Research Article

Hani A. Mansour*, Salwa El Sayed Mohamed*, David A. Lightfoot*

Molecular studies for drought tolerance in some Egyptian wheat genotypes under different irrigation systems

<https://doi.org/10.1515/opag-2020-0030>

received August 16, 2019; accepted April 17, 2020

Abstract: This research work was carried out to evaluate drought stress for the differentiation of bread wheat (*Triticum aestivum* L.) genotypes in their ability to tolerate drought. An experiment was carried out on six genotypes ('Sides 1', 'Shindwell 1', 'Gemmiza 9', 'Sakha 93', 'Saheel 1' and 'Masr 2'). A randomized complete block design with three replications along two separate tests under the drip and the sprinkler irrigation systems was used in this experiment. One of the irrigation treatments applied the normal amount of irrigation water and the other applied end-season drought stress conditions through two successful agricultural seasons 2016/2017 and 2017/2018. The impact on biomass, grain yield and water productivity of the six genotypes was measured. Random amplified polymorphic DNA (RAPD) markers were used to evaluate genetic variation among the six genotypes. PCR–RAPD analysis showed that there were several differences in both the size and number of bands between the varieties. Based on these markers, genetic similarity coefficients were calculated and a dendrogram was constructed. The dendrogram analysis delineated three major clusters. The current study showed that RAPD markers are useful in the assessment of the genetic diversity among the wheat genotypes. The drip irrigation system gave the highest values of both the biomass and the grain yield for the six genotypes, while the sprinkler irrigation gave the lowest values.

Comparing the six genotypes in terms of the biomass, grain yield and water productivity, it was concluded that, the highest water productivity (WP) genotype was Sides 1, except during water stress with the sprinkler irrigation system. It was followed by genotype Sakha 93, then genotype Shindwell 1, while genotype Gemmiza 9 gave the lowest in all cases, except without water stress under drip irrigation.

Keywords: wheat genotypes, morphology, DNA (RAPD), irrigation systems, water productivity

1 Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops, which is widely cultivated in Egypt and the world, providing food calories and protein to the human population. Drought is one of the important environmental challenges, which growers must face around the world. Drought causes huge grain losses every year, especially in the developing countries, and current trends in the global climate change will most likely lead to further losses (Caetano-Anolles et al. 1991; Martin et al. 1991; Kobata et al. 1996; Lopezcastaneda and Richards 1994; Cao et al. 2000; Ribaut et al. 2002; Morgante and Salamini 2003; Li et al. 2015). The problem of worldwide water shortage and uneven distribution of rainfall makes the improvement of drought tolerance very important (Luo and Zhang 2001).

In sandy soils and under different irrigation systems, there are positive relationships between the lack of water stress, the vegetative growth, the economics of yield and water productivity of various Egyptian wheat varieties. These relationships are both linear or nonlinear in nature (Mansour et al. 2015a–2016; Mansour 2015).

Detailed climatic data are required because daily temperature changes often have a significant effect on economic yield, which affects water use efficiency, with both high temperature and low temperature causing the dry material to be less productive. This is evident in the production stage, and it is likely that the future productivity of the economic crop and the productivity of the water unit

* **Corresponding author: Hani A. Mansour**, Water Relations and Field Irrigation Dept., Agricultural and Biological Research Division, National Research Centre, Eldokki, Giza, Egypt, e-mail: mansourhani2011@gmail.com,

* **Corresponding author: Salwa El Sayed Mohamed**, Department of Molecular Biology, Genetic Engineering and Biotechnology Research Institute (GEBRI), University of Sadat City, Sadat City, Egypt, e-mail: salwa3eg@yahoo.com

* **Corresponding author: David A. Lightfoot**, PSAS Dept., Southern Illinois University at Carbondale (SIUC), Illinois, USA, e-mail: ga4082@siu.edu

ORCID: Hani A. Mansour 0000-0001-5353-7053

will be highly volatile, if the climate remains without fluctuations for long periods (Semenov and Porter 1995; Isik and Devadoss 2006). In response to climatic variability, the productivity of different varieties of crops is different (Ibrahim et al. 2018; Tayel et al. 2018).

The very large differences between crop productivity and gaps are defined when determining the maximum productivity of farmers. If the irrigation of wheat, maize and rice crops is carried out, the differences do not reach 80% of productivity (Lobell et al. 2009). It is possible to improve crop productivity for farmers by using modern techniques and highly sophisticated irrigation systems, based on sensors to determine the best management of adding nutrients and water together. Farmers' use of these advanced technologies varies by location of activity and the potential of farmers, which, of course, leads to variation in crop productivity from one location to another and from one farm to another (Grassini et al. 2015).

Breeding for drought tolerance is a major objective in arid and semiarid regions of the world due to inadequate precipitation, shortage of irrigation water and the high-water demand for crop evapotranspiration in such climates. The lack of water in Egypt, due to the Grand Ethiopian Renaissance Dam, makes improving drought tolerance particularly important. The random amplified polymorphic DNA (RAPD) technique, based on the polymerase chain reaction (PCR), has been one of the most used molecular techniques to study DNA marker polymorphisms, which can occur due to the base substitutions at primer binding sites (Williams et al. 1993). Drought resistance is now considered by breeders and molecular biologists to be a valid breeding target. Also, in the past, the breeding efforts for improving drought tolerance were hindered by quantitative genetic (Passioura 2002). Tuberosa and Salvi (2007) stated that the genomics based on these approaches provide access to agronomically desirable alleles, which presented at the quantitative trait loci (QTLs), impact such responses, thus enabling us to more effectively improve the drought resistance and yield of crops under water shortage conditions. They commented on how to get the information on QTLs which govern the response to drought and the candidate genes responsible for QTL impacts can be used to elucidate the physiological basis of drought resistance and help select the genotypes with an improvement in yield under water shortage (Vierling and Nguyen 1992; Bar-dakci 2001).

The aim of the current study was to provide information on the molecular and genetic characteristics of six wheat genotypes for drought tolerance, and the effect of different irrigation systems and water stress on biomass, grain yield and water productivity of wheat.

2 Materials and methods

The methodology of the current study could be divided into two parts. The first part describes the irrigation system components and climate, soil conditions, wheat plants, cultivars, etc. of field experiments and the second part elucidates the laboratory study of the genomic engineering for evaluating the cultivars, which were most productive under drought conditions.

2.1 Field experiments

The current study was carried out in the Research and Production Station, National Research Centre, El-Nubaria City, El-Behira Governorate. During two successful seasons, two field trials were carried out in the 2016/2017 and 2017/2018 seasons, to find out the effect of both drip and sprinkler irrigation systems, water drought treatments (normal irrigation with 100% ET_0 and stress with 50% ET_0) and six wheat genotypes (Sides 1, Shindwell 1, Gemmiza 9, Sakha 93, Saheel 1 and Masr 2) on biomass, grain yield and water productivity.

2.2 Study location

The design of the experiment was in randomized complete blocks with three replicates. A soil sample was taken representatively during soil preparation from the surface layer (0–30 cm) for analysis before applying fertilizers. This analysis informed the application of N fertilizers as 50 kg urea/fed and 70 kg ammonium nitrate/fed; however, the normally recommended rates of P and K fertilizers were used. The physical soil properties were as follows: the soil was classified as sandy with high pH, low salinity and organic matter, with a medium level of calcium carbonate. Other measurements included: field capacity recorded (12 $\theta_w\%$), permanent wilting point (4.1 $\theta_w\%$), available water (7.9 $\theta_w\%$), bulk density (1.57 g/cm³) and hydraulic conductivity (6.76 m/h).

The main plots had drip and sprinkler irrigation systems, and the subplots were the two water drought treatments (normal irrigation with 100% ET_0 and stress with 50% ET_0). The details of the climatic data (ET_0 , Max and Min temperatures, GS, P and Ari) of the field location are shown in Table 1 and Figure 2. The six wheat genotypes were Sides 1, Shindwell 1, Gemmiza 9, Sakha 93, Saheel 1 and Masr 2. Biomass, grain yield and water productivity were evaluated.

The irrigation networks as shown in Figure 3. These components of the irrigation network were installed

Table 1: Climatic parameters of the year 2017 represented El-Nubaria climate station. T_m , mean temperature (°C); T_{max} , highest temperature (°C); T_{min} , lowest temperature (°C); P , precipitation (mm)

Months	T_m	T_{max}	T_{min}	P , mm	ET_0 (T)	ET_0 (H)
Jan.	14.3	20.0	8.6	4.2	28.0	90.1
Feb.	15.5	21.5	9.4	4.5	31.3	99.9
Mar.	17.6	24.4	10.9	2.4	48.3	113.2
Apr.	21.3	28.7	13.9	1.3	77.3	127.7
May	24.6	32.2	16.9	0.4	116.1	132.3
Jun.	27.4	35.0	19.9	0.0	139.5	134.9
Jul.	29.2	36.4	21.9	0.1	151.7	139.2
Aug.	29.2	36.1	22.3	0.0	151.7	143.7
Sep.	27.7	34.3	21.0	0.0	139.5	142.8
Oct.	24.0	30.2	17.8	1.0	108.8	126.8
Nov.	19.7	25.6	13.8	1.8	63.0	107.8
Dec.	15.9	21.4	10.4	2.8	37.0	91.6
Annual	22.2	28.8	15.6	18.5	1092.2	1450.1

and operated, according to Mansour (2015), Mansour and Aljughaiman (2015), Mansour and El-Melhem (2015) and Mansour *et al.* (2015a,b).

The design of cultivated varieties was in randomized complete blocks, under both drip and sprinkler irrigation systems, where the plot size under the drip system was 12 m² and under sprinkler system was 25 m². Also, annual time of applied fertilizer was 25/12 for each season with 50 kg urea/fed, and 70 kg ammonium nitrate/fed, but P and K fertilizers were added according to the recommended scheduling by the Egyptian Ministry of Agriculture and Land Reclamation.

The drought susceptibility index (DSI) was calculated using the formula given by Fischer and Wood (1979):

$$DSI = (1 - Y_d/Y_p)/D$$

where, Y_d = seed yield of the genotypes under moisture stress condition. Y_p = seed yield of the genotypes under irrigated condition. D = mean yield of all strains under

Figure 1: Location of the experimental area; Egypt (a), El-Nubaria District (b), NRC Farm (c).

Figure 2: Volumetric graph of the year 2017 represented climate station in the studied area. T_m , mean temperature in Celsius; P , precipitation (mm); E_{To} , potential evapotranspiration (mm); GS, Growing season; Ari, Aridity index.

Figure 3: Layout of irrigation systems, study factors and all treatments of the field experiments.

moisture stress condition/mean yield of all strains under irrigated condition.

Drought tolerance efficiency (DTE) was estimated using the formula given by Fischer and Wood (1981).

$$\text{DTE (\%)} = \text{Yield under stress} / \text{yield under nonstress} \times 100$$

2.3 Plant material

The PCR analysis was conducted using genomic DNA from the six wheat varieties (Sides 1, Shindwell 1, Gemmiza 9, Sakha 93, Saheel 1 and Masr 2) and cereals of wheat varieties (Sides 1, Shindwell 1). These varieties were obtained from the Agricultural Research Station in Shindawil Island (Regional Research Station of Upper Egypt in Shandawil) and wheat varieties such as Gemmiza 9, Sakha 93, Saheel 1 and Masr 2 were obtained from the Field Crops Institute in Nubaria Agricultural Research Station. Water-sensitive wheat varieties (Masr 2 and Gemmiza 9) and -resistant varieties (Sakha 93 and Saheel 1) were used. The wheat varieties were grown in pots.

2.4 DNA extraction

Small leaves, of about 500 mg weight, were frozen and converted into powder by grinding them with liquid nitrogen. This powder was added to tubes of 9.0 mL of a CTAB temporary storage drive to extract. These mixtures were incubated at a temperature of 650°C for 60–90 min. After this, 4.5 mL of chloroform/octanol (1:24) was added, and the tubes were shaken for 10 min using a centrifuge (3,200 rpm). The floating material in the new tubes was transferred into 6 mL of isopropanol and left for an hour (Williams *et al.* 1990, Rohlf 1993, Sun *et al.* 2003, Tolk and Howell 2003, Roy *et al.* 2004, Salvi and Tuberosa 2005). Then they were placed in a centrifuge for 10 min, and the small balls obtained were placed in tubes called sterile Eppendorf, which contained 400 TE of buffer with 108.0 mL of hydrochloric acid, and a pH of 8.0, and 1.0 mL of a substance EDTA, pH = 8.0 (thus, the DNA was extracted from the genotypes from the wheat leaves and it was stored at minus 20 degrees Celsius for use by Doyle and Doyle (1990)).

2.5 Determination of DNA concentration by ultraviolet spectroscopy

The DNA was diluted by adding 20 µL of the DNA solution to 0.98 mL of distilled water in a small tube for

centrifugation and good mixing, and heating by UV lamp for 20 min. The wavelength of the optical spectrum was set to 260 nm. Distilled water was added to the mixture, and the extent of the absorption of the whipping of the DNA was measured. So, the DNA concentration was calculated, according to Sambrook *et al.* (1989).

2.6 Amplification by PCR

Table 3 illustrates that the Pharmacia biotechnology test was carried out by Amersham Pharmacia Biotech UK Limited, HP79 NA, England, where an enlarged DNA amplification was performed. The reaction volumes for amplification were 25 µL, each containing 1 PCR × buffer with 50 (MgCl₂ millimeter carbon chloride), and 10 millilitres of hydrochloric acid (pH 9.0). The mixture was prepared to interact with 15 µL mineral oil and was exposed to the following conditions: 940°C for three minutes, followed by 45 cycles for 1 min. At 94°C for 1 min, at 36°C for 2 min. At 72°C, final for 7 min and extension at 72°C. Amplification products were imaged alongside 1.6% gel DNA markers with TBE × buffer and were detected by adding an ethidium bromide solution for 30 min, and the gels were added in deionized water for 10 min, and they were imaged on a device to document the gel in the presence of UV light.

2.7 Data handling and cluster analysis

Data were recorded and analysed on the computer in the presence of preliminary amplification or lack thereof. If this product was already present in a genetic makeup, it was assigned a value of one (1), and in the absence of a genetic makeup, it was set to zero (0) after excluding the ranges that accept recurrence. Marital comparisons were used from the genotypes, and based on the presence or absence of a unique and common multiple shape product. This was done by renewing similar transactions according to Jacquard (1908). Similarity coefficients were used to create designs for bifurcations, and this was done using a method that was not recommended for use with the UPGMA.

3 Results and discussion

Data in Table 2 show the total number of 27 PCR amplification products as a result of using five different random primers. Over the six wheat varieties, RAPD-PCR showed only five monomorphic bands and

Table 2: The sequence of the RAPD primers used in the study

No. of primer	Nucleotide sequence (5' to 3')
OPAO-03	AGTCGGCCCA
OPAO-05	TGGAAGCACC
OPAO-07	GATGCGACGG
OPAO-08	ACTGGCTCTC
OPAO-10	GACATCGTCC

22 polymorphic ones of the total variants, which were not common in all six varieties.

These results suggest that these varieties might respond differently in relation to the treatments of drought stress (Bousba et al. 2012). However, it is worth mentioning that the 16 bands that appeared in the banding pattern of Saheel 1 were found in the banding pattern of Sakha 93. Moreover, 15 of the 16 bands of Saheel 1 cultivar had similar amplified bands in the cultivar, Masr 2. These results were confirmed by the dendrogram (Figure 4), where the three varieties, Sakha 93, Saheel 1 and Masr 2, were in the same cluster. In addition, the whole 16 amplified PCR products of the Saheel

1 cultivar were all found to be similar to the Sakha 93 cultivar (Table 3) since both varieties had the highest similarity value (0.86). Table 3 shows that the highest genetic similarity score was observed between Sakha 93 and Saheel 1. Moreover, the lower genetic similarity value (0.83) was observed between the cultivar Sides 1 and Gemmiza 9. Both varieties are in the same cluster (Figure 5). However, Shindwell 1 and Gemmiza 9 had the least genetic similarity, indicating that Shindwell 1 was the most divergent genotype among the six varieties. This result is shown in Figure 1, where Shindwell 1 is located separately in a unique cluster from the other five remaining varieties. In addition, Shindwell 1 had the least total similarity score (3.89) in comparison to the other varieties, assuring its location as a separate cluster (Table 4). This is similar to the findings of Tahir (2008).

Unweighted Pair Group Method, with Arithmetic Average (UPGMA) dendrogram of six accessions of releasing varieties of wheat collections, was based on RAPD data. The dendrogram was constructed from the matrix of Dice's similarity coefficients.

Table 3: Presence (1) versus absence (0) of PCR-amplified fragments from six wheat varieties using five random primers

Name	Sides 1	Shindwell 1	Gemmiza 9	Sakha 93	Saheel 1	Masr 2
Band 1	1	1	1	1	1	1
Band 2	0	1	0	0	0	1
Band 3	1	1	1	1	1	1
Band 4	0	1	0	1	1	1
Band 5	1	0	1	1	1	1
Band 6	0	0	0	1	0	1
Band 7	0	0	0	1	0	0
Band 8	1	1	1	1	1	0
Band 9	1	1	1	1	1	1
Band 10	0	1	0	0	0	1
Band 11	1	0	1	1	1	1
Band 12	1	1	1	0	0	0
Band 13	0	1	0	0	0	0
Band 14	1	1	1	1	1	1
Band 15	1	1	1	1	1	1
Band 16	0	0	0	1	0	0
Band 17	1	0	1	1	1	1
Band 18	1	0	0	0	0	0
Band 19	1	0	1	1	0	0
Band 20	0	0	0	1	0	1
Band 21	0	1	0	0	0	1
Band 22	1	1	0	1	1	1
Band 23	1	0	1	1	1	1
Band 24	0	1	0	1	1	1
Band 25	1	1	0	1	1	1
Band 26	1	0	0	1	1	1
Band 27	1	0	0	1	1	1
Total	17	15	12	21	16	20

Figure 4: Dendrogram showing the phylogenetic relationships and resulted clusters for the six wheat varieties. 1-Sides 1, 2-Shindwell 1, 3-Gemmiza 9, 4-Sakha 93, 5-Saheel 1 and 6-Masr 2.

Figure 5: RAPD polymorphism in six wheat species (Sides 1, Shindwell 1, Gemmiza 9, Sakha 93, Saheel 1 and Masr 2). Primer No. 3, Primer No. 5, Primer No. 7, Primer No. 8 and Primer No. 10, respectively.

Table 4: Genetic similarity values among six wheat varieties in a matrix form

Lane	1	2	3	4	5	6
1	1	0.55	0.83	0.79	0.85	0.7
2	0.55	1	0.5	0.54	0.63	0.67
3	0.83	0.5	1	0.67	0.71	0.56
4	0.79	0.54	0.67	1	0.86	0.83
5	0.85	0.63	0.71	0.86	1	0.83
6	0.7	0.67	0.56	0.83	0.83	1
Total	4.72	3.89	4.27	4.69	4.88	4.59

Data in Table 5 show the effect of using different irrigation systems (drip and spray) and different water

quantities (natural water 1,200 m³ feddan without water stress, 600 m³ feddan in case of water stress calculated by evapotranspiration ET₀ from the data presented in Table 1 and Figure 2), and the effect of using the six genotypes of wheat (Masr 2, Sakha 93, Gemmiza 9, Saheel 1, Sides 1 and Shindwell 1) on grain yield, biomass and water productivity.

It is possible to deduce that the grain and biomass yield have taken the same direction as the data, while the water productivity has taken a different direction due to the quantities of water calculated by them. Both mean grain and biomass yield were highest under drip irrigation and the values were 2,557, while the mean values for both were lowest under spray irrigation with values of 2,049 and 4,556 kg/fed, respectively.

Table 5: Effect of irrigation system, water stress, wheat varieties of grain, biomass yield and water productivity

Irrigation system (I)	Water amount (II) (m ³ /fed)	Wheat varieties	Grain (kg/fed)	Biomass (kg/fed)	WP (kg/m ³)
Drip	Normal 1,200	Masr 2 (sensitive)	2,649	6,636	2.21
		Sakha 93 (resistant)	2,821	3,974	2.35
		Gemmiza 9 (sensitive)	1,545	3,963	1.29
		Saheel 1 (resistant)	1,926	6,159	1.61
		Sides 1	3,730	6,883	3.11
		Shindwell 1	2,776	4,294	2.31
		Mean	2,575a	5,318a	2.15d
	Stress 600	Masr 2 (sensitive)	2,611	5,890	4.35
		Sakha 93 (resistant)	2,789	3,516	4.65
		Gemmiza 9 (sensitive)	1,513	4,356	2.52
		Saheel 1 (resistant)	1,890	5,184	3.15
		Sides 1	3,696	6,999	6.16
		Shindwell 1	2,739	3,919	4.56
		Mean	2,540b	4,977b	4.23a
		Mean	2,557e	5,148e	3.19e
Sprinkler	Normal 1,200	Masr 2 (sensitive)	2,287	6,037	3.81
		Sakha 93 (resistant)	1,650	4,435	2.75
		Gemmiza 9 (sensitive)	1,512	3,774	2.52
		Saheel 1 (resistant)	2,845	5,275	4.74
		Sides 1	2,736	4,077	4.56
		Shindwell 1	2,083	4,010	3.47
		Mean	2,186c	4,601c	3.64b
	Stress 600	Masr 2 (sensitive)	2,015	5,946	3.36
		Sakha 93 (resistant)	1,377	4,344	2.30
		Gemmiza 9 (sensitive)	1,240	3,684	2.07
		Saheel 1 (resistant)	2,572	5,184	4.29
		Sides 1	2,464	3,986	4.11
		Shindwell 1	1,811	3,919	3.02
		Mean	1,913d	4,511d	3.19c
		Mean	2,049f	4,556f	3.42f
LSD at 0.05			15.8	22.4	0.48
LSD at 0.05 of interaction (I) × (II)			135.2	185.3	0.14

In the case of studying the effect of water stress, the mean values of both grain and biomass were obtained under drip irrigation without water stress (2,575 and 5,318 kg/fed, respectively). In case of water stress, the lowest values for both grain and biomass crops were 2,540 and 4,977 kg/fed, respectively. The mean values of both grain yield and biomass were obtained with natural water and without water stress at mean values of 2,186 and 4,601 kg/fed, respectively. In the case of water stress, the lowest values were: 1,913 and 4,511 kg/fed, respectively.

In contrast, the results obtained for water productivity were generally higher with spray irrigation, with a 6% increase compared with drip irrigation. In comparing water productivity under water stress with natural water without water stress, the proportion of increase in water productivity was greater under water stress by 49% under drip irrigation Panama and 12% under spray irrigation, and these ratios are the same proportion of

water savings if the use of these items is followed under the same conditions and under water stress by 50% of evapotranspiration ET_0 .

When comparing the six genotypes under all the previous factors, it can be concluded that the biomass value, grain yield and water productivity were highest using genotype Sides 1, except for water stress with sprinkler irrigation system, while genotype Gemmiza 9 was the lowest in all cases except with normal water without water stress under drip irrigation.

Due to the differences in the characteristics of the six wheat genotypes, with differences in its responses to climatic factors like temperature and the study factors under different irrigation systems and the presence of water stress or normal irrigation water, all of these resulted in significant differences between all six wheat genotypes. This is consistent with previous researches conducted by Goyal and Mansour (2015), Mansour and

Figure 6: The effect of wheat varieties and irrigation systems on the drought-resistant index.

El-Melhem (2015), Mansour et al. (2019a–c), Tayel et al. (2012–2018), and Mansour and Aljughaiman (2015).

Figure 6 shows that the drought tolerance index was clearly affected by the irrigation method and also the genetic parameters of the Egyptian wheat varieties used in the current study, where the value of the drought tolerance index under sprinkler irrigation was clearly higher than its value under drip irrigation by more than ten times.

As for the varieties, the values also clearly differed between all varieties, and the highest value was recorded under the Gemmiza 9 variety, while the lowest value was recorded under the Saheel 1 variety.

4 Discussion

Water productivity (WP) based on Condon et al. (2002) was assessed for different Egyptian wheat varieties under different irrigation systems (sprinkler and drip) by reducing the use of water to only 40% of the amount normally needed for crop production. The relationship between the irrigation system and drought tolerance in the experimental area (sandy soil) could not be achieved without using suitable irrigation systems, which controlled the amounts of water applied to the different wheat varieties (Mansour et al. 2015a,b; Hellal et al. 2019; Abd-Elmabod et al. 2019).

It has also been well documented that high potential leads to high productivity under conditions of limited water and is generally associated with reduced water consumption (for example, Munoz et al. 1998).

Advantages related to the possibility of lower yields, such as the presence of young plants (Martin et al. 1999) because of the short growth period (Munoz et al. 1998), are attributed to the high WP because they reduced water use. Dehydration was also avoided with the improving soil moisture absorption by the roots for low WP in the Egyptian wheat varieties. Other reviews by Mansour et al. (2016) showed more clearly the differences in WP between the genotypes based on the differences in the quantities of water use rather than the differences in the grain yield of those plants.

These measurements clearly demonstrated the importance of stored soil moisture (Mansour et al. 2019a). Therefore, in this case there were absolutely no relationships among the various WPs and maintaining production of plants under shortage of water. In dryland conditions, stored soil moisture is attributed to the advantage of young plants, with moderate growth and short growth periods (Mansour et al. 2019b).

5 Conclusion

The first cluster consisted of two groups. The first group comprised of Sakha 93 (4) and Saheel 1 (5), at a level of 86% genetic similarity. The second group comprised of the closely related species Masr 2 (6), at a level of 83% genetic similarity to group I. The second cluster consisted of one of the groups, which comprised of Gemmiza 9 (3) and Sides 1 (1), at a level of 83% genetic similarity. The third cluster consisted of only one group, comprised of only one species

Shindwell 1 (2). The three clusters were like each other at a level of 50% genetic similarity. Genetic similarity ranged between 50% and 86%.

Upon observing the genetic diversity in the analysis of the current study, we can conclude that the technique called RAPD-PCR can estimate the genetic diversity between the different varieties of wheat we had, with the very quick discovery of a huge number of genomes that can bear water shortages. Using this analysis, a description of the various genotypes and genotypes for bread wheat can be made, which helps to know the degree of drought tolerance, when conducting molecular breeding. This allows the early discovery of drought tolerant wheat genotypes for cultivation in high temperature and lower water supply, which occurs in Egypt.

With regard to studying the response of the six genotypes under all factors of the study, it can be concluded that the biomass value, grain yield and water productivity were highest using genotype Sides-1 in all cases, except for water stress with sprinkler irrigation system, while genotype Gemmiza 9 was the lowest in all cases, except with normal water without water stress under drip irrigation.

Conflict of interest: Authors declare no conflict of interest.

References

- [1] Abd-Elmabod SK, Mansour H, Abd El-Fattah Hussein A, Zhang Z, Anaya-Romero M, de la Rosa D, et al. Influence of irrigation water quantity on the land capability classification. *Plant Arch.* 2019;2:2253–61.
- [2] Bardakci F. Random amplified polymorphic DNA (RAPD) markers. *Turk J Biol.* 2001;25:185–96.
- [3] Bousba R, Baum M, Djekoune A, Labadidi S, Djighly A, Benbelkacem K, et al. Screening for drought tolerance using molecular markers and phenotypic diversity in Durum wheat genotypes. *World Appl Sci J.* 2012;16(9):1219–26, ISSN 1818-4952.
- [4] Caetano-Anolles G, Bassam BJ, Gresshoff PM. DNA amplification fingerprinting using very short arbitrary oligonucleotide primers. *BioTech.* 1991;9:553–6.
- [5] Cao W, Scoles G, Hucl P, Chibbar RN. Phylogenetic relationships of five morphological groups of hexaploid wheat (*Triticum aestivum* L. *emThell.*) based on RAPD analysis. *Genome.* 2000;43(4):724–7.
- [6] Condon AG, Richards RA, Rebetzke GJ, Farquhar GD. Improving intrinsic water-use efficiency and crop yield. *Crop Science.* 2002;42:122–31.
- [7] Doyle JJ, Doyle JL. Isolation of plant Vigna leaves. The amount of DNA recovered per gram of DNA from fresh tissue. *Focus.* 1990;12(13):15.
- [8] Fischer RA, Wood JT. Drought resistance in spring wheat varieties. III. Yield associations with morpho-physiological traits. *Australian J Agric Res.* 1979;30:1001–11. doi: 10.1071/AR9791001
- [9] Goyal MR, Mansour HAA. Closed circuit trickle irrigation design: theory and applications. Canada: Apple Academic Press, Taylor and Frances; 2015.
- [10] Grassini P, van Bussel LGJ, Van Wart J, Wolf J, Claessens L, Yang H, et al. How good is good enough? Data requirements for reliable crop yield simulations and yield-gap analysis. *Field Crops Res.* 2015;177:49–63.
- [11] Hellal F, Mansour H, Abdel-Hady M, El-Sayed S, Abdelly C. Assessment water productivity of barley varieties under water stress by AquaCrop model. *AIMS Agric Food.* 2019;4(3):501–17. doi: 10.3934/agrfood.3.501
- [12] Ibrahim A, Csúr-Varga A, Jolánkai M, Mansour H, Hamed A. Monitoring some quality attributes of different wheat varieties by infrared technology. *Agric Eng Int CIGR J.* 2018;20(1):201–10.
- [13] Isik M, Devadoss S. An analysis of the impact of climate change on crop yields and yield variability. *Appl Econ.* 2006;38:835–44.
- [14] Kobata T, Okuno T, Yamamoto T. Contributions of capacity for soil water extraction and water use efficiency to maintenance of dry matter production in rice subjected to drought. *Nihon Sakumotsu Gakkai Kiji.* 1996;65:652–62.
- [15] Li T, Hasegawa T, Yin X, Zhu Y, Boote K, Adam M, et al. Uncertainties in predicting rice yield by current 130 crop models under a wide range of climatic conditions. *Global Change Biol.* 2015;21:1328–41.
- [16] Lobell DB, Cassman KG, Field CB. Crop yield gaps: their importance, magnitudes, and causes. *Ann Rev Environ Res.* 2009;34:179.
- [17] Lopezcastaneda C, Richards RA. Variation in temperate cereals in rainfed environments. 3. Water use and water-use efficiency. *Field Crops Res.* 1994;39:85–98. doi: 10.1016/0378-4290(94)90011-6.
- [18] Luo LJ, Zhang QF. The status and strategy on drought resistance of rice (*Oryza sativa* L.). *Chinese J Rice Sci.* 2001;15:209–14.
- [19] Mansour HAA. Design considerations for closed circuit design of drip irrigation system (book chapter), closed circuit trickle irrigation design: theory and applications. India: Apple Academic Press, Taylor and Frances; 2015.
- [20] Mansour HAA, Aljughaiman AS. Water and fertilizer use efficiencies for drip irrigated corn: Kingdom of Saudi Arabia (book chapter) closed circuit trickle irrigation design: theory and applications. Pakistan: Apple Academic Press, Taylor and Frances; 2015.
- [21] Mansour HAA, El-Melhem Y. Performance of drip irrigated yellow corn: Kingdom of Saudi Arabia (book Chapter), closed circuit trickle irrigation design: theory and applications. Pakistan: Apple Academic Press, Taylor and Frances; 2015.
- [22] Mansour HAA, Tayel MY, Lightfoot DA, El-Gindy AM. Energy and water savings in drip irrigation systems. *Closed Circuit Trickle Irrigation Design: Theory and Applications.* Canada: Apple Academic Press (AAP); 2015a. pp. 149–78.
- [23] Mansour HA, Abdel-Hady M, El-Dardiry EI, Bralts VF. Performance of automatic control different localized irrigation systems and lateral lengths for: emitters clogging and maize (*Zea mays* L.) growth and yield. *Int J Geo.* 2015b;9(2):1545–52.
- [24] Mansour HA, Abd El-Hady M, Bralts VF, Engel BA. Performance automation controller of drip irrigation system and saline water

- for wheat yield and water productivity in Egypt. *J Irrigat Drain Eng Am Soc Civil Eng (ASCE)*, *J Irrig Drain Eng.* 2016;142(10):1–6.
- [25] Mansour HA, Abd-Elmabod SK, AbdelGawad S. The impact of sub-surface drip irrigation and different water deficit treatments on the spatial distribution of soil moisture and salinity. *Plant Arch.* 2019a;2:384–92.
- [26] Mansour HA, Osama AN, Maybelle SG, El-Nasharty AB. Management of two irrigation systems and Algae Foliar application on wheat plant growth. *AIMS Agric Food.* 2019b;4(3):824–32. doi: 10.3934/agrfood.3.824
- [27] Mansour HA, El-Hady MA, Eldardiry El, Aziz AM. Wheat crop yield and water use as influenced by sprinkler irrigation uniformity. *Plant Arch.* 2019c;2:2296–303.
- [28] Martin GB, Williams JGK, Tanksley SD. Rapid Identification of markers linked to a *Pseudomonas* resistance gene in tomato by using random primers and near-isogenic lines. *Proc Natl Acad Sci U S A.* 1991;88:2336–40.
- [29] Martin B, Tauer CG, Lin RK. Carbon isotope discrimination as a tool to improve water-use efficiency in tomato. *Crop Sci.* 1999;39:1775–83.
- [30] Morgante M, Salamini F. From plant genomics to breeding practice. *Curr Opin Biotechnol.* 2003;14:214–9.
- [31] Munoz P, Voltas J, Araus JL, Igartua E, Romagosa I. Changes over time in the adaptation of barley releases in North-eastern Spain. *Plant Breeding.* 1998;117:531–5.
- [32] Passioura JB. Environmental biology and crop improvement. *Funct Plant Biol.* 2002;29:537–46.
- [33] Ribaut JM, Banziger M, Betran J, Jiang C, Edmeades GO, Dreher K, et al. Use of molecular markers in plant breeding drought tolerance improvement in tropical maize. In: Kang MS, editor. *Quantitative Genetics, Genomics, and Plant Breeding*. India: CABI Publishing; 2002. pp. 85–99.
- [34] Vierling RA, Nguyen HT. Use of RAPD markers to determine the genetic diversity of diploid, wheat genotypes. *Theor Appl Genet.* 1992;84:835–8.
- [35] Rohlf FJ. *NTSYS-pc numerical taxonomy and multivariate bsystem*, version 1.80. New York, USA: Applied Biostatistics Inc.; 1993.
- [36] Roy JK, Lakshmikumaran MS, Balyan HS, Gupta PK. AFLPbased genetic diversity and its comparison with diversity based on SSR, SAMPL, and phenotypic traits in bread wheat. *Biol Gen.* 2004;42:43–59.
- [37] Salvi S, Tuberosa R. To clone or not to clone plant QTLs: present and future challenges. *Trends Plant Sci.* 2005;10:297–304.
- [38] Semenov MA, Porter JR. Climatic variability and the modelling of crop yields. *Agric Forest Meteor.* 1995;73:265–83.
- [39] Sun G, Bond M, Nass H, Martin R, Dong Z. RAPD polymorphisms in spring wheat varieties and lines with different level of *Fusarium* resistance. *Theor Appl Genet.* 2003;106(6):1059–67.
- [40] Tahir NAR. Assessment of genetic diversity among wheat varieties in Sulaimanyah using random amplified polymorphic DNA (RAPD) analysis. *Jordan J Biol Sci.* 2008;1(4):159–64.
- [41] Tayel MY, Mansour HA, El-Gindy AM. Effect of drip irrigation circuit design and lateral line lengths iv- on uniformity coefficient and coefficient of variation. *J Appl Sci Res.* 2012;8(5):2741–8.
- [42] Tayel MY, Sabhan MS, Mansour HA. Effect of plowing conditions on the tractor wheel slippage and fuel consumption in sandy soil. *Int J Chem Tech Res.* 2015;8(12): 151–9.
- [43] Tayel MY, Eldardiry El, Mansour HA. Wheat yield versus seed bed conditions. *Biosci Res.* 2018;15(3):1943–51.
- [44] Tolk JA, Howell TA. Water use efficiencies of grain sorghum grown in three USA southern Great Plains soils. *Agric Water Manage.* 2003;59:97–111. doi: 10.1016/S0378-3774(02) 00157-9
- [45] Tuberosa R, Salvi S. Genomics-based approaches to improve drought tolerance of crops. *Trends Plant Sci.* 2007;11:405–12.
- [46] Williams JGK, Hanafey MK, Rafalski JA, Tingey SV. Genetic analysis using random amplified polymorphic DNA markers. *Methods Enzymol.* 1993;218:704–40.
- [47] Williams JGK, Kubelik AR, Livak KJ, Rafalski JA, Tingey SV. DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. *Nucleic Acid Res.* 1990;18:6531–6535.