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Evaluation of Doubled Haploid Maize Hybrids under Normal and Drought Condition

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Abstract

This experiment was conducted to evaluate the performance of doubled haploid maize hybrids under normal and drought condition. Fifteen doubled haploid maize hybrids were sown in Research Area of Plant Breeding and Genetics, University of Agriculture Faisalabad by using Randomized Complete Block Design during spring 2019. The experimental area was divided into two blocks. Both blocks contain two replications of 15 hybrids. One out of these two blocks was treated with normal irrigations and second block was treated with drought. Data was recorded for various growth and yield related traits. To estimate the performance of doubled haploid maize hybrids under normal and drought conditions the recorded data was subjected to ANOVA by using the STATISTIX 8.1 software. LSD mean comparison test at 0.05% level of significance for hybrids and hybrids × treatment interaction was also calculated. Analysis of variance showed the significant difference among all the hybrids and also in hybrid × treatment interaction. Hybrids DH-26S × 3B and DH-100A × 21 showed maximum 100 grain weight (31.9g) under drought condition. Hybrid DH-100A × 21 showed maximum biomass (278.9g) under drought condition. Genetic advancement and heritability percentage were also calculated for all parameter and listed in the tables. The results showed that maximum genetic advancement was found in biomass; (56), (47) respectively under normal and drought condition.

Keywords: Maize, Double Haploid hybrids, Heritability, Genetic advancement, Drought.

1. INTRODUCTION

Maize belongs to family Paoaceae. Corn or maize is the 3rd prominent crop after rice and wheat in the worldwide. The corn is originated from Mexico region of the Central America. The major purpose of maize cultivation is to obtain high production of grains yield. Maize grains have significant nutritional values. Maize grains consist of about 4.89 % oil, 9.78% protein, 72.01 % starch, 9.5% crude fiber and 9.71% embryo. The forage which is obtained from maize consists of 51.71 % detergent fiber, 23.02 % acid detergents, 26.88% forage crude fiber, 28.8% cellulose, 10.34 % crude protein, 9.1 % forage water content and 40.20 % forage dry matter [1].

The maize is ranked 4th prominent crop after rice, wheat and cotton in Pakistan. Corn enhances 0.5% to total GDP and boost 2.4% to agriculture sector. In Pakistan, maize is cultivated twice in a year during spring and autumn. The environmental condition and climatic condition of Pakistan is suitable for maize production. Maize grain production in Punjab is 69 percent and KPK produced 31 percent, these two provinces are major maize grain producer. Sindh and Baluchistan produced less than one percent of total maize grain production [2]. In drought condition, moisture level of soil and soil water reduced. Drought is major problem in all over world and it is very alarming situation for field crop and food

production [3]. Drought is an abiotic factor which effects the maize at all levels of growth [4]. Afterwards barley, maize is more drought tolerant cereal crop as compare to further cereal crops [5]. Drought effected the maize by decreasing metabolic activities, changing enzyme configuration, disturbing ionic balance, decreasing leaf area and lowering water use efficiency [6].

Drought tolerant maize verities can be produced by conventional breeding method. But now a day's maize breeder use haploid breeding technology to produced drought tolerant hybrids [7]. Double haploid technology is a modern technique to produce the inbred lines by using the inducer lines. These inducer lines are used to develop the haploids. Than by using the colchicine, chromosome of haploids become double and then finally acquire the double haploid lines. Only two generations are needed to obtain the homozygosity in the doubled haploid technology. While in conventional breeding method seven to eight generation are required to obtain the homozygous lines. Thus DH technology reduced the time of breeding process, saves the cash and many other resources. DH technology offers several benefits in genetics and maize breeding [8, 9]. Double haploid technology also used in the selection of germplasm with help of molecular markers. Now a day, in vivo doubled haploid technology used in the worldwide to increase the production and efficiency of maize crop [10].

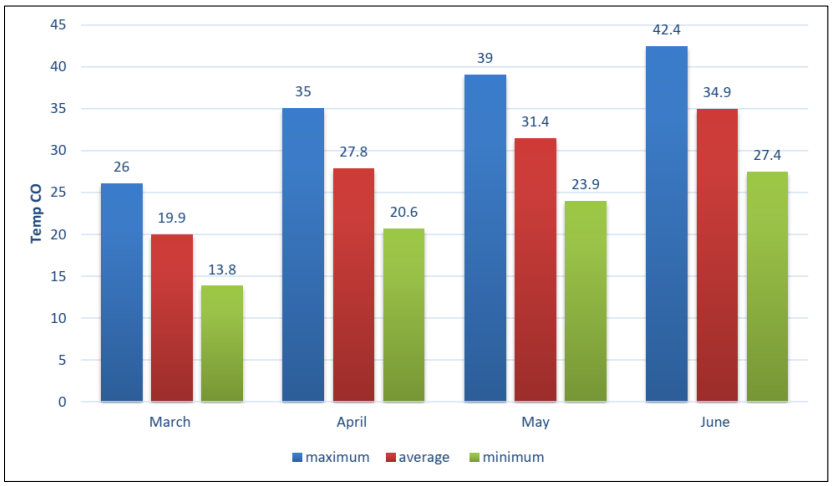
Main objective of this experiment is to estimate the performance of doubled haploid maize hybrids for various physiological and morphological traits under water deficit conditions. Estimation of variability for various physiological and morphological traits of DH hybrids under normal and water stress conditions. Best DH maize hybrids can be selected for water deficit condition. The germplasm of DH hybrids can be retained through this experiment. The information so derivative may be helpful in developing selection criterion and for further upcoming breeding programs to develop maize drought tolerant genotypes.

2. MATERIALS AND METHODS

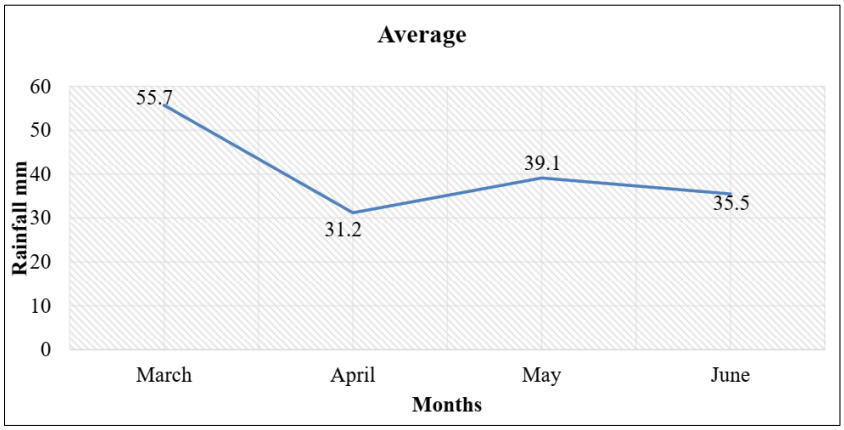
2.1. Metrological Data

The aspect of climatic data of whole the experimental period is given in graphical representation.

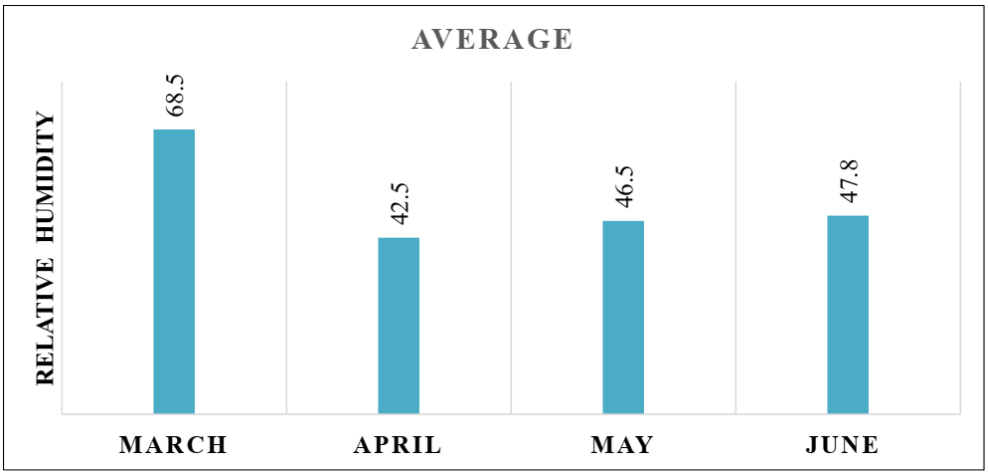
2.1.1. Maximum, Minimum and Average Temperature during the Period of Field Experiment



2.1.2. Average Rainfall during the Period of Field Experiment



2.1.3. Relative Humidity during the Period of Field Experiment



2.2. Plant Material

Fifteen doubled haploid maize hybrids were taken from Tissue Culture Lab of Department of PBG, UAF. Names of doubled haploid maize hybrids given below in table.

2.2.1. Name of Doubled Haploid Maize Hybrids

1	**DH-3B × 14C**	**6**	**DH-2R × 21**	**11**	**DH-26S × 3B**
2	DH-14E × 54	7	DH-21 × 14D	12	DH-25B × 16B
3	DH-21E × 100L	8	DH-29 × 2B	13	DH-21C × 100E
4	DH-100I × 54	9	DH-100A × 21	14	DH-21A × 100G
5	DH-48B × 100G	10	DH-44 × 54	15	DH-2L × 1D

2.3. Experimental Detail

In the field of PBG, UAF fifteen doubled haploid maize hybrids were sown by using Randomize Complete Block Design (RCBD) in spring 2019. Field contains two plots; each plot had two sets of replication as Set1R1, Set1R2 under normal condition and Set2R1, Set2R2 under drought condition. In each replication, 15 doubled haploids were sown. In each hybrid, five plants were selected to analyze following parameters.

1. Tasseling to silking interval	5. Cob diameter
2. Flag leaf area	6. Hundred grains weight
3. Stem diameter	7. Biomass
4. Cob length	8. Harvest index

2.4. Biometrical Approaches

The recorded data of doubled haploid maize hybrids were examined by analysis of variance as procedure given by [11]. LSD mean comparison test was performed to check the significant and non-significant differences among the doubled haploid maize hybrids. Genetic advancement was also calculated following by [12].

3. RESULTS AND DISCUSSION

3.1. Analysis of Variance

3.1.1. Tasseling to Silking Interval

The analysis of variance showed the highly significant results as shown in Table 3.1.1(a). Table LSD all-pairwise mean comparisons test of tasseling to silking interval for hybrids and LSD all-pairwise comparisons test of tasseling to silking interval for treatment × hybrid showed highly significant differences as shown in Table 3.1.1(b) and Table 3.1.1(c). The results of graphical representation of means of tasseling to silking interval for doubled haploid maize hybrids under normal and drought condition showed that hybrid DH-2R × 21 had minimum days (5) tasseling to silking interval under normal condition. Hybrid DH-26S × 3B showed maximum days (6) tasseling to silking interval under drought condition. The average range of tasseling to silking interval was between 5 to 6 days. Genetic advancement for this parameter was (0.7388) along with 84.0084% heritability under normal condition. Genetic advancement for this parameter was (0.3730) along with 71.9549% Heritability under drought condition [13].

Table 3.1.1(a) Analysis of variance for tasseling to silking interval in doubled haploid maize hybrids

SOV	DF	SS	MS	F	P
Replication	1	0.08817	0.08817		
Treatment	1	0.30817	0.30817	12.47	0.0014**
Hybrids	14	4.78	0.34143	13.81	0**
Treatment × Hybrid	14	1.43933	0.10281	4.16	0.0006**
Error	29	0.71683	0.02472		
Total	59	7.3325			

NS= Non significant *= Significant at 5% level **= Significant at 1% level
Grand Mean = 6.1750 CV = 2.55

Table 3.1.1(b) LSD all-pairwise comparisons test of tasseling to silking interval for hybrid

Hybrid	Mean	Homogeneous Groups
DH-21C × 100E	6.725	A
DH-25B × 16B	6.7	A
DH-26S × 3B	6.55	AB
DH-48B × 100G	6.425	BC
DH-14E × 54	6.2	CD
DH-2L × 1D	6.15	DE
DH-100A × 21	6.15	DE
DH-21E × 100L	6.1	DEF
DH-21 × 14D	6.075	DEF
DH-21A × 100G	6.025	DEFG
DH-3B × 14C	5.95	EFG
DH-44 × 54	5.925	EFG
DH-100I × 54	5.925	EFG
DH-29 × 2B	5.9	FG
DH-2R × 21	5.825	G

Alpha = 0.05 SE for Comparison = 0.1112
Critical T Value = 2.045 CV for Comparison = 0.2274

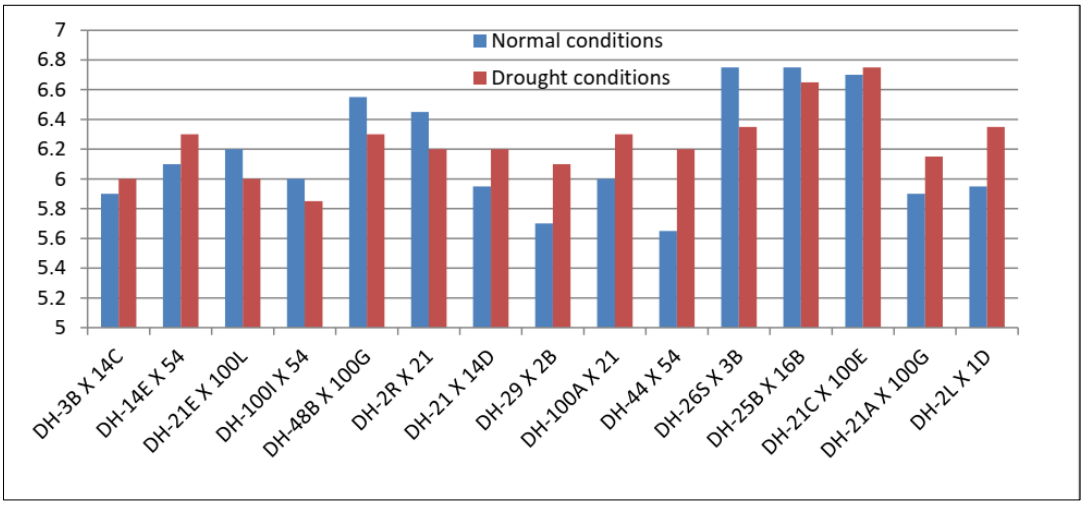
Table 3.1.1(c) LSD all-pairwise comparisons test of tasseling to silking interval for treatment × hybrid

Hybrid	Treatment	Mean	Homogeneous Groups
DH-26S × 3B	1	6.75	A
DH-25B × 16B	1	6.75	A
DH-21C × 100E	2	6.75	A
DH-21C × 100E	1	6.7	A
DH-25B × 16B	2	6.65	AB
DH-48B × 100G	1	6.55	ABC
DH-26S × 3B	2	6.35	BCD
DH-2L × 1D	2	6.35	BCD
DH-14E × 54	2	6.3	CDE
DH-48B × 100G	2	6.3	CDE
DH-100A × 21	2	6.3	CDE
DH-21E × 100L	1	6.2	DEF
DH-2R × 21	2	6.2	DEF
DH-21 × 14D	2	6.2	DEF
DH-44 × 54	2	6.2	DEF
DH-21A × 100G	2	6.15	DEFG
DH-14E × 54	1	6.1	DEFG
DH-29 × 2B	2	6.1	DEFG
DH-100I × 54	1	6	EFGH
DH-100A × 21	1	6	EFGH
DH-3B × 14C	2	6	EFGH
DH-21E × 100L	2	6	EFGH
DH-21 × 14D	1	5.95	FGHI
DH-2L × 1D	1	5.95	FGHI

Hybrid	Treatment	Mean	Homogeneous Groups
DH-3B × 14C	1	5.9	FGHI
DH-21A × 100G	1	5.9	FGHI
DH-100I × 54	2	5.85	GHI
DH-29 × 2B	1	5.7	HIJ
DH-44 × 54	1	5.65	IJ
DH-2R × 21	1	5.45	J

Alpha = 0.05 SE for Comparison = 0.1572
Critical T Value = 2.045 CV for Comparison = 0.3216

Graphical Representation of Means of Tasseling Silking Interval for Doubled Haploid Maize Hybrids under Normal and Drought Condition



3.1.2. Stem Diameter

The analysis of variance showed highly significant results as shown in Table 3.1.2(a). LSD all-pairwise mean comparisons test of stem diameter for hybrids and LSD all-pairwise mean comparisons test of stem diameter for treatment × hybrid showed the highly significant difference among hybrids and among the interaction of treatments and hybrids. The graphical representation of means of stem diameter showed that hybrid DH-25B ×16B had minimum (0.97cm) stem diameter under normal condition. Hybrid DH-25B ×16B showed maximum (1.605cm) stem diameter under drought condition. The phenotypic coefficient of variance for stem diameter was (11.2209) and genotypic coefficient of variance was (10.6013) under normal condition as shown in table 3.2(a) Genetic advancement for this parameter was (0.2670) along with 89.26% heritability under normal condition. The phenotypic coefficient of variance for stem diameter was (6.1131) and genotypic coefficient of variance was (5.9142) under drought condition as shown in table 3.2(b). Genetic advancement for this parameter was (0.1640) along with 93.5983% heritability under drought condition [14].

Table 3.1.2(a) Analysis of variance for stem diameter in doubled haploid maize hybrids

SOV	DF	SS	MS	F	P
Replication	1	0.00353	0.00353		
Treatment	1	0.13254	0.13254	95.92	0**
Hybrids	14	0.18409	0.01315	9.52	0**
Treatment × Hybrid	14	0.57386	0.04099	29.66	0**
Error	29	0.04007	0.00138		
Total	59	0.93409			

Grand Mean = 1.3447 CV = 2.76

Table 3.1.2(b) LSD all-pairwise comparisons test of stem diameter for hybrid

Hybrid	Mean	Homogeneous Groups
DH-2L × 1D	1.4775	A
DH-21 ×14D	1.4	B
DH-48B × 100G	1.375	BC

Hybrid	Mean	Homogeneous Groups
DH-21C ×100E	1.3725	BCD
DH-29 ×2B	1.3675	BCD
DH-21A × 100G	1.3675	BCD
DH-3B × 14C	1.365	BCD
DH-21E × 100L	1.3625	BCD
DH-26S × 3B	1.34	CDE
DH-100A × 21	1.3275	CDE
DH-14E × 54	1.32	DE
DH-100I × 54	1.2875	EF
DH-25B × 16B	1.2875	EF
DH-2R × 21	1.265	F
DH-44 × 54	1.255	F

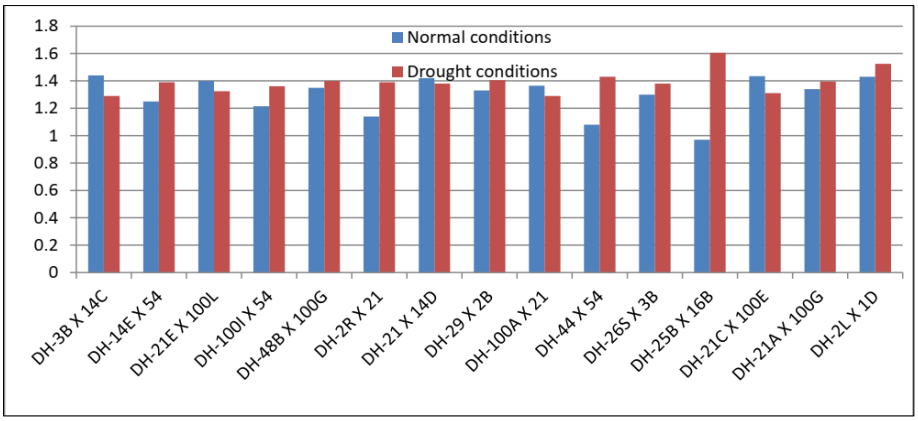
Alpha = 0.05 SE for Comparison = 0.0263
Critical T Value = 2.045 CV for Comparison = 0.05

Table 3.1.2(c) LSD all-pairwise comparisons test of stem diameter for treatment × hybrid

Hybrid	Treatment	Mean	Homogeneous Groups
DH-25B × 16B	2	1.605	A
DH-2L × 1D	2	1.525	B
DH-3B × 14C	1	1.44	C
DH-21C × 100E	1	1.435	CD
DH-2L × 1D	1	1.43	CD
DH-44 × 54	2	1.43	CD
DH-21 × 14D	1	1.42	CDE
DH-29 × 2B	2	1.405	CDEF
DH-21E × 100L	1	1.4	CDEFG
DH-48B × 100G	2	1.4	CDEFG
DH-21A × 100G	2	1.395	CDEFG
DH-14E × 54	2	1.39	CDEFG
DH-2R ×21	2	1.39	CDEFG
DH-21 × 14D	2	1.38	CDEFGH
DH-26S × 3B	2	1.38	CDEFGH
DH-100A × 21	1	1.365	CDEFGHI
DH-100I × 54	2	1.36	DEFGHI
DH-48B × 100G	1	1.35	EFGHI
DH-21A × 100G	1	1.34	FGHI
DH-29 × 2B	1	1.33	FGHI
DH-21E × 100L	2	1.325	GHIJ
DH-21C × 100E	2	1.31	HIJ
DH-26S × 3B	1	1.3	IJ
DH-3B × 14C	2	1.29	IJK
DH-100A × 21	2	1.29	IJK
DH-14E × 54	1	1.25	JK
DH-100I × 54	1	1.215	KL
DH-2R × 21	1	1.14	LM
DH-44 × 54	1	1.08	M
DH-25B × 16B	1	0.97	N

Alpha = 0.05 SE for Comparison = 0.0372
Critical T Value = 2.045 CV for Comparison = 0.0760

Graphical Representation of Means of Stem Diameter for Doubled Haploid Maize Hybrids under Normal and Drought Condition



3.1.3. Flag Leaf Area

The analysis of variance showed highly significant results. The LSD all-pairwise mean comparisons test of flag leaf area for hybrids and LSD all-pairwise mean comparisons test of flag leaf area for treatment × hybrid showed the highly significant differences among hybrids and among the interaction of treatments and hybrids. The graphical representation showed that Hybrid DH-14E × 54 showed maximum (170.74cm2) flag leaf area under drought condition. The average range of flag leaf area was 127cm2 – 170cm2. The phenotypic coefficient of variance for flag leaf area was (8.8694) and genotypic coefficient of variance was (8.8446) under normal condition as shown in table 3.2(a). Genetic advancement for this parameter was (27.4052) along with 99.4396% heritability under normal condition. The phenotypic coefficient of variance for flag leaf area was (6.0728) and genotypic coefficient of variance was (6.0292) under drought condition as shown in table 3.2(b). Genetic advancement for this parameter was (18.2334) along with 98.5700% heritability under drought condition [15].

Table 3.1.3(a) Analysis of variance for flag leaf area in doubled haploid maize hybrids

SOV	DF	SS	MS	F	P
Replication	1	1.39	1.392		
Treatment	1	132.48	132.48	124.11	0.0000**
Hybrids	14	2035.38	145.384	136.2	0.0000**
Treatment × Hybrid	14	5203.68	371.692	348.21	0.0000**
Error	29	30.96	1.067		
Total	59	7403.89			

Grand Mean = 149.35 CV = 0.69

Table 3.1.3(b) LSD all-pairwise comparisons test of flag leaf area for hybrid

Hybrid	Mean	Homogeneous Groups
DH-21A × 100G	158.69	A
DH-29 × 2B	156.47	B
DH-21E × 100L	155.67	BC
DH-48B × 100G	154.57	C
DH-26S × 3B	152.23	D
DH-14E × 54	151.88	DE
DH-2R × 21	150.96	DEF
DH-3B × 14C	150.46	EF
DH-2L × 1D	150.12	F
DH-21C × 100E	147.14	G
DH-100I × 54	145.89	GH
DH-25B × 16B	145.31	H
DH-100A × 21	141.35	I
DH-21 × 14D	141.16	I
DH-44 × 54	138.38	J

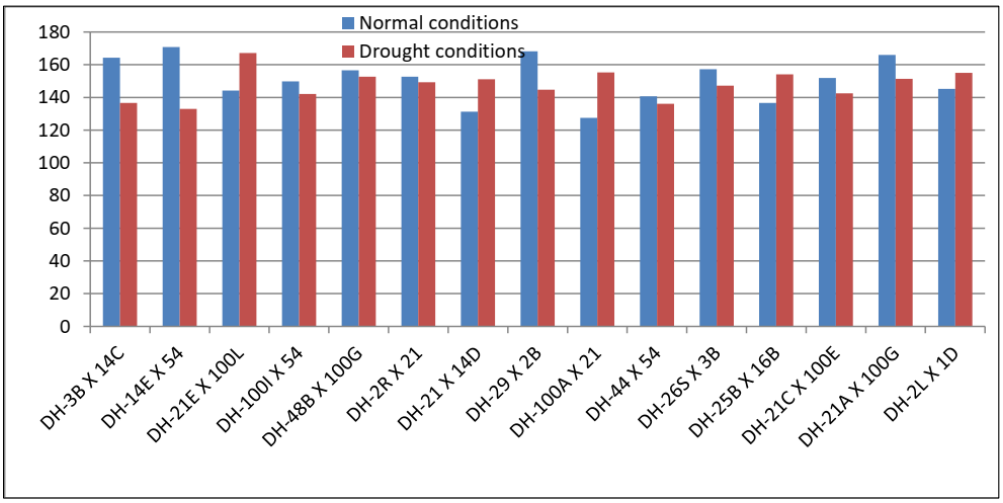
Alpha = 0.05 SE for Comparison = 0.7306
Critical T Value = 2.045 CV for Comparison = 1.4942

Table 3.1.3(c) LSD all-pairwise comparisons test of flag leaf area for treatment × hybrid

Hybrid	Treatment	Mean	Homogeneous
DH-14E × 54	1	170.74	A
DH-29 × 2B	1	168.21	B
DH-21E × 100L	2	167.12	BC
DH-21A × 100G	1	165.98	CD
DH-3B × 14C	1	164.29	D
DH-26S × 3B	1	157.24	E
DH-48B × 100G	1	156.51	EF
DH-100A × 21	2	155.28	EFG
DH-2L × 1D	2	155	FG
DH-25B × 16B	2	154.03	GH
DH-48B × 100G	2	152.64	HI
DH-2R × 21	1	152.62	HI
DH-21C × 100E	1	151.84	IJ
DH-21A × 100G	2	151.4	IJK
DH-21 × 14D	2	151.04	IJK
DH-100I × 54	1	149.75	JK
DH-2R × 21	2	149.3	KL
DH-26S × 3B	2	147.23	LM
DH-2L × 1D	1	145.24	MN
DH-29 × 2B	2	144.73	N
DH-21E × 100L	1	144.21	NO
DH-21C × 100E	2	142.45	OP
DH-100I × 54	2	142.03	P
DH-44 × 54	1	140.65	P
DH-3B × 14C	2	136.63	Q
DH-25B × 16B	1	136.6	Q
DH-44 × 54	2	136.1	Q
DH-14E × 54	2	133.02	R
DH-21 × 14D	1	131.28	R
DH-100A × 21	1	127.43	S

Alpha= 0.05 SE for Comparison =1.0332
Critical T Value = 2.045 CV for Comparison = 2.1131

Graphical Representation of Means of Flag Leaf Area for Doubled Haploid Maize Hybrids under Normal and Drought Condition



3.1.4. Cob Length

The analysis of variance showed the significant results. LSD all-pairwise mean comparisons test of cob length for hybrids and LSD all-pairwise mean comparisons test of cob length for treatment × hybrid showed the highly significant differences among hybrids

and among the interaction of treatments and hybrids. Graphical representation of means of cob length showed that hybrid DH-100A × 21 had minimum (10.27cm) cob length under normal condition. Hybrid DH-29 × 2B showed maximum (15.53cm) cob length under drought condition. The average range of cob length was 10cm – 15cm. The phenotypic coefficient of variance for cob length was (10.9383) and genotypic coefficient of variance was (10.8662) under normal condition as shown in table 3.2(a). Genetic advancement for this parameter was (2.8269) along with 98.6862% heritability under normal condition. The phenotypic coefficient of variance for cob length was (7.5659) and genotypic coefficient of variance was (7.3330) under drought condition as shown in table 3.2(b). Genetic advancement for this parameter was (1.8811) along with 93.9369% heritability under drought condition [16].

Table 3.1.4(a) Analysis of variance for cob length in doubled haploid maize hybrids

SOV	DF	SS	MS	F	P
Replication	1	0.0976	0.09761		
Treatment	1	0.2747	0.27473	6.76	0.0145*
Hybrid	14	34.1664	2.44046	60.01	0.0000**
Hybrid*Treatment	14	45.2755	3.23396	79.52	0.0000**
Error	29	1.1794	0.04067		
Total	59	80.9936			

Grand Mean = 12.780 CV = 1.58

Table 3.1.4(b) LSD all-pairwise comparisons test of cob length for hybrid

Hybrids	Mean	Homogeneous Groups
DH-29 × 2B	14.665	A
DH-21E × 100L	13.415	B
DH-25B × 16B	13.395	B
DH-2L × 1D	13.38	B
DH-14E × 54	13.253	B
DH-26S × 3B	12.825	C
DH-21 × 14D	12.79	C
DH-21A × 100G	12.72	CD
DH-21C × 100E	12.658	CDE
DH-48B v 100G	12.478	DEF
DH-100I × 54	12.4	EFG
DH-100A × 21	12.195	FGH
DH-2R × 21	12.123	GH
DH-3B × 14C	12.08	H
DH-44 × 54	11.33	I

Alpha= 0.05 SE for Comparison=0. 1626
Critical Q Value 2.045 CV for Comparison = 0.2916

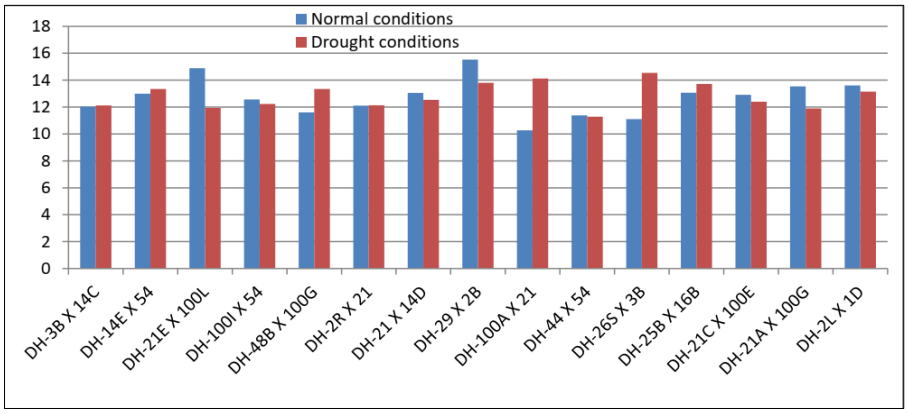
Table 3.1.4(c) LSD all-pairwise comparisons test of cob length for treatment × hybrid

Hybrids	Treatment	Mean	Homogeneous Groups
DH-29 × 2B	1	15.53	A
DH-21E × 100L	1	14.89	B
DH-26S × 3B	2	14.54	B
DH-100A × 21	2	14.12	C
DH-29 × 2B	2	13.8	CD
DH-25B × 16B	2	13.72	CDE
DH-2L × 1D	1	13.61	DE
DH-21A × 100G	1	13.54	DEF
DH-14E × 54	2	13.51	DEF
DH-48B × 100G	2	13.345	EFG
DH-2L × 1D	2	13.15	FGH
DH-25B × 16B	1	13.07	GH
DH-21 × 14D	1	13.05	GH
DH-14E × 54	1	12.995	GH
DH-21C × 100E	1	12.915	HI

Hybrids	Treatment	Mean	Homogeneous Groups
DH-100I × 54	1	12.57	IJ
DH-21 × 14D	2	12.53	IJK
DH-21C × 100E	2	12.4	JKL
DH-100I × 54	2	12.23	JKLM
DH-2R × 21	2	12.135	KLM
DH-3B × 14C	2	12.12	KLM
DH-2R × 21	1	12.11	LM
DH-3B × 14C	1	12.04	LM
DH-21E × 100L	2	11.94	MN
DH-21A × 100G	2	11.9	MN
DH-48B × 100G	1	11.61	NO
DH-44 × 54	1	11.38	OP
DH-44 X 54	2	11.28	OP
DH-26S × 3B	1	11.11	P
DH-100A × 21	1	10.27	Q

Alpha = 0.05 SE for Comparison = 0.2017
Critical T Value = 2.045 CV for Comparison = 0.4125

Graphical Representation of Means of Cob Length for Doubled Haploid Maize Hybrids under Normal and Drought Condition



3.1.5. Cob Diameter

The analysis of variance showed the significant results as shown in Table 3.1.5(a). LSD all-pairwise mean comparisons test of cob diameter for hybrids and LSD all-pairwise mean comparisons test of cob diameter for treatment × hybrid showed the highly significant difference among hybrids and among the interaction of treatments and hybrids. Graphical representation of means of cob diameter showed that Hybrid DH-26S × 3B showed maximum (3.4150cm) cob diameter under drought condition. The average range of cob diameter was 2.88cm – 3.41cm. The phenotypic coefficient of variance for cob diameter was (4.6103) and genotypic coefficient of variance was (4.4117) under normal condition as shown in table 3.2(a). Genetic advancement for this parameter was (0.2783) along with 91.5717% heritability under normal condition. The phenotypic coefficient of variance for cob diameter was (4.0431) and genotypic coefficient of variance was (3.1962) under drought condition as shown in table 3.2(b). Genetic advancement for this parameter was (0.1679) along with 62.4951% heritability under drought condition [17].

Table 3.1.5(a) Analysis of variance for cob diameter in doubled haploid maize hybrids

SOV	DF	SS	MS	F	P
Replication	1	0.01838	0.01838		
Treatment	1	0.00937	0.00937	1.89	0.1793*
Hybrid	14	0.48139	0.03496	7.06	0.0000**
Hybrid*Treatment	14	0.48130	0.03438	6.94	0.0000**
Error	29	0.14357	0.00495		
Total	59	1.14202			

Grand Mean = 3.2128 CV = 2.19

Table 3.1.5(b) LSD all-pairwise comparisons test of cob diameter for hybrid

Hybrids	Mean	Homogeneous Groups
DH-29 × 2B	3.335	A
DH-21E ×100L	3.2925	AB
DH-2L × 1D	3.29	AB
DH-100A × 21	3.27	AB
DH-25B ×16B	3.2625	AB
DH-26S × 3B	3.26	AB
DH-14E v 54	3.2575	AB
DH-21A × 100G	3.2525	ABC
DH-21 × 14D	3.235	ABCD
DH-100I × 54	3.1925	BCD
DH-21C × 100E	3.1525	CD
DH-3B × 14C	3.15	D
DH-48B × 100G	3.145	D
DH-2R × 21	3.14	D
DH-44 × 54	2.9575	E

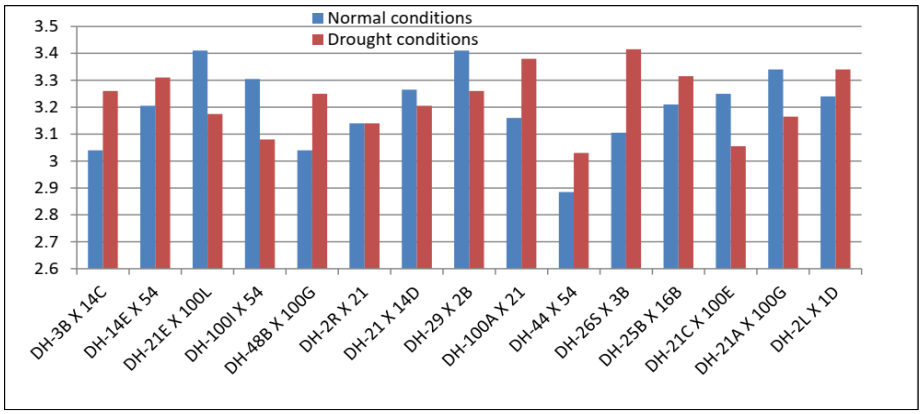
Alpha = 0.05 SE for Comparison = 0.0498
Critical Q Value = 2.045 CV for Comparison = 0.1018

Table 3.1.5(c) LSD all-pairwise comparisons test of cob diameter for treatment × hybrid

Hybrid	Treatment	Mean	Homogeneous Groups
DH-26S × 3B	2	3.4150	A
DH-21E × 100L	1	3.4100	A
DH-29 × 2B	1	3.4100	A
DH-100A × 21	2	3.3800	AB
DH-21A × 100G	1	3.3400	ABC
DH-2L × 1D	2	3.3400	ABC
DH-25B × 16B	2	3.3150	ABCD
DH-14E × 54	2	3.3100	ABCD
DH-100I × 54	1	3.3050	ABCDE
DH-21 × 14D	1	3.2650	BCDEF
DH-3B × 14C	2	3.2600	BCDEF
DH-29 × 2B	2	3.2600	BCDEF
DH-21C × 100E	1	3.2500	BCDEF
DH-48B × 100G	2	3.2500	BCDEF
DH-2L × 1D	1	3.2400	BCDEFG
DH-25B × 16B	1	3.2100	CDEFGH
DH-14E × 54	1	3.2050	CDEFGH
DH-21 × 14D	2	3.2050	CDEFGH
DH-21E × 100L	2	3.1750	DEFGHI
DH-21A × 100G	2	3.1650	EFGHIJ
DH-100A × 21	1	3.1600	FGHIJ
DH-2R × 21	1	3.1400	FGHIJ
DH-2R × 21	2	3.1400	FGHIJ
DH-26S × 3B	1	3.1050	GHIJ
DH-100I × 54	2	3.0800	HIJ
DH-21C × 100E	2	3.0550	IJ
DH-3B × 14C	1	3.0400	IJ
DH-48B × 100G	1	3.0400	IJ
DH-44 × 54	2	3.0300	J
DH-44 × 54	1	2.8850	K

Alpha = 0.05 SE for Comparison = 0.070
Critical Q Value = 2.045 CV for Comparison = 0.143

Graphical Representation of Means of Cob Diameter for Doubled Haploid Maize Hybrids under Normal and Drought Condition



3.1.6. 100 Grain Weight

The analysis of variance showed the non-significant difference for treatment but highly significant difference for hybrids and treatments × hybrids interaction as shown in table 3.1.6(a). LSD all-pairwise mean comparisons test of 100 grain weight for hybrids and LSD all-pairwise mean comparisons test of 100 grain weight for treatment × hybrid showed the highly significant differences among hybrids and among the interaction of treatments and hybrids. Graphical representation showed that Hybrid DH-21E × 100L showed maximum (32.7g) 100 grain weight under drought condition. The average range of 100 grain weight was between 28g -33g. The phenotypic coefficient of variance for 100 grain weight was (3.7127) and genotypic coefficient of variance was (3.5203) under normal condition as shown in table 3.2(a). Genetic advancement for this parameter was (2.1141) along with 89.9032% heritability under normal condition. The phenotypic coefficient of variance for 100 grain weight was (2.9182) and genotypic coefficient of variance was (2.5588) under drought condition as shown in table 3.2(b). Genetic advancement for this parameter was (1.4160) along with 76.8855% heritability under drought condition [18].

Table 3.1.6(a) Analysis of variance for 100 grain weight in doubled haploid maize hybrids

SOV	DF	SS	MS	F	P
Replication	1	0.8882	0.88817		
Treatment	1	0.1815	0.1815	1.13	0.2965^{NS}
Hybrids	14	20.4333	1.45952	9.09	0^{**}
Treatment × Hybrid	14	34.006	2.429	15.13	0^{**}
Error	29	4.6568	0.16058		
Total	59	60.1658			

Grand Mean = 30.692 CV = 1.31

Table 3.1.6(b) LSD all-pairwise comparisons test of grain weight for hybrid

Hybrid	Mean	Homogeneous Groups
DH-29 × 2B	31.825	A
DH-21E × 100L	31.35	AB
DH-25B × 16B	31.2	BC
DH-21 × 14D	31.1	BCD
DH-2L × 1D	30.975	BCDE
DH-14E × 54	30.9	BCDE
DH-26S × 3B	30.9	BCDE
DH-48B × 100G	30.725	CDEF
DH-100I × 54	30.55	DEFG
DH-21A × 100G	30.5	EFG
DH-21C × 100E	30.45	EFG
DH-2R × 21	30.3	FG
DH-3B × 14C	30.2	FG
DH-100A × 21	30.1	G
DH-44 × 54	29.3	H

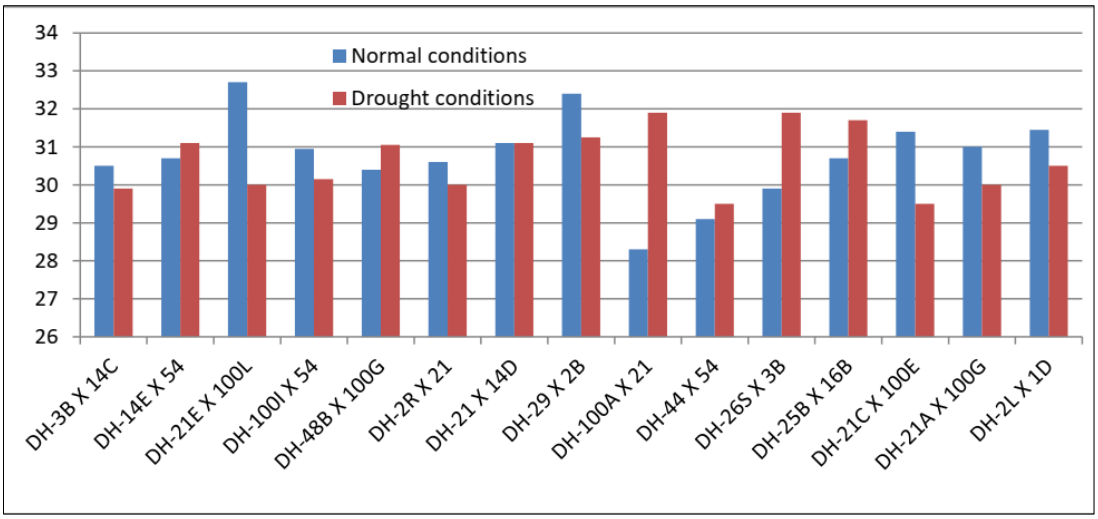
Alpha = 0.05 SE for Comparison = 0.2834
Critical T Value = 2.045 CV for Comparison = 0.5795

Table 3.1.6(c) LSD all-pairwise comparisons test of grain weight for treatment × hybrid

Hybrid	Treatment	Mean	Homogeneous Groups
DH-21E × 100L	1	32.7	A
DH-29 × 2B	1	32.4	AB
DH-100A × 21	2	31.9	ABC
DH-26S × 3B	2	31.9	ABC
DH-25B × 16B	2	31.7	BCD
DH-2L × 1D	1	31.45	CDE
DH-21C × 100E	1	31.4	CDEF
DH-29 × 2B	2	31.25	CDEFG
DH-21 × 14D	1	31.1	CDEFGH
DH-14E × 54	2	31.1	CDEFGH
DH-21 × 14D	2	31.1	CDEFGH
DH-48B × 100G	2	31.05	DEFGH
DH-21A × 100G	1	31	DEFGH
DH-100I × 54	1	30.95	DEFGHI
DH-14E × 54	1	30.7	EFGHIJ
DH-25B × 16B	1	30.7	EFGHIJ
DH-2R × 21	1	30.6	FGHIJ
DH-3B ×14C	1	30.5	GHIJ
DH-2L × 1D	2	30.5	GHIJ
DH-48B × 100G	1	30.4	HIJ
DH-100I × 54	2	30.15	IJK
DH-21E × 100L	2	30	JK
DH-2R × 21	2	30	JK
DH-21A × 100G	2	30	JK
DH-26S × 3B	1	29.9	JKL
DH-3B × 14C	2	29.9	JKL
DH-44 × 54	2	29.5	KL
DH-21C × 100E	2	29.5	KL
DH-44 × 54	1	29.1	LM
DH-100A × 21	1	28.3	M

Alpha = 0.05 SE for Comparison = 0.4007
Critical T Value = 2.045 CV for Comparison = 0.8196

Graphical Representation of Means of 100 Grain Weight for Doubled Haploid Maize Hybrids under Normal and Drought Condition



3.1.7. Biomass

The analysis of variance showed the highly significant results. LSD all-pairwise mean comparisons test of biomass for hybrids and LSD all-pairwise mean comparisons test of biomass for treatment × hybrid showed the highly significant differences among hybrids

and among the interaction of treatments and hybrids. Graphical representation of means of biomass showed that Hybrid DH-100A × 21 showed maximum (278.9g) biomass under drought condition. The average range of biomass was 162g – 289g. The phenotypic coefficient of variance for biomass was (13.9079) and genotypic coefficient of variance was (12.9508) under normal condition as shown in table 3.2(a). Genetic advancement for this parameter was (56.5594) along with 86.7095% heritability under normal condition. The phenotypic coefficient of variance for biomass was (9.7352) and genotypic coefficient of variance was (9.7249) under drought condition as shown in table 3.2(b). Genetic advancement for this parameter was (47.9222) along with 99.7885% heritability under drought condition [19].

Table 3.1.7(a) Analysis of variance for biomass in doubled haploid maize hybrids

SOV	DF	SS	MS	F	P
Replication	1	110.3	110.27		
Treatment	1	2086.9	2086.95	30.56	0**
Hybrids	14	18145.7	1296.12	18.98	0**
Treatment × Hybrid	14	23263.6	1661.68	24.33	0**
Error	29	1980.7	68.3		
Total	59	45587.3			

Grand Mean = 233.57 CV = 3.54

Table 3.1.7(b) LSD all-pairwise comparisons test of biomass for hybrid

Hybrid	Mean	Homogeneous Groups
DH-29 × 2B	262.73	A
DH-21A × 100G	249.87	B
DH-21E × 100L	248.79	BC
DH-48B × 100G	244.1	BCD
DH-2L × 1D	239.12	BCDE
DH-21 × 14D	238.77	BCDE
DH-21C × 100E	237.79	CDE
DH-100I × 54	236.85	CDE
DH-25B × 16B	235.3	DEF
DH-26S × 3B	231.99	EFG
DH-14E × 54	230.42	EFGH
DH-2R × 21	224.85	FGH
DH-100A × 21	220.7	GH
DH-3B × 14C	218.89	H
DH-44 × 54	183.37	I

Alpha = 0.05 SE for Comparison = 5.8439
Critical T Value = 2.045 CV for Comparison = 11.952

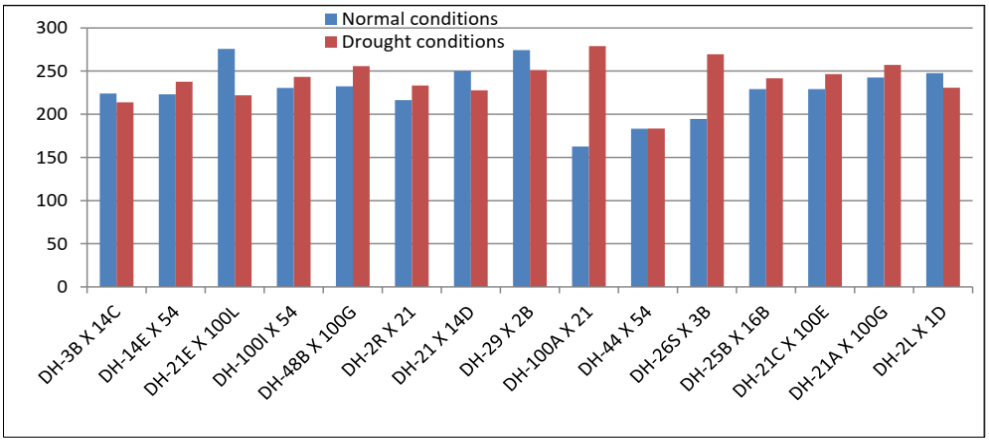
Table 3.1.7(c) LSD all-pairwise comparisons test of biomass for treatment × hybrid

Hybrids	Treatment	Mean	Homogeneous Groups
DH-100A × 21	2	278.9	A
DH-21E × 100L	1	275.64	A
DH-29 × 2B	1	274.34	A
DH-26S × 3B	2	269.48	AB
DH-21A × 100G	2	257.15	BC
DH-48B × 100G	2	255.8	BC
DH-29 × 2B	2	251.11	CD
DH-21 × 14D	1	249.94	CDE
DH-2L × 1D	1	247.59	CDEF
DH-21C × 100E	2	246.4	CDEFG
DH-100I × 54	2	243.13	CDEFGH
DH-21A × 100G	1	242.59	CDEFGH
DH-25B × 16B	2	241.56	CDEFGH
DH-14E × 54	2	237.72	DEFGHI
DH-2R × 21	2	233.29	EFGHIJ
DH-48B × 100G	1	232.39	FGHIJ

Hybrids	Treatment	Mean	Homogeneous Groups
DH-2L × 1D	2	230.65	GHIJK
DH-100I × 54	1	230.57	GHIJK
DH-21C × 100E	1	229.19	HIJK
DH-25B × 16B	1	229.03	HIJK
DH-21 × 14D	2	227.61	HIJK
DH-3B × 14C	1	223.95	IJK
DH-14E × 54	1	223.11	IJK
DH-21E × 100L	2	221.93	IJK
DH-2R × 21	1	216.4	JK
DH-3B × 14C	2	213.84	K
DH-26S × 3B	1	194.5	L
DH-44 × 54	2	183.43	L
DH-44 × 54	1	183.32	L
DH-100A × 21	1	162.51	M

Alpha = 0.05 SE for Comparison = 8.2645
Critical T Value = 2.045 CV for Comparison = 16.903

Graphical Representation of Means of Biomass for Doubled Haploid Maize Hybrids under Normal and Drought Condition



3.1.8. Harvest Index

The analysis of variance showed the highly significant results. LSD all-pairwise mean comparisons test of harvest index for hybrids and LSD all-pairwise mean comparisons test of harvest index for treatment × hybrid showed the highly significant differences among hybrids and among the interaction of treatments and hybrids. Graphical representation of means of harvest index showed that Hybrid DH-26S × 3B showed maximum (0.51) harvest index under drought condition. The phenotypic coefficient of variance for Harvest index was (9.9785) and genotypic coefficient of variance was (9.6951) under normal condition as shown in table 3.2(a). Genetic advancement for this parameter was (0.0806) along with 94.3998% heritability under normal condition. The phenotypic coefficient of variance for harvest index was (10.5533) and genotypic coefficient of variance was (10.3584) under drought condition as shown in table 3.2(b). Genetic advancement for this parameter was (0.0897) along with 96.3412% heritability under drought condition [19].

Table 3.1.8(a) Analysis of variance for harvest index in doubled haploid maize hybrids

SOV	DF	SS	MS	F	P
Replication	1	0.00002	0.00002		
Treatment	1	0.00254	0.00254	30.19	0^{**}
Hybrids	14	0.03802	0.00272	32.35	0^{**}
Treatment × Hybrid	14	0.06489	0.00464	55.2	0^{**}
Error	29	0.00244	0.00008		
Total	59	0.1079			

Grand Mean = 0.4218 CV = 2.17

Table 3.1.8(b) LSD all-pairwise comparisons test of harvest index for hybrid

Hybrid	Mean	Homogeneous Groups
DH-29 × 2B	0.475	A
DH-100A × 21	0.4475	B
DH-48B × 100G	0.445	BC
DH-26S × 3B	0.4325	CD
DH-21A × 100G	0.4325	CD
DH-2R × 21	0.43	DE
DH-3B × 14C	0.425	DEF
DH-25B × 16B	0.425	DEF
DH-100I × 54	0.4225	DEF
DH-21C × 100E	0.4175	EF
DH-21 × 14D	0.415	F
DH-21E × 100L	0.415	F
DH-14E × 54	0.39	G
DH-2L × 1D	0.385	G
DH-44 × 54	0.37	H

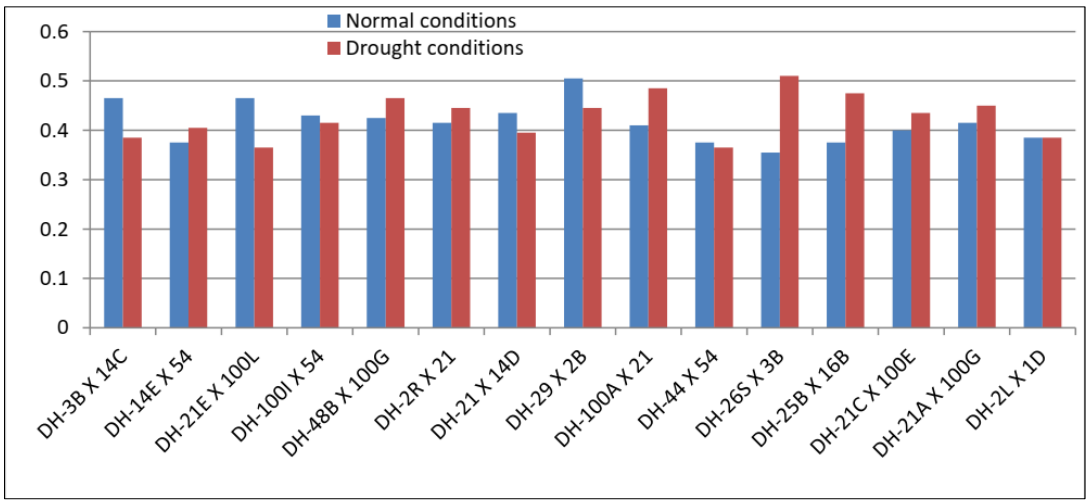
Alpha = 0.05 SE for Comparison = 6.479
Critical T Value = 2.045 CV for Comparison = 0.0133

Table 3.1.8(c) LSD all-pairwise comparisons test of harvest index for treatment × hybrid

Hybrid	Treatment	Mean	Homogeneous Groups
DH-26S × 3B	2	0.51	A
DH-29 × 2B	1	0.505	A
DH-100A × 21	2	0.485	B
DH-25B × 16B	2	0.475	BC
DH-3B × 14C	1	0.465	CD
DH-21E × 100L	1	0.465	CD
DH-48B × 100G	2	0.465	CD
DH-21A × 100G	2	0.45	DE
DH-2R × 21	2	0.445	EF
DH-29 × 2B	2	0.445	EF
DH-21 × 14D	1	0.435	EFG
DH-21C × 100E	2	0.435	EFG
DH-100I × 54	1	0.43	FGH
DH-48B × 100G	1	0.425	GHI
DH-2R × 21	1	0.415	HIJ
DH-21A × 100G	1	0.415	HIJ
DH-100I × 54	2	0.415	HIJ
DH-100A × 21	1	0.41	IJK
DH-14E × 54	2	0.405	JK
DH-21C × 100E	1	0.4	JKL
DH-21 × 14D	2	0.395	KL
DH-2L × 1D	1	0.385	LM
DH-3B × 14C	2	0.385	LM
DH-2L × 1D	2	0.385	LM
DH-14E × 54	1	0.375	MN
DH-44 × 54	1	0.375	MN
DH-25B × 16B	1	0.375	MN
DH-21E × 100L	2	0.365	NO
DH-44 × 54	2	0.365	NO
DH-26S × 3B	1	0.355	O

Alpha = 0.05 SE for Comparison = 9.16
Critical T Value = 2.045 CV for Comparison = 0.0187

Graphical Representation of Means of Harvest Index for Doubled Haploid Maize Hybrids under Normal and Drought Condition



3.2(a) Genetic Parameters under normal condition

Characters	Genotypic coefficient of variance	Phenotypic coefficient of variance	Heritability %	Genetic advancement
Tasseling silking interval	6.4108	6.9944	84.0084	0.7388
Stem diameter	10.6013	11.2209	89.26	0.2677
Flag leaf area	8.8446	8.8694	99.4396	27.4052
Cob length	10.8662	10.9383	98.6862	2.8269
Cob diameter	4.4117	4.6103	91.5717	0.2783
100 Grain Weight	3.5203	3.7127	89.9032	2.1141
Biomass	12.9508	13.9079	86.7095	56.5594
Harvest Index	9.6951	9.9785	94.3998	0.0806

3.2(b) Genetic Parameters under Drought condition

Characters	Genotypic coefficient of variance	Phenotypic coefficient of variance	Heritability %	Genetic advancement
Tasseling silking interval	3.4174	4.0287	71.9549	0.3730
Stem diameter	5.9142	6.1131	93.5983	0.1640
Flag leaf area	6.0292	6.0728	98.5700	18.2334
Cob length	7.3330	7.5659	93.9369	1.8811
Cob diameter	3.1962	4.0431	62.4951	0.1679
100 Grain Weight	2.5588	2.9182	76.8855	1.4160
Biomass	9.7249	9.7352	99.7885	47.9222
Harvest Index	10.3584	10.5533	96.3412	0.0897

CONCLUSION

In this study, all doubled haploid maize hybrids were significantly different from each other under drought condition. Some hybrids like Hybrid DH-25B ×16B showed maximum (1.605cm) stem diameter under drought condition along with higher heritability, Hybrid DH-21E × 100L showed maximum (32.7g) 100 grain weight under drought condition, Hybrid DH-100A × 21 showed maximum (278.9g) biomass under drought condition along with higher heritability, and Hybrid DH-26S × 3B showed maximum (0.51) harvest index along with higher heritability under drought condition. So these hybrids which performed best in yield related parameters can be used in further investigation.

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