, General commission for scientific agricultural researchers.

Genomic DNA was extracted from 2-3 leaves, using Cetyltrimethylammonium bromide CTAB method as described by Saghai-Marooof *et al.*, 1984 (with some modifications), then, DNA was quantified and its purity was assessed using a UV Spectrophotometer. Inter- Simple Sequence Repeats- ISSR, a polymerase chain reaction (PCR) depending technique, was used. 20 ISSR primers were used, only eight of which showed polymorphism between the studied Varieties, therefore they were adopted in our study. The polymerase chain reaction (PCR) was performed using thermos-cycler from (Eppendorf and Euro Clone) with a total reaction volume of 10µl including 4ng of DNA (template DNA), 800µM of the used primer, 200µM of dNTPs (dATP, dGTP, dTTP, dCTP), 1X of reaction mix (1XPCR Buffer), 1.5mM of MgCl<sup>2</sup>, and 0.1 U of Taq Polymerase enzyme. The thermal program used consisted of one cycle for 5 minutes at 94° C, followed by 35 cycles each consisting of 45 seconds of denaturing at 94° C, followed by 45 seconds at the appropriate annealing temperature of the used primer, followed by 90 seconds of Extension at 72° C, then the reaction was finished with one 8-minute cycle at 72° C. Table (1) shows used primers, their sequences, and their annealing temperature. PCR products were loaded on 2% agarose gel, and compared with a DNA ladder (Gene ruler 100bp plus DNA ladder).

**Table 1. ISSR used primers, their sequences, and their annealing temperature**

ISSR primer	Sequence	annealing temperature
866	(CTC)6	53
W814	(CT)8TG	44-46
862	(AGC)6	53
8565	GTC (ACC)6 AC	64-66
812	(GA)8A	49
16	CGT(CA)7C	49
17	CAG(CA)7C	51-53
5	(CA)8GT	48

**Results analysis:** A random complete blots design was used with three replications. Data were analyzed according to ANOVA, and the correlation relationships between the studied field traits were studied using GenStat 10. T.Test was used to analyze genetic association between morphophysiological traits and molecular markers, by using Excel program.

### Results and Discussion

**Analysis of variance:** Results showed significant differences between the two sites (irrigated and rainfed conditions), the varieties and the interaction between them. Variance could be due to the effect of drought on the performance of the varieties in general, Table (2).

Results showed significant differences in grain yield between the two studied sites as well as between the studied varieties, as the cultivar Duma3 outperformed the rest of the varieties at the site of Izraa, and its grain yield reached 4427 kg/ha, while the variety Cham3 was the most productive of grains at the irrigated site of Karahta with 7336 kg/ha, while Hourani yielded the least grain yield in both locations, (3043 and 4730 kg/ha in Izraa and Karahta, respectively), where drought caused a decrease in its grain yield by 36%, Cham3 was the most affected by drought which caused a decrease in its grain yield by 45%, while Cham5 was the least affected by drought, as its grain yield decreased by 26%, Table (2).

Mahasna (2012) mentioned that the decrease in soil water content leads to a decrease in the efficiency of shoot types due to the lack of available photosynthesis products, and thus the formation of fewer shoots, fewer grains, and lower grain yield.

Results also showed a significant variation between the two studied sites and between the studied varieties regarding 1000 kernels weight. In Karahta, Duma3 had the highest value for 1000 kernels weight (55.33 g), while Duma1 had the lowest values (49.5 g). However, 1000 kernels weight for Duma1 decreased as a result of drought in Ezraa by no more than 2% and it reached (48.67 g), achieving the highest value in Ezraa and surpassing Cham3 (37.83g), which was the most affected by drought, as its 1000 kernels weight decreased by 25%, Table (2). The variation in 1000 kernels weight between the studied varieties may be due the high efficiency in manufacturing a greater amount of dry matter and the rate of grain filling, which led to an increase in the size and degree of grain filling (Gifford *et al.*, 1984).

Table (2) also showed that there are significant differences between the two studied sites regarding grains per spike. It is worth noting that Duma1, which had the highest number of grains per spike (40 grains/ spike) in the irrigated site, was the most affected by drought, as its grains per spike decreased and reached 18 kernels/ spike in Ezraa, 55% lower than in the irrigated site, while Cham5 was the least affected by drought with a decrease of up to 26%, as its grains per spike was 34 and 25 grains/ spike in each of Karahta and Ezraa, respectively.

As for spikes per square meter, results showed that there are significant differences between the two study sites and between the studied varieties. Duma3 had the highest number of spikes/ m<sup>2</sup> in both of Karahta and Ezraa, reaching 521.3 and 261.7 spikes/ m<sup>2</sup> in the two sites respectively, noting that it was the least affected by drought for this trait, with a decrease of 50%. While Hourani had the lowest number of spikes/ m<sup>2</sup> in both Karahta and Ezraa, reaching 414.7 and 181.7 spikes/ m<sup>2</sup> in the two sites respectively, with a decrease of 56%. Cham9 was the most affected by drought with a decrease of 63%, Table (2), and this is due to the decrease in the water content of the soil, which leads to the death of many shoots or their failure to transform into fruitful shoots due to the lack of available photosynthesis products (Mahasna, 2012).

As for plant height, the height of Hourani in Karahta reached 98.17 cm, achieving the highest value, surpassing Duma3, which reached a height of 79.63 cm in the same site, while in Ezraa, Cham5 was the longest of the varieties (83.5 cm) and Duma3 the lowest (70 cm), noting that Duma1 was the least affected by drought with a decrease of 8%, while the height of Hourani was the most affected by drought with a decrease of 19%, noting that significant differences were observed between each of the sites and varieties, and the increase in plant height at the irrigated site was due to an increase in the amount of the water available to the plants, maintaining the fullness effort within the stem cells and maintaining the elongation of the plant cells, leading to an increase in the length of the phalanges and thus the final plant height (Cossgrove, 1989).

As for peduncle length, Hourani was the most affected by drought stress, with a decrease of 25%, while Duma1 was the least affected by drought, with a decrease of 8%. The significant decrease in the peduncle length was due to drought's effect on the process of photosynthesis, and because the elongation of plant cells is one of the most sensitive

physiological processes to drought conditions (Al-Odah *et al.*, 2008).

Significant differences were observed between sites regarding chlorophyll content. Cham9 achieved the largest value at the irrigated site of Karahta (55.33), while Cham5 achieved the largest value (50.67) in Ezraa. Cham3 was the most affected by drought stress with a decrease of 15%, while Duma3 was the least affected by drought, with a decrease of only 1%.

As for relative water content, significant differences were observed between the two studied sites, Cham5 achieved the largest water content in both sites (87 and 71.2% in both Karahta and Ezraa, respectively), and Duma3 was the most affected by drought, as the water content of it decreased in Ezraa by 25%, while Duma1 was the least affected by a decrease of 14%, Table (2).

**Correlations between studied traits:** Table (3) indicates significant positive correlations between 1000 kernels weight and each of plant height and spikes per square meter (0.71 and 0.75 respectively) in the first season of the study, and between grain yield and spikes per square meter (0.78), and peduncle length and plant height (0.88), and between relative water content and 1000 kernels weight (0.77) in the second season, in the site of Karahta. Table (3) also indicates significant, negative correlations between 1000 kernels weight and each of chlorophyll content and grains per spike (-0.79 and -0.88 respectively). and between plant height and each of grain yield and spikes per square meter (-0.94 and -0.75 respectively), and between peduncle length and each of grain yield and spikes per square meter (-0.91 and -0.74 respectively), and between chlorophyll content and spikes per square meter (-0.67), and between relative water content and grains per spike (-0.93) in the second season, in Karahta.

Table (4) indicates significant positive correlation between plant height and each of peduncle length and chlorophyll content (0.82 and 0.88 respectively) in the first season in Ezraa.

Table (4) also indicates significant positive correlations between chlorophyll content and each of grain yield and spikes per square meter, and 1000 kernels weight (0.78, 0.76, and 0.084, respectively), and 1000 kernels weight and each of grain yield and spikes per square meter (0.84, 0.89, respectively) in

the second season in Ezraa. Results of our study are similar to number of researchers, including (Mustafa, 2010; Beharav *et al.*, 1998; Nachit, 1998, Jarrah, 1993; Darwinkel, 1978).

**Molecular study:** Twenty-one markers resulted out of 8 studied ISSR primers. T.test was performed to analyze the compatibility relationships of genetic loci with the studied traits. Figure (1) shows an agarose gel image loaded with PCR products (ISSR 812).

336 associations were observed (21 genetics x 8 studied traits x 2 study sites). Only 75 of them were significant, and were selected in our study.

Results showed 18 associations for number of grains per spike, 12 for both of number of spikes per square meter and 1,000 kernels weight, 11 for plant height, 10 for peduncle length, 6 for chlorophyll content, 4 for grain yield and only two.

It is worth mentioning that the Correlation coefficient values were high (0.8-1) for all significant Associations observed, indicating the close association between the genetic loci and the studied traits, Table (5).

The number of associated loci to the studied traits ranged from two loci associated to the trait relative water content to 18 sites associated with grains per spike. This result is similar to the results obtained by Roy *et al.*, (2006).

In addition, results showed that there is more than one loci associated with each trait. This is due to the fact that these traits are quantitative and controlled by a number of genes rather than a single gene (Mualla and Harba, 2005).

Although our varieties are improved, this study showed good results in terms of association between genetic loci and traits. This is because the studied traits are quantitative with low heritability coefficient, in addition to the fact that the studied varieties have genetic stability for these traits and are adapted to local environment. Our results are to be used in selection the promising genotypes under drought stress by using marker assisted selection (MAS), (Lande and Thompso, 1990).

This information can be used in breeding programs aiming to speeding it up and shortening the time required to select genotypes that contain the desired trait.

**Table 2, Average of the two seasons of the study, the general average for each variety and sites and the percentage of decrease, for the studied traits**

	plant height cm							Grain yield Kg/ha								
	Hourani	Duma3	Duma1	Cham9	Cham5	Cham3	Site average	Hourani	Duma3	Duma1	Cham9	Cham5	Cham3	Site average		
Ezraa/average	80	70	73.67	82.67	83.5	72.83	B 81.78	Ezraa/average	3043	4427	4125	4187	4345	4047	B 4029	
Karahta/average	98.17	79.67	79.83	90.5	94.67	84.17	A 87.83	Karahta/average	4730	7037	7027	6553	5857	7336	A 6423	
variety average	B 90.17	C 77.83	78.42C	88.42B	A 94.17	C 79.83		variety average	B 3886	A 5732	5576A	A 5370	A 5101	5692A		
Decrease %	19	12	8	9	12	13		Decrease %	36	37	41	36	26	45		
	Varieties x Sites			Varieties		Sites		Varieties x Sites			varieties		Sites			
C.V %= 5.6	*5.965			**3.918		3.64*		L.S.D	C.V %= 19			1105.1		**810.7	**422.3	L.S.D
	peduncle length cm							1000 kernels weight g								
	Hourani	Duma3	Duma1	Cham9	Cham5	Cham3	Site average	Hourani	Duma3	Duma1	Cham9	Cham5	Cham3	Site average		
Ezraa/average	33	29.33	28.67	30.42	36.08	25.92	B 30.57	Ezraa/average	38.67	43.33	48.67	45.17	44.83	37.83	B 43.08	
Karahta/average	43.8	38.68	31.22	33.86	43.13	32.87	A 37.26	Karahta/average	50.33	55.33	49.5	52.33	54	50.17	A 51.94	
variety average	A 38.4	B 34.01	C 29.94	BC 32.14	A 39.61	C 29.39		variety average	B 44.5	A 49.33	A 49.08	A 48.75	A 49.42	B 44		
Decrease %	25	24	8	10	16	21		Decrease %	23	22	2	14	17	25		
	Varieties x Sites			varieties		Sites		Varieties x Sites			varieties		Sites			
C.V %= 12.5	6.337			**3.49		*4.946		L.S.D	C.V %= 10.4			5.827		*4.084	**2.91	L.S.D
	chlorophyll content							grains per spike								
	Hourani	Duma3	Duma1	Cham9	Cham5	Cham3	Site average	Hourani	Duma3	Duma1	Cham9	Cham5	Cham3	Site average		
Ezraa/average	46.33	49.17	48.67	48.5	50.67	45.67	B 48.17	Ezraa/average	21	21	18	25	25	22	B 22.03	
Karahta/average	53.33	49.5	54.83	55.33	54.67	54	A 53.61	Karahta/average	36	35	40	39	34	39	A 36.22	
variety average	49.83	49.33	51.75	51.92	52.67	49.83		variety average	28	28	29	32	30	31		
Decrease %	13	1	11	12	7	15		Decrease %	43	40	55	35	26	43		
	Varieties x Sites			varieties		Sites		Varieties x Sites			varieties		Sites			
C.V %=8.1	4.663			3.407		**1.843		L.S.D	C.V %=19.7			6.456		4.832	**1.999	L.S.D
	relative water content %							spikes per square meter								
	Hourani	Duma3	Duma1	Cham9	Cham5	Cham3	Site average	Hourani	Duma3	Duma1	Cham9	Cham5	Cham3	Site average		
Ezraa/average	68.5	62.2	68.2	64	71.2	67.8	B 66.97	Ezraa/average	181.7	261.7	222.3	189.7	204.7	220.8	B 213.5	
Karahta/average	80.8	82.7	79.3	82.8	87	80.2	A 82.14	Karahta/average	414.7	521.3	458	515.3	464.7	498.7	A 478.8	
variety average	74.7	72.4	73.8	73.4	79.1	74		variety average	B 298.2	A 391.5	AB 340.2	AB 352.5	AB 334.7	AB 359.8		
Decrease %	15	25	14	23	18	15		Decrease %	56	50	51	63	56	56		
	Varieties x Sites			varieties		Sites		Varieties x Sites			varieties		Sites			
C.V %= 10.5	10.22			6.45		**6.771		L.S.D	C.V %= 20			**82.78		*57.01	44.19**	L.S.D

\*\* significant differences at the level of statistical significance 1%, \* significant differences at the level of statistical significance 5% - different letters indicate significant differences.

**Table (3), correlation coefficients between studied traits at Karahta.**

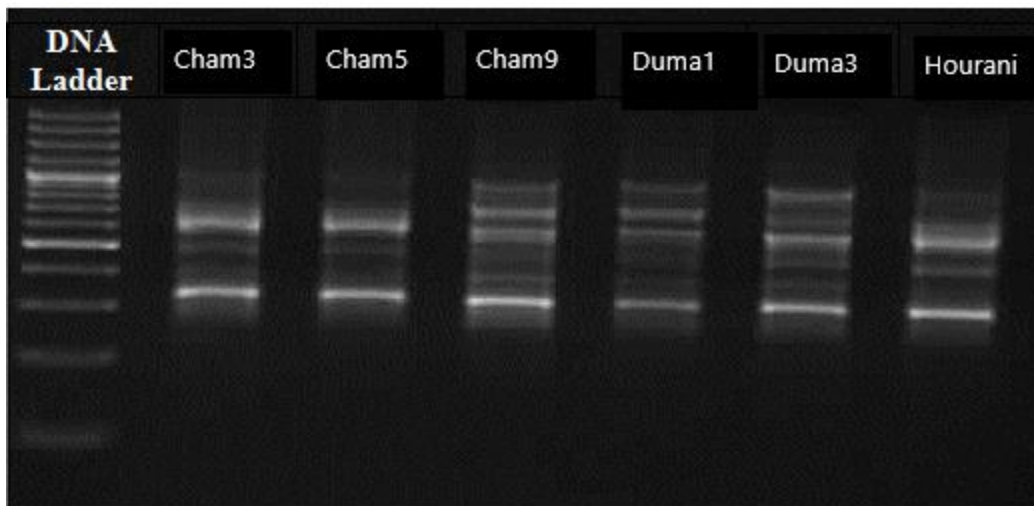
<b>Correlations between studied traits (Karahta, first season)</b>							
	water content	chlorophyll content	peduncle length	plant height	grain yield	spikes per square meter	grains per spike
chlorophyll content	0.47						
peduncle length	0.33	0.22					
plant height	0.52	0.41	-0.15				
grain yield	-0.24	0.37	-0.02	-0.62			
spikes per square meter	0.58	0.15	0.01	0.19	0.06		
grains per spike	-0.08	0.11	-0.56	-0.25	0.64	0.55	
1000 kernels weight	0.48	0.13	-0.21	0.71*	-0.45	0.75*	0.24
<b>Correlations between studied traits (Karahta, second season)</b>							
	water content	chlorophyll content	peduncle length	plant height	grain yield	spikes per square meter	grains per spike
chlorophyll content	-0.48						
peduncle length	0.42	0.06					
plant height	0.42	0.15	0.88*				
grain yield	-0.2	-0.27	0.91-*	0.94-*			
spikes per square meter	-0.1	0.67-*	0.74-*	0.75-*	0.78*		
grains per spike	0.93-*	0.59	-0.35	-0.28	0.04	0.01	
1000 kernels weight	0.77*	0.79-*	0.05	-0.13	0.31	0.39	0.88-*

\*Significant correlation at the level of statistical significance 5%.

**Table (4), correlation coefficients between studied traits at Ezraa.**

<b>Correlations between studied traits ( Ezraa , first season)</b>							
	water content	chlorophyll content	peduncle length	plant height	grain yield	spikes per square meter	grains per spike
chlorophyll content	-0.21						
peduncle length	0.53	0.7					
plant height	0.15	0.88*	0.82*				
grain yield	-0.15	0.53	0.22	0.42			
spikes per square meter	-0.47	-0.32	-0.58	-0.71	0.17		
grains per spike	0.13	0.47	0.49	0.67	0.4	-0.49	
1000 kernels weight	-0.04	0.5	0.3	0.47	0.2	-0.35	-0.28
<b>Correlations between studied traits ( Ezraa , second season)</b>							
	water content	chlorophyll content	peduncle length	plant height	grain yield	spikes per square meter	grains per spike
chlorophyll content	0.33						
peduncle length	0.36	0.03	0.55				
plant height	0.44	0.23	0.63				
grain yield	-0.26	0.78*	-0.4	-0.12			
spikes per square meter	0.37	0.76*	0.32	0.4	0.57		
grains per spike	-0.28	0.32	-0.08	0.51	0.56	0.45	
1000 kernels weight	0.09	0.84*	-0.02	0.02	0.84*	0.89*	0.41

\*Significant correlation at the level of statistical significance 5%.



**Figure 1, Image of an agarose gel loaded with PCR products (ISSR 812)**

**Table 5, Correlation coefficient values for the Associations between the genetic loci and traits.**

Loci n.	Trait	Loci	Prob.	Corr. co.	Loci n.	Trait	Loci	Prob.	Cor.co.
1	grain yield	862/834	***	1	1	Grains/ spike	862/834-1	**	0.9
2		812/1044	***	1	2		862/459	**	0.8
3		812/1000	***	1	3		812/1044-1	**	0.9
4		812/725	***	1	4		812/1000-1	**	0.9
1	Spikes/ square meter	862/864-1	**	1	5		812/725	**	0.9
2		862/834	***	1	6		5/836	**	0.8
3		862/459	**	0.9	7		862/864-2	***	1
4		812/1044	***	1	8		862/342	**	0.9
5		812/1000	***	1	9		866/589	**	0.9
6		812/725	***	1	10		866/300	**	0.9
7		5/836	**	0.9	11		w814/272	***	1
8		862/864-2	**	0.9	12		16/713	***	1
9		866/760	***	1	13	8565/1141	**	1	
10		866/497	**	0.8	14	812/1044-2	***	1	
11		812/500	***	1	15	812/1000-2	***	1	
12		17/463	***	0.8	16	17/1059	***	0.8	
1	1000 kernels weight	866/760	**	1	17	5/755	**	0.9	
2		812/500	**	1	18	5/700	**	0.9	
3		17/463	**	1	1	Chlorophyll Content	862/864	***	1
4		862/864	**	1	2		862/459	**	0.9
5		862/834	**	0.9	3		866/300	**	0.9
6		862/342	**	0.8	4		8565/1141	**	0.8
7		866/300	**	0.9	5		17/1059	**	0.8
8		8565/1141	**	0.9	6		5/836	**	0.9
9		812/1044	**	0.9	1	relative water content	862/459	**	0.9
10		812/1000	**	0.9	2		5/836	**	0.9
11		812/725	**	0.9	1	Plant height	862/459	**	0.9
12		17/1059	**	0.9	2		w814/272	**	0.9
1	peduncle length	862/864-1	**	0.9	3		16/713	**	0.9
2		862/459	**	0.8	4		5/836	**	0.9
3		866/300	**	0.9	5		5/755	**	0.9
4		5/836	**	0.8	6		5/700	**	0.9
5		862/864-2	**	0.9	7		862/834	**	0.9
6		862/834	***	1	8		866/497	**	0.9
7		866/300	**	0.8	9		812/1044	**	0.9
8		812/1044	***	1	10		812/1000	**	0.9
9		812/1000	***	1	11	812/725	**	0.9	
10		812/725	***	1					

Prob.: probability, Cor.co.: Correlation coefficient, \*\*\*Significant associations when 0.001<P, \*\*Significant associations when 0.01<P

**Conclusions and Recommendations**

From the above we conclude:

- Studied varieties performed differently in the two sites of study, affected by drought.
- Positive and negative significant correlations were found between yield and its components, in addition to significant correlation relationships between yield components and each of plant height, peduncle length, water content and chlorophyll content.
- There is association between genetic loci and traits, and there is more than one loci associated with each trait This is due to the

fact that these traits are quantitative and controlled by a number of genes rather than a single gene.

Accordingly, we recommend:

- Emphasizing on the studied traits, such as yield, its components, relative water content and chlorophyll content, as important traits in the selection processes aiming at improving wheat yield under drought conditions.
- Using the genetic loci that have shown associations with the studied traits in developing the effectiveness of the plant breeding program, through indirect selection, using the molecular markers associated with simple or quantitative important traits, which are unaffected by the

environment and can be adopted in the early stage of plant growth.

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