Research Article

Assessment of Heritability and Genetic Advance in Maize (*Zea mays* L.) under Natural and Water Stress Conditions

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Abstract | Two sets of maize inbred lines containing 04 inbred lines were selected as parents viz., drought tolerant and susceptible from a diverse gene pool and crossed to produce 02 hybrids. The cross 1 comprised of a drought tolerant inbred line as VDR-51 and a susceptible inbred line 5CDR-53. The cross 2 comprised of a drought tolerant inbred line as DR3-126 and a susceptible inbred line DR-37. The trial was sown under triplicated split plot in a randomized complete block design (RCBD) under drought and rain-fed conditions. Both heritability and genetic advance estimates were higher for grain yield and plant height, hence additive gene action was depicted. While, narrow sense heritability and genetic advance was lower for remaining parameters under both the environmental conditions which clearly specified that non-additive gene action was present. Results indicated that the said breeding material might be better suited for heterosis breeding under drought prone semi-arid areas.

Received | Febraury 20, 2018; **Accepted** | December 03, 2018; **Published** | February 05, 2019
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Citation | Ilyas, M., S.A. Khan, S.I. Awan and S. Rehman. 2019. Assessment of heritability and genetic advance in maize (*Zea mays* L.) under natural and water stress conditions. *Sarhad Journal of Agriculture,* 35(1): 144-154.
DOI | http://dx.doi.org/10.17582/journal.sja/2019/35.1.144.154
Keywords | Maize, Water stress, Heritability, Genetic advance

Introduction

Maize (*Zea mays* L.) is the 3rd most significant cereal crop after wheat and rice in the world (FAO, 2016). It provides food, feed, employment, income generation for small-holder families and raw-materials for industries all around the world. Despite increased volume of research and extensive exploitation of heterosis (Apraku et al., 2010) maize yield in the tropics is lower when compared to temperate countries. Hence, it is imperative to consistently strive for higher grain yield selection.

The genetic improvement of any crop depends on the amount of genetic variability residing within the crop species. Breeders can opt to make selections for improvement or possible hybridization if sufficient amount of variability is present within the plant material (Bello et al., 2006). Estimates of heritability undertake that the closely related individuals are more likely to be similar to one another than the unrelated ones (Rafiq et al., 2010). It helps in allocation of resources for efficient selection of desirable traits and in achievement of higher genetic gain utilizing lesser resources and time. Various methods are available for the estimation of heritability i.e., broad-sense or narrow-sense, on single plant, mean of entry or individual plot. Parent-offspring regression analysis has also been utilized to calculate heritability in both plants and animals (Smalley et al., 2004).

Genetic advance elucidates the amount of improvement achieved in a trait under a specific selection pressure. Higher amount of genetic advance along with higher heritability estimates indicates the most appropriate conditions for selection. It also indicates the occurrence of additive gene action in the character and ensures crop improvement through selection of these characters. The combination of heritability and genetic advance estimates is more dependable and meaningful than their separate use (Nwangburuka et al., 2012). Consistent improvement of maize is necessary for the enhanced competition for the crop. It can be done through effective selection of appropriate parents having significant genetic diversity. The purpose of this study was to estimate the heritability and genetic advance for yield and yield attributes in maize F_1, F_2 and backcross generations along with their parents under natural and water stress environments.

Materials and Methods

The studies were carried out at the Department of Plant Breeding and Molecular Genetics, Faculty of Agriculture, University of The Poonch Rawalakot, Azad Jammu and Kashmir, Pakistan. The genepool comprised of 108 maize inbred lines obtained from Maize and Millets Research Institute, Yusufwala, Sahiwal, Pakistan were screened for drought tolerance by sowing under normal and water stressed conditions in two separate trials. Based on screening under drought and normal conditions two sets of inbred lines (four inbred lines) were considered as parents viz., drought tolerant and susceptible to drought. The selected parents were sown as multiple rows during mid of June, 2013 to perform crossing between genetically diverse parents. The cross 1 comprised of a drought tolerant inbred line as VDR-51 and a susceptible inbred line 5CDR-53. The cross 2 comprised of a drought tolerant inbred line as DR3-126 and a susceptible inbred line DR-37. Selfing of the parents was also performed. The parents were sown at two dates of sowing to facilitate synchronization of late and early maturing parents. The F_2 generation was obtained after selfing F_1 plants, while backcrosses were obtained after crossing F_1 with either of the parents. The F_1, F_2 and backcross generations along with parents were planted in a triplicate split plot design having randomized complete block arrangement under drought and rain-fed conditions.

The trial was conducted inside a tunnel and drought treatments were covered with plastic sheet four weeks prior to flowering to impose drought stress one week before flowering and allowed to remain covered up to two weeks after flowering. The field selected for drought treatments consisted of terraces at least five feet high to protect seepage of rain water and plastic sheet covering the tunnel was slipped at least six feet below the ground level. For good stand, two seeds were planted per site. Single healthy seedling per site was kept after thinning. Non-experimental rows were planted to reduce edge/border effect at the beginning and end of each replication. The spacing was kept 25cm among plants and 75cm between rows. The standard dose of fertilizer was applied to each of the experimental unit. The treatments under natural conditions were not covered by plastic sheet i.e., they were kept under rain-fed conditions. Total rainfall received by the treatments under natural conditions during the course of experiment was 674.70 mm while the treatments under drought conditions received 337.70 mm rainfall which is 50% less than the natural treatments.

The data regarding various parameters was taken under control as well as water stressed conditions from each entry. The parameters included plant height, ear height, leaves per plant, ear and flag leaf area, days to pollen shed, days to silk emergence, anthesis-silking interval, branches per tassel, shelling percentage, number of kernels per row, number of kernel rows per ear, 100-kernel weight, grain yield, biological yield and harvest index.

Statistical analysis

Means were computed and analysis of variance was done as Steel et al. (1997). Broad sense and narrow sense heritability were estimated from the data on variances of non-segregating and segregating generations as Rojas and Sprague (1952). Similarly, heritability estimates were determined using the following formulae suggested by Kelly and Bliss (1975).

Heritability in broad sense

$$h^2\,(BS) = VF2 - (VP1+VP2+VF1)\,/\,3VF2$$

Where;

VP_1, VP_2, VF_1 and VF_2 = Parent 1, Parent 2, F_1 and F_2 variances, respectively.

Heritability in narrow sense

$$h^2 (NS) = 2VF_2 - (VBC_1 + VBC_2) VF_2$$

Where;

VF_2, VBC_1 and VBC_2 = F_2, backcross with parent 1, backcross with parent 2 variances.

Genetic advance

Genetic advance was estimated as Falconer and Mackay (1996).

$$Genetic\ advance\ (GA) = K.\ \sigma^2p.\ h^2$$

Where;

K = Selection differential at 10% selection intensity;
σ^2p = Standard deviation of the phenotypic variance;
h^2 = Heritability estimates.

Results and Discussion

Analysis of variance

Analysis of variance for the two maize crosses i.e. VDR-51 × 5CDR-53 and DR3-126 × DR-37 under natural and drought stress conditions were summarized in the Table 1, 2, 3 and 4. Analysis of variance revealed that flag leaf area, plant height and grain yield were showing non-significant results for treatments as well their interaction with genotypes, while significant results were noticed for genotypes. The traits like ear height, No. of leaves per plant, days to pollen shedding, days to silk emergence, No. of branches per tassel and harvest index were showing significant results for treatments and highly significant interaction for genotypes. Whereas, some traits like number of leaves per plant, ear leaf area, flag leaf area and number of branches per tassel were showing non-significant interaction among treatments and genotypes. Highly significant results were witnessed for genotypes, treatments and their interaction in parameters like days to pollen shed, anthesis silking interval, shelling percentage, kernel row per ear, No. of kernel per row, 100-kernel weight and biological yield. Similar results were reported by Malook et al. (2016) where analysis of variance was highly significant in case of plant height, leaves per plant, cobs per plant, leaf area, grain rows per cob, and 100-grain weight under normal and drought stress conditions. Our results were in strong conformity with these results.

Estimates of narrow sense and broad sense heritability the two maize crosses i.e. VDR-51 × 5CDR-53 and DR3-126 × DR-37 under natural and drought stress conditions were summarized in the Table 5, while the estimates of genetic advance were given in the Table 6.

Plant height

Broad sense heritability varied from 0.60 (DR3-126 × DR-37 with drought stress) to 0.74 (VDR-51 × 5CDR-53 with natural conditions) and that of narrow sense heritability varied from the 0.52 (cross DR3-126 × DR-37 under drought stress conditions) to 0.70 (VDR-51 × 5CDR-53 under natural conditions). Plant height seemed highly heritable as the values of heritability was very high which indicated that it might had high potential for improvement. Similar results for plant height were also described by Rafique et al., 2004 and Sumathi et al., 2005. Genetic advance varied from 35.5 (VDR-51 × 5CDR-53 under natural conditions) to 29.6 (DR3-126 × DR-37 under drought conditions). Higher heritability and genetic advance for plant height depicting that it was governed by additive genes and selection might be effective for the said trait.

Ear height

The results showed that maximum broad sense heritability was witnessed in cross DR3-126 × DR-37 (0.71) under drought stress, whereas lowest broad sense heritability was observed in VDR-51 × 5CDR-53 (0.45) under natural conditions. Maximum heritability in narrow sense was observed in cross DR3-126 × DR-37 (0.29) under drought as well as natural conditions. Lowest magnitude of the narrow sense heritability was observed in VDR-51 × 5CDR-53 (0.15) under natural conditions. Both the heritabilities varied from moderate to higher levels indicating that the index of transmission of ear height for the said crosses with very high and might had a potential for the improvement. It also indicated that environment was playing a minor role in expression of the ear height. The findings of this study were in line with Benjamin (2001), Rafique et al. (2004) and Ali et al. (2013). The values of genetic advance varied from 18.88 (for DR3-126 × DR-37 under drought stress) to 7.52 (for VDR-51 × 5CDR-53 under natural conditions). The heritability estimates were moderate to higher and those of genetic advance were low to medium indicating that the trait was controlled by non-additive genes and selection might not be fruitful for the said trait. High heritability estimates might be the result of positive effect of the environment instead of genotype.

Table 1: *Analysis of variance for various traits in maize cross VDR-51 x 5CDR-53.*

Source	DF	PH	EH	NL/P	ELA	FLA	DPS	DSE	ASI
Reps	2	325.94	45.63	0.01	1107.6	835.18	108.85	475.90	2107.50
Treatment	1	672.71^{NS}	55.9*	0.59*	1007.1*	0.0016^{NS}	1154.1**	618.30*	3007.00**
Reps × Trt	2	2432.05	3.7	0.03	26.30	0.0016	74.85	320.90	526.50
Genotypes	5	8509.20*	3898**	14.06**	88325.60**	14192.60**	7071.88**	4125.96**	88725.60**
Trt × Gens	5	751.07^{NS}	49.92^{NS}	0.10^{NS}	11.70^{NS}	0.0016^{NS}	389.26**	242.16*	411.60**
Reps×Trt×Gens	20	540.47	41.45	0.36	533.50	162.72	22.33	197.17	83.45

Where; **PH:** *Plant Height;* **EH:** *Ear Height;* **NL/P:** *Number of Leaves per Plant;* **ELA:** *Ear Leaf Area;* **FLA:** *Flag Leaf Area;* **DPS:** *Days to Pollen Shed;* **DSE:** *Days to Silk Emergence;* **ASI:** *Anthesis-Silking Interval.*

Table 2: *Analysis of variance for various traits in maize cross VDR-51 x 5CDR-53.*

Source	DF	NBT	S%	KRPE	KPR	100KW	GY	BY	HI
Reps	2	3.24	57.94	0.10	0.86	12.94	301.38	391.95	491.95
Treatment	1	60.81*	454.68**	9.35**	1268.67**	364.68**	269.32^{NS}	804.70**	1004.70*
Reps × Trt	2	1.45	51.55	0.02	15.16	6.54	146.41	32.05	272.05
Genotypes	5	257.86**	97.26**	16.78**	278.06**	97.26**	4056.17**	8535.60**	8575.60**
Trt × Gens	5	1.08^{NS}	20.96**	1.68*	50.39**	2.96^{NS}	172.36^{NS}	777.46**	817.46**
Reps×Trt×Gens	20	3.84	11.78	0.49	3.94	7.28	179.72	40.46	50.46

Where; **NBT:** *Number of Branches per Tassel;* **S%:** *Shelling Percentage;* **KRPE:** *Number of Kernel Rows per Ear;* **KPR:** *Kernels per Row;* **100KW:** *100-Kernel Weight;* **GY:** *Grain Yield;* **BY:** *Biological Yield;* **HI:** *Harvest Index.*

Table 3: *Analysis of variance for different traits in maize cross DR3-126 x DR-37.*

Source	DF	PH	EH	NL/P	ELA	FLA	DPS	DSE	ASI
Reps	2	4783.28	93.44	0.10	1793.20	138.82	500.86	340.77	71.77
Treatment	1	2483.20^{NS}	39.84*	1.73*	2494.40^{NS}	749.02**	2268.67*	734.78**	196.78**
Reps × Trt	2	1861.06	2.52	0.10	1405.60	0.01	515.15	63.29	79.29
Genotypes	5	5349.03**	5484.06**	14.56**	78837.30**	17294.20**	478.06**	291.24**	183.64**
Trt × Gens	5	269.11^{NS}	8.54^{NS}	0.37^{NS}	1071.70^{NS}	62.45^{NS}	250.39*	139.71**	32.11**
Reps×Trt×Gens	20	757.72	23.23	0.25	931.10	201.97	53.94	7.07	11.17

Where; **PH:** *Plant Height;* **EH:** *Ear Height;* **NL/P:** *Number of Leaves per Plant;* **ELA:** *Ear Leaf Area;* **FLA:** *Flag Leaf Area;* **DPS:** *Days to Pollen Shed;* **DSE:** *Days to Silk Emergence;* **ASI:** *Anthesis-Silking Interval.*

Table 4: *Analysis of variance for different traits in maize cross DR3-126 x DR-37.*

Source	DF	NBT	S%	KRPE	KPR	100KW	GY	BY	HI
Reps	2	5.76	68.39	1.0239	2.39	8.05	58.85	241.95	941.95
Treatment	1	64.77^{NS}	1162.62**	12.733*	1030.62*	509.78**	1054.10*	504.70**	1904.70*
Reps × Trt	2	13.29	67.02	0.1779	1.02	7.05	24.87	22.05	722.05
Genotypes	5	157.24**	278.43**	13.1734**	252.03**	107.83*	7051.87**	8475.60**	8755.60**
Trt × Gens	5	5.71^{NS}	110.40**	1.0126^{NS}	84.01**	5.10^{NS}	369.27**	717.46**	997.46**
Reps×Trt×Gens	20	4.57	9.31	0.8031	2.71	7.24	17.33	25.46	95.46

Where; **NBT:** *Number of Branches per Tassel;* **S%:** *Shelling Percentage;* **KRPE:** *Number of Kernel Rows per Ear;* **KPR:** *Kernels per Row;* **100KW:** *100-Kernel Weight;* **GY:** *Grain Yield;* **BY:** *Biological Yield;* **HI:** *Harvest Index.*

Number of leaves per plant

The number of leaves per plant in both the crosses under drought and natural conditions exhibited moderate broad sense heritability showing a range of 0.43 (for DR3-126 × DR-37 cross under drought stress) to 0.59 (for cross VDR-51 × 5CDR-53 under natural conditions). Whereas, in case of narrow sense heritability the range was 0.13

Table 5: *Broad-sense and narrow-sense heritability estimates for two maize crosses under natural as well as drought stress conditions.*

Parameters	Cross 1 (N)		Cross 1 (D)		Cross 2 (N)		Cross 2 (D)	
	h^2 (BS)	h^2 (NS)	h^2 (BS)	h^2 (NS)	h^2 (BS)	h^2 (NS)	h^2 (BS)	h^2 (NS)
Plant Height	0.74	0.62	0.72	0.59	0.65	0.50	0.60	0.52
Ear Height	0.45	0.15	0.57	0.25	0.62	0.29	0.71	0.29
Leaves Per Plant	0.59	0.55	0.54	0.50	0.43	0.13	0.46	0.2
Ear Leaf Area	0.70	0.30	0.60	0.50	0.70	0.60	0.60	0.60
Flag Leaf Area	0.48	0.34	0.47	0.33	0.72	0.29	0.65	0.11
Days to Pollen Shed	0.75	0.41	0.78	0.61	0.79	0.63	0.86	0.53
Days to Silk Emergence	0.48	0.41	0.79	0.42	0.85	0.43	0.71	0.55
Anthesis-Silking Interval	0.81	0.59	0.78	0.23	0.79	0.64	0.65	0.19
Branches Per Tassel	0.62	0.55	0.35	0.25	0.53	0.21	0.71	0.21
Shelling %	0.79	0.65	0.83	0.69	0.81	0.42	0.75	0.63
Kernels Per Row	0.73	0.39	0.28	0.23	0.64	0.29	0.42	0.13
Kernel Rows Per Ear	0.53	0.41	0.31	0.28	0.49	0.34	0.43	0.31
100-Kernel Weight	0.52	0.41	0.62	0.55	0.67	0.38	0.70	0.34
Grain Yield	0.89	0.82	0.97	0.93	0.96	0.52	0.98	0.82
Biological Yield	0.75	0.64	0.68	0.43	0.71	0.65	0.71	0.34
Harvest Index	0.79	0.41	0.79	0.65	0.81	0.52	0.79	0.69

Where; N = Natural conditions; D = Drought conditions; h^2 (BS) = Broad sense heritability; h^2 (NS) = Narrow sense heritability.

Table 6: *Estimates of genetic advance for two maize crosses under natural as well as drought stress conditions.*

Parameters	Cross 1 (N)	Cross 1 (D)	Cross 2 (N)	Cross 2 (D)
Plant Height	35.5	31.5	30.3	29.6
Ear Height	7.52	14.69	17.59	18.88
Leaves Per Plant	1.63	1.69	1.23	1.10
Ear Leaf Area	10.80	12.00	8.40	12.40
Flag Leaf Area	10.7	5.23	8.33	4.70
Days to Pollen Shed	12.67	9.70	12.52	10.23
Days to Silk Emergence	15.23	23.91	19.13	23.42
Anthesis-Silking Interval	5.23	3.89	6.96	3.94
Branches Per Tassel	8.06	4.50	2.55	6.43
Shelling %	7.43	9.71	7.49	9.74
Kernels Per Row	1.93	1.01	1.59	1.57
Kernel Rows Per Ear	6.99	4.73	7.32	5.22
100-Kernel Weight	7.51	5.62	5.01	3.49
Grain Yield	34.83	25.94	30.24	28.07
Biological Yield	12.31	8.91	9.41	6.73
Harvest Index	5.23	6.54	5.43	6.12

Where; N = Natural conditions; D = Drought conditions.

(DR3-126 × DR-37 cross under natural conditions) to 0.55 (for VDR-51 × 5CDR-53 under natural conditions). The index of transmission for number of leaves per plant was moderate which indicated that there might be a chance that the trait could be fixed. The genetic advance ranged from 0.29 to 1.63 which also confirmed the dominance of non-additive genes in regulating this trait. Heritability was moderate while genetic advance was low showing that this parameter was under the control of non-additive genes and selection might not be effective.

Table 7: *Maximum, minimum and mean values along with variance and standard deviation of morpho-physiological traits in maize crosses.*

Traits	Min	Max	Mean	Variance	Std. Dev
Plant Height	90.00	295.00	192.09	1004.96	28.37
Ear Height	105.00	185.00	184.11	103.21	13.13
Ear Leaf Area	55.13	1124.80	575.89	9627.73	27.52
Flag Leaf Area	25.16	290.08	147.81	1122.89	31.04
Days to Pollen Shed	528.00	801.00	682.00	186.32	75.00
Days to Silk Emergence	551.00	825.00	710.50	375.38	75.10
Anthesis-Silking Interval	23.00	24.00	23.50	0.50	12.75
Kernels/Ear	8.00	18.00	11.64	3.11	1.73
Leaves/Plant	9.00	18.00	13.59	3.27	1.77
Branches per Tassel	2.00	39.00	20.75	20.23	4.35
Kernel/Row	12.00	35.00	23.09	10.38	3.12
Shelling Percentage	5.34	99.27	50.54	506.82	22.51
100-Kernel Weight	13.00	28.00	20.14	4.93	1.02
Grain Yield	8.57	96.76	44.68	71.18	6.94
Biological Yield	59.10	21.10	319.90	17.89	59.10
Harvest Index	14.50	458.58	13.97	397.88	11.74

Ear leaf area

Both the crosses exhibited higher heritability under natural as well as drought stress conditions for ear leaf area. Maximum magnitude of the broad sense heritability (0.70) was observed in VDR-51 × 5CDR-53 and DR3-126 × DR-37 crosses collectively under natural conditions, whereas lowest magnitude of the broad sense heritability (0.6) was observed in both these crosses under drought stress conditions. Narrow sense heritability varied from 0.3 (for VDR-51 × 5CDR-53 cross under natural conditions) to 0.6 for the crosses in both treatments. Narrow sense and broad sense heritability in both the crosses under natural and drought conditions was high which attributed that the ear leaf area was least influenced by the environment and might be controlled by genetic affects. Abdelmula and Sabiel (2007) also reported similar results for ear leaf area. The genetic advance ranged from 8.4 (for cross DR3-126 × DR-37 under natural conditions) to 12.4 in the same cross under drought conditions. The genetic advance was low confirming that the trait was under the control of non-additive genes. The higher estimates of the heritability and lower estimates of genetic advance indicated the preponderance of non-additive genes and selection might not be fruitful. High heritability might be due to the environmental effects.

Flag leaf area

The broad sense heritability varied from 0.47 for VDR-51 × 5CDR-53 under drought stress conditions to 0.72 in DR3-126 × DR-37 cross under natural conditions. However, maximum magnitude of the narrow sense heritability (0.34) was observed in VDR-51 × 5CDR-53 under natural conditions, whereas lowest magnitude of the narrow sense heritability (0.11) was observed in DR3-126 × DR-37 cross under drought stress conditions. Broad sense heritability for this trait was of higher magnitude, whereas heritability in narrow sense was of low to moderate level. Singh et al. (1989) also told similar results for flag leaf area in maize. The results showed that the genetic advance varied from 4.7 (for cross DR3-126 × DR-37 under drought stress) to 10.7 (for VDR-51 × 5CDR-53 in natural conditions). These results showed that the trait was governed by the non-additive genes, as indicated by the low magnitude of the genetic advance. The estimates of the heritability were high and those of genetic advance were low indicating that the trait was under the influence of non-additive effects and selection might not be rewarding for this trait. High heritability estimates might be due to the environmental effects rather than genes.

Days to pollen shed

The range for heritability in broad sense varied from 0.75 to 0.86. However, heritability in narrow sense varied from 0.41 (for cross VDR-51 × 5CDR-53 under natural conditions) to 0.63 (for cross DR3-

126 × DR-37 under natural conditions). The results showed that heritability in broad sense was higher than the heritability in narrow sense. Days to pollen shed exhibited high estimates for narrow as well as broad sense heritability in both crosses under both the environments. Similar results were reported by Benjamin (2001), Sumathi et al. (2005), Ali et al. (2013) and Yuwono et al. (2017). The results indicated that genetic advance was low indicating the preponderance of non-additive genes and selection might not be fruitful for this trait. Higher heritability might be the result of environmental influence.

Days to silk emergence

Days to silk emergence exhibited high levels of $h^2_{(BS)}$ in both crosses under drought and natural conditions except in the cross VDR-51 × 5CDR-53 under natural conditions. Whereas, low to moderate levels of $h^2_{(NS)}$ for all the crosses. Highest magnitude of broad sense heritability was detected in cross DR3-126 × DR-37 (0.85) under natural conditions and minimum magnitude of broad sense heritability was observed in VDR-51 × 5CDR-53 (0.48) under natural conditions for days to silk emergence. The narrow sense heritability for these crosses was in the range of 0.41 (for VDR-51 × 5CDR-53 under natural conditions) to 0.55 (for cross DR3-126 × DR-37 under drought stress conditions). High heritability for days to silk emergence existed in the studied crosses under natural and drought stress conditions. The results showed that there existed a huge potential to select for early silking and ultimately early maturing germplasm. Benjamin (2001), Beyne (2005), Sumathi et al. (2005), Ali et al. (2013) and Yuwono et al. (2017) also reported similar results. The results indicated that the heritability was higher and genetic advance was low indicating that days to silk emergence was controlled by non-additive gene action and selection might not be rewarding.

Anthesis-silking interval

Highest magnitude of heritability in broad sense was observed in cross VDR-51 × 5CDR-53 (0.81) under natural conditions, whereas minimum magnitude of the heritability in broad sense was detected in cross DR3-126 × DR-37 (0.65) under drought stress conditions. However, highest magnitude of narrow sense heritability 0.59 was observed in VDR-51 × 5CDR-53 (0.65) under natural conditions, whereas lowest value of heritability in narrow sense was observed in DR3-126 × DR-37 cross (0.19) under drought stress conditions. The genetic advance for the anthesis-silking interval showed that the maximum value of genetic advance was observed in cross DR3-126 × DR-37 (6.96) under natural conditions, whereas lowest magnitude of the genetic advance was observed in the VDR-51 × 5CDR-53 (3.89) under natural conditions. The results showed that the trait anthesis-silking interval was being controlled by non-additive genes, hence hybrid breeding might be better option for its improvement. The heritability was high for anthesis-silking interval, while the genetic advance was low. These results specified the supremacy of non-additive gene action and selection might not be rewarding.

Number of branches per tassel

The estimates of broad sense heritability for branches per tassel were higher than narrow sense heritability. The heritability in broad sense varied from 0.71 (for DR3-126 × DR-37 under drought stress) to 0.35 (for VDR-51 × 5CDR-53 under drought conditions) and that of heritability in narrow sense ranged from the 0.21 (for cross DR3-126 × DR-37 under drought stress conditions) to 0.55 (for VDR-51 × 5CDR-53 cross under natural conditions). Heritability in broad sense ranged from medium to high while heritability in narrow sense varied from low to moderate which indicated that branches per tassel were slightly influenced by environment along with genetic control. The value of the genetic advance varied from 8.06 (for VDR-51 × 5CDR-53 under natural conditions) to 4.50 (for cross DR3-126 × DR-37 under drought conditions). The value of the genetic advance was low showing that this parameter was influenced by dominant genes and exploitation of heterosis might be fruitful in improving this trait. The estimates of the heritability were medium to higher and those of genetic advance were low demonstrating the control of non-additive genes in expression of said trait. The selection for number of branches per tassel might not be rewarding.

Shelling percentage

Shelling percentage in both the crosses under drought and natural conditions exhibited higher broad sense heritability showing a range of 0.79 (for cross VDR-51 × 5CDR-53 under natural conditions) to 0.75 (for DR3-126 × DR-37 cross under drought stress). Whereas, narrow sense heritability ranged from 0.42 (DR3-126 × DR-37 cross under natural conditions) to 0.65 (for VDR-51 × 5CDR-53 under natural conditions). Shelling percentage exhibited high levels of narrow sense and broad sense heritability. Shelling percentage probably had high role in controlling grain yield, hence heritability estimates for shelling percentage could indirectly contribute to greater grain yield. It was also concluded that considering shelling percentage in the breeding program might help in breeding hybrids with high grain yield. The magnitude of the genetic advance was low ranging from (7.43 to 9.74) which also confirmed the preponderance of the non-additive genes in controlling shelling percentage. While, considering both genetic advance and heritability these results specified that the selection for shelling % might also be non-rewarding as the estimates of the heritability were high for shelling % and those of genetic advance were low showing that non-additive genes were controlling this trait.

Number of kernels per row

This trait exhibited high levels of $h^2_{(BS)}$ in both crosses under natural conditions. Whereas, low to moderate levels of $h^2_{(NS)}$ for both the crosses. Highest magnitude of broad sense heritability was witnessed in VDR-51 × 5CDR-53 cross (0.73) under natural conditions and minimum magnitude of broad sense heritability was observed in DR3-126 × DR-37 (0.28) under natural conditions for this trait. The estimates of the $h^2_{(NS)}$ for these crosses were in the range of 0.13 (for DR3-126 × DR-37 under drought conditions) to 0.39 (for cross VDR-51 × 5CDR-53 under natural conditions). The moderate and low heritabilities indicated that the kernels per row were affected by environment. Sujiprihati et al. (2003) and Ahsan et al. (2013) had similar observations and reported similar results. The result for the genetic advance for the kernel per row were summarized in the Table 6. The results showed that the genetic advance varied from 1.01 (for cross VDR-51 × 5CDR-53 under natural conditions) to 1.93 (for VDR-51 × 5CDR-53 under drought conditions). When genetic advance and heritability were considered simultaneously the results showed that the heritability was medium to high and genetic advance was high to low for various crosses showing that this trait was influenced by non-additive genes and selection for number of kernels per row might be non-rewarding for these crosses. But for the crosses where genetic advance was high selection might be fruitful.

Number of kernel rows per ear

The results indicated that the broad sense heritability varied from 0.31 for VDR-51 × 5CDR-53 cross under drought stress to 0.53 in VDR-51 × 5CDR-53 under natural conditions. However, maximum value of the heritability in narrow sense (0.41) was observed in VDR-51 × 5CDR-53 cross under drought conditions, whereas lowest value of the heritability in narrow sense (0.28) was observed in VDR-51 × 5CDR-53 cross under natural conditions. This trait showed low to moderate value for both narrow and broad sense heritability. The results indicated that the kernel rows per ear were also affected by the environment. Sujiprihati et al. (2003) and Ahsan et al. (2013) had similar observations and reported similar results. However, the magnitude of the genetic advance varied from 4.73 (for VDR-51 × 5CDR-53 under drought conditions) to 7.32 (for cross DR3-126 × DR-37 under natural conditions) indicating a lower value for genetic advance. When both genetic advance and heritability were considered these results showed that the selection for No. of kernel rows per ear might also be non-rewarding as this parameter was controlled by non-additive genes.

100-Kernel weight

The results showed that maximum broad sense heritability was depicted in DR3-126 × DR-37 cross (0.70) under drought stress, whereas lowest broad sense heritability was observed in VDR-51 × 5CDR-53 (0.52) under natural conditions. Whereas, maximum magnitude of narrow sense heritability was observed in VDR-51 × 5CDR-53 (0.55) cross under drought conditions. Lowest magnitude of the narrow sense heritability was observed in DR3-126 × DR-37 (0.34) under drought conditions. In broad sense heritability hundred grain weight had high value and had moderate to high levels of narrow sense heritability. The results indicated that the trait was governed by genes rather than the environment. Aziz et al. (1998), Sumathi et al. (2005), Ali et al. (2013) and Yuwono et al. (2017) also reported similar results. The values of the genetic advance varied from 3.49 (for DR3-126 × DR-37 under drought stress) to 7.51 (for VDR-51 × 5CDR-53 under natural conditions) which was considered low in magnitude. When considering both genetic advance and heritability it was observed that the selection for this trait might also be non-rewarding as the estimates of the heritability were high and those of genetic advance were low indicating the influence of non-additive gene action.

Grain yield

Both the crosses exhibited higher values of broad sense heritability under natural as well as drought stress conditions for grain yield. Maximum magnitude of the broad sense heritability was observed in DR3-126 × DR-37 (0.98) cross under drought stress conditions, whereas lowest magnitude of the broad sense heritability was observed in VDR-51 × 5CDR-53 (0.96) cross under natural conditions. Narrow sense heritability magnitudes varied from 0.52 (for cross DR3-126 × DR-37 under natural conditions) to 0.93 (for VDR-51 × 5CDR-53 cross under drought conditions). High level of heritability were observed in broad and narrow sense for grain yield for both crosses under natural and drought stress conditions. Similar kind of results were reported previously in maize by Presterl et al. (2003); Abdelmula and Sabiel (2007); Lorenzana and Bernardo (2008); Ahsan et al. (2013) and Yuwono et al. (2017). The genetic advance ranged from 28.07 (for cross DR3-126 × DR-37 under drought conditions) to 34.83 in cross VDR-51 × 5CDR-53 under natural conditions. When both heritability and genetic advance were considered instantaneously additive effects were depicted which indicated that the selection might be rewarding for grain yield as the estimates of both the heritability and genetic advance were high.

Biological yield

The results showed that heritability in broad sense ranged from 0.75 to 0.68. Whereas, those for heritability in narrow sense ranged from 0.34 (for DR3-126 × DR-37 under drought conditions) to 0.65 for same cross under natural conditions. The results showed that heritability in broad sense was high in magnitude than those of narrow sense heritability. Heritability was high for this trait. Ali et al. (2013) also confirmed results of the present study. When both heritability and genetic advance were considered simultaneously it was indicated that the selection for biological yield might not be fruitful as the estimates of the heritability and genetic advance specified that it is controlled by non-additive genes.

Harvest index

Heritability in broad sense was higher in both the maize crosses under natural as well as drought stress conditions (Table 5). Highest magnitude of broad sense heritability was observed in DR3-126 × DR-37 (0.81) under natural conditions, whereas minimum magnitude of the broad sense heritability was observed in cross DR3-126 × DR-37 (0.79) under drought stress conditions. However, highest magnitude of narrow sense heritability was observed in DR3-126 × DR-37 (0.79) under drought conditions, whereas lowest magnitude of the narrow sense heritability 0.41 was observed in VDR-51 × 5CDR-53 cross under natural conditions. Heritability in broad sense was much higher as compared to heritability in narrow sense. It indicated that the harvest index was governed mainly by the genetic affects and index of transmission of the trait high. Ahsan et al. (2013) also reported similar results for the harvest index in maize. The magnitude of the genetic advance for the harvest index was summarized in the Table 6. The results showed that the maximum value of genetic advance was observed in VDR-51 × 5CDR-53 (6.54) cross under drought conditions, whereas lowest magnitude of the genetic advance was observed in the VDR-51 × 5CDR-53 (5.23) under natural conditions. The results showed that the trait was influenced by non-additive genes, hence hybrid breeding might be better option for its improvement. Simultaneous consideration of both heritability and genetic advance showed that the selection for harvest index might not be effective as the estimates of the heritability were high and those of genetic advance were low indicating that the trait was controlled by non-additive genes.

Conclusions and Recommendations

Medium to high heritability along with low genetic advance depicted a dominant type of gene action for almost all the parameters under both the environmental conditions pointed out that the material might be better suited for heterosis breeding for the drought prone semi-arid areas.

Acknowledgements

The authors are thankful to Mr. Khadam Hussain, Assistant Botanist, Maize and Millets Research Institute, Yousafwala, Pakistan for the provision of maize inbred lines.

Author's Contribution

Sardar Ali Khan supervised the research conducted by Muhammad Ilyas. Shahid Iqbal Awan was the member of supervisory committee and helped in planning of experiments and manuscript writing. Shafiq-Ur-Rehman assisted in data collection and analysis.

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