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Stability and Yielding Performance of Seven Chickpea Genotypes (*Cicer Arietinum* L.) Over a Range of Environments in Sulaimani, Iraq

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Abstract

Seven genotypes of Chickpea (*Cicer arietinum* L.), namely; FLIP 97-706C, FLIP 03-87C, FLIP 05-74C, FLIP 05-87C, FLIP 05-110C, FLIP 05-142C, and FLIP 05-150C were evaluated in three different environments in Sulaimani-Qlyasan during every spring from 2016 until 2018.Using Randomized Completely Block Design (RCBD) with three replications in order to study the stability and genotypic resultant growth and yieldcharacters. The results exhibited highly significant effects due to genotypes ×seasons in most of the studied characters with the exception of no. of seeds/pod and no. of branches/plant. The genotype (FLIP 05-150C) was considered the best genotype, which had the high homeostasis values for six characters plant height (0.984), plant weight (0.954), no. of pods/plant (0.951), no. of seeds/plod (0.977), 100 seed weight (0.973) and seed weight/plant(0.930). This genotype needs to be assessed in more varied environments examine. The highest genotypic resultant values were recorded by the genotype (FLIP 05-150C) for plant height (1.109), plant weight (1.020), no. of pods/plant (1.427), no. of seeds/pod (1.001), 100 seed weight (1.095) and seed weight/plant (1.150), indicating this genotype had high performance at different environments and should be not disregarded in future studies.

Introduction

Chickpea (*Cicer arietinum* L.) is a major essential legume used fundamentally as a food and fodder and cultivated in the broad area of the world. Chickpea is cultivating in a different sowing dates, this towards the various genotypes to obtain the acceptable yield performance. It is an essential reservoir of vegetable protein and has a great role in nitrogen fixation into the soil. Decreasing the yield and yield fluctuation depends on the sensitivity of genotypes and instability in the environment [1]. The total world production of Chickpea was 14.7 million tons in 2017 from this India comes in the 1st place and produced 9 million tons followed by Australia with 2 million tons, while Myanmar, Ethiopia, Turkey, Russian Federation, Pakistan, United States of America, and Iran produced 527, 474, 470, 419, 330, 313, 271, and 189 thousand tons respectively[2].The existence of varieties and environment interactions makes the yield stability has more important to develop the lowering yield crops [3]. Genotype × environment interaction should be consider so that the breeder can determine to restructure the program to minimize the interaction effect, or use it to produce verities with specific adaptation to particular environments [4]. The interactions between various yield components and the effects of the environment made the character of seed yield composite. The various phenotypic homeostasis measures were used to evaluate the echo of genotypes when grown in different environments. Summarized genotype-by-environment interaction through homeostasis and genotypic resultant [5]. The environmental changes and the use of varieties that are not adapted to a wide range of environmentsare the main cause of the fluctuation in chickpea; the more stable genotypes are those that show a low degree of fluctuation in yielding ability under different environments. Chickpea production can be enhanced and stabilized by two approaches, the first one is stratification of chickpea growing development of suitable genotypes for the region and the second one is the development of cultivars with wide adaptability for its cultivation in different environments [6]. The G×E interaction has been studied by different researchers in chickpea and other important agricultural crops and they almost describe stable genotypes using different parametric and non-parametric multivariate statistical methods [7], [8], [9], [10], [11], [12],[13], [14], and [15].

Grain yield in chickpea, in different genotypes grown in a wide environment varies from one environment to another [16]. This phenomenon lead to get different production results from the (genotype × environment) interactions in different cultivation conditions [17]. The effects of (genotype × environment) interaction at significant levels reduce the relationship between genotypic values, preventing the genetic progression expected in breeding, which aim to breed high-quality genotypes [18].The differences in the magnitude of genotypes responses to the environments leads tosignificant differences in chickpea grain yields among genotypes [19]. Environmental effect on yield was 86.44%, whereas the effects of genotype and genotype only 2.48% and 11.08%, respectively [20]. High productivity and adaptability to the environment depend on the physiological responses of cultivars used in certain environmental conditions [21].

The objective of this investigation was to assess the stability and yielding performance of seven chickpea genotypes under different growing seasons and the nature and magnitudeof (genotype × environment) interactions.As well as to identify the most stable performance genotype under environmental condition of Sulaimani.

Materials and Methods

This study was conducted in Qlyasan Agriculture Research Station / College of Agricultural Engineering Sciences / University of Sulaimani/Sulaimani /Iraqi Kurdistan Region(35° 34′ 307″ N, 45° 21′ 992″ E and 765 MASL), 3 Km North West of Sulaimani city during three springcropping seasons2015-2016, 2016-2017, and 2017-2018. Seven Genotypes of Chickpea (*Cicer arietinum* L.), namely; FLIP 97-706C, FLIP 03-87C, FLIP 05-74C, FLIP 05-87C, FLIP 05-110C, FLIP 05-142C, and FLIP 05-150C; whichwere introduced by Sulaimani Agricultural Research Center, Ministry of Agriculture and Water Resource, Kurdistan Regional Government. At each season, the experiment was planted in Randomized Complete Block Design with three replicates. Each genotype was planted in 15th February in a plot of (2m × 2m) with four rows inside the plot. Row to row and plant-to-plant distance remained at 0.30 m and 0.20 m respectively. Five samples were harvested in each plot manually in 20th June for each season. Soil samples were analyzed at the laboratories of the Natural Resources Department/ College of Agricultural Engineering Sciences / University of Sulaimani as shown in Appendix (1). The Metrological data of the growing seasons from October to June, which achieved from Sulaimani Metrological Stations andrevealed in Appendix (2).

Statistical analysis

Once all genotypes data were collected, data from 7 genotypes were utilized to perform all statistical analysis as a general test. Combined analysis of variance across environments conducted according to [22]. Homeostasis and genotypic resultant were calculated according to the following equations [23].

$$\text{H}omeostatsi\ s\ (\text{H}) = 1 - \frac{S}{\bar{X}_{i.}}$$

Where:

S: The Standard Deviation= $S = \sqrt{S^2} = \sqrt{\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n-1}}$

i.: The value of genotype

$\bar{X}_{i.}$: The average character value across studied environments.

$$\text{Genotypic Resultant } (\text{GR}) = \left(1 - \frac{S}{\bar{X}_{i.}}\right) \times \left(\frac{\bar{X}_{i.}}{\bar{X}_{..}}\right)$$

Where,

$\bar{X}_{i.}$: The average character value crossing the studied environments.

$\bar{X}_{.j}$: The average character value for a particular environment crossing genotypes.

$\bar{X}_{..}$: The general mean of a particular character for all genotypes and all environments.

Results and Discussion

Appendix (3) indicates the presence of highly significant interaction due to genotypes × environments for the characters plant height (cm), plant weight (g), 100 seed weight (g), seed weight/plant (g) and significant only for the character no. of pod/plant, similar findings were also reported by [24]. Consequently, the result demonstrates the presence of genotype and environmental differences that could control the expression of these characters and the significant contribution of genotypes × environments interactions in influencing genotype performance, while this interaction was not significant for the characters no. branches/plant, no. of seed/pod. In other words, not all characters except the no. of branches/plant and no. of seed/pod have shown superiority in the three seasons.

Table (1) exhibit the means of the studied characters across seasons; the genotype (FLIP 05-150C) recorded the maximum plant height, no. of pods/plant, 100 seed weight and seed weight/plant with 70.667, 69.600, 32.462 and 16.629 respectively. Furthermore, the genotype (FLIP 03-87C) showed the highest values of plant weight and no. of branches/plant which were 163.189 and 2.789 respectively, whereas, the genotype (FLIP 05-110C) observed the maximum value for the character no. of seeds/pod. These results confirm that the (FLIP 05-150C) has the best genotype that showed the highest values for most desirable characters as mentioned previously. Table (2) show that the genotype (FLIP 05-150C) also showed high homeostasis and genotypic resultants for all characters except no. of branch/plant, which means that this genotype was more stable, and had acceptable performance across environments according to [25].

Figure (1) demonstrated that the mean values of Homeostasis and genotypic resultant for the studied characters. Generally, the characters plant height, plant weight, no. of pods/plant, no. of seeds/pod, 100 seed weight and seed weight/plant showed stable and high genotypic resultant with average values (0.902 and 0.904), (0.874 and 0.882), (0.906 and 0.910), (0.953 and 0.952), (0.903 and 0.905) and (0.873 and 0.875) respectively.On the contrary, the characters no. of branches/plant obtained the lowest unstable and genotypic resultant average values with (0.826 and 0.823). The stability of the genotypes depending on the value of homeostasis, if the value was more than 85% it means that this genotype was stable across environments, and if the value of genetic resultant was high and close to unity, it means that the genotype has anacceptable performance across different environments. These results are correspondence with [5], [23], and [25].

Table 1: Means of the studied characters across seasons.

Genotypes	Seasons	Plant height (cm)	Plant weight (g)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}	100 seed weight (g)	Seed weight plant^{-1} (g)
FLIP 97-706C	2016	61.000	170.440	3.000	53.200	1.050	30.417	15.730
	2017	54.000	155.660	2.333	43.333	1.000	26.393	11.963
	2018	67.000	162.170	2.400	52.667	1.023	28.027	14.429
	Mean	***60.667***	***162.757***	***2.578***	***49.733***	***1.024***	***28.279***	***14.041***
	SD	***6.506***	***7.407***	***0.367***	***5.549***	***0.025***	***2.023***	***1.913***
FLIP 03-87C	*2016*	*62.667*	*169.640*	*2.800*	*45.500*	*1.063*	*31.883*	*15.579*
	2017	*55.000*	*154.180*	*3.000*	*35.333*	*1.077*	*26.817*	*10.767*
	2018	*65.667*	*165.746*	*2.567*	*40.667*	*1.007*	*31.300*	*11.677*
	Mean	***61.111***	***163.189***	***2.789***	***42.389***	***1.049***	***30.000***	***12.674***
	SD	***5.501***	***8.041***	***0.217***	***5.549***	***0.037***	***2.772***	***2.557***
FLIP 05-74C	*2016*	*65.000*	*163.930*	*2.933*	*44.600*	*1.047*	*30.070*	*13.130*
	2017	*60.333*	*142.100*	*2.400*	*33.250*	*1.000*	*23.407*	*10.737*
	2018	*69.333*	*154.893*	*2.000*	*39.667*	*1.087*	*30.533*	*13.541*
	Mean	***64.889***	***153.641***	***2.444***	***39.172***	***1.044***	***28.003***	***12.469***
	SD	***4.501***	***10.969***	***0.468***	***5.691***	***0.043***	***3.988***	***1.515***
FLIP 05-87C	*2016*	*65.333*	*161.223*	*2.800*	*43.067*	*1.040*	*26.150*	*13.047*
	2017	*52.333*	*109.230*	*2.267*	*36.133*	*1.013*	*26.183*	*10.513*
	2018	*62.667*	*144.407*	*2.067*	*41.333*	*1.030*	*32.173*	*11.080*
	Mean	***60.111***	***138.287***	***2.378***	***40.178***	***1.028***	***28.169***	***11.547***
	SD	***6.866***	***26.531***	***0.379***	***3.608***	***0.013***	***3.468***	***1.330***
FLIP 05-110C	*2016*	*64.667*	*159.400*	*2.600*	*39.767*	*1.057*	*28.657*	*11.743*
	2017	*50.000*	*102.297*	*2.000*	*35.400*	*1.017*	*28.603*	*12.693*
	2018	*67.000*	*154.382*	*2.000*	*45.000*	*1.310*	*23.567*	*13.849*
	Mean	***60.556***	***138.693***	***2.200***	***40.056***	***1.128***	***26.942***	***12.762***
	SD	***9.216***	***31.620***	***0.346***	***4.4.807***	***0.159***	***2.923***	***1.055***
FLIP 05-142C	*2016*	*60.333*	*163.667*	*2.600*	*43.533*	*1.103*	*28.610*	*13.831*
	2017	*52.667*	*103.073*	*2.267*	*38.667*	*1.010*	*24.800*	*11.820*
	2018	*69.333*	*157.808*	*2.133*	*44.667*	*1.010*	*31.050*	*16.353*
	Mean	***60.778***	***141.516***	***2.333***	***42.289***	***1.041***	***28.153***	***14.001***
	SD	***8.342***	***33.421***	***0.240***	***3.188***	***0.054***	***3.150***	***2.271***
FLIP 05-150C	*2016*	*72.667*	*166.213*	*3.167*	*71.467*	*1.057*	*32.847*	*17.618*
	2017	*70.000*	*153.233*	*2.533*	*65.333*	*1.083*	*31.477*	*15.347*
	2018	*70.000*	*166.242*	*2.267*	*71.667*	*1.107*	*33.063*	*16.923*
	Mean	***70.667***	***161.896***	***2.656***	***69.600***	***1.082***	***32.462***	***16.629***
	SD	***1.155***	***7.502***	***0.462***	***3.414***	***0.025***	***0.860***	***1.164***

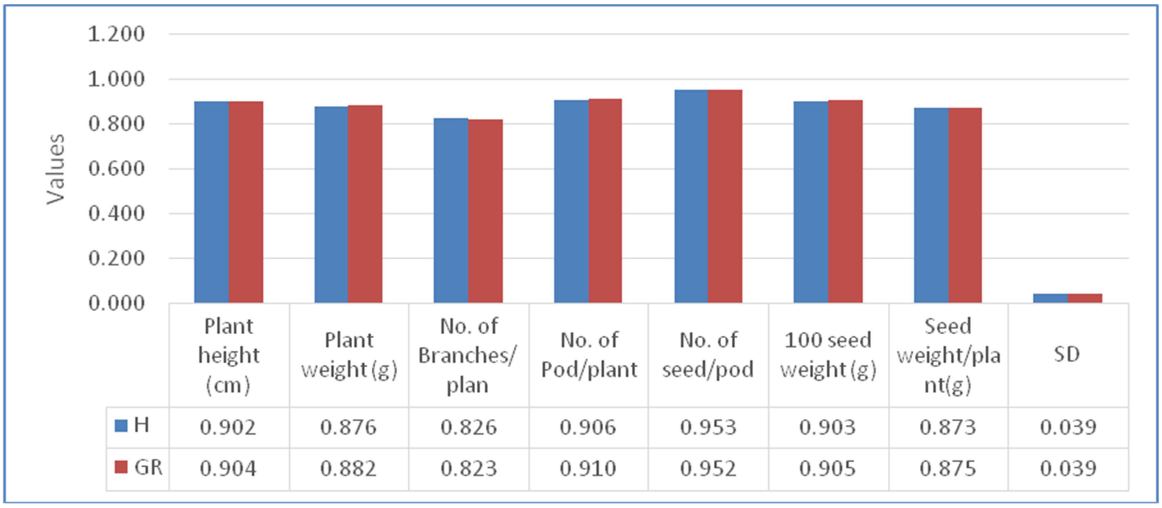

Figure1**:** Means of homeostasis (H) and genotypic resultants (GR) for the studied characters.

Table 2: Homeostasis (H) and genotypic resultants (GR) of the studied characters across the seasons.

Genotypes	Genetic Parameters	Plant height (cm)	Plant weight (g)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seeds pod^{-1}	100 seed weight (g)	Seed weight plant^{-1} (g)
FLIP 97-706C	H	0.893	0.954	0.858	0.888	0.976	0.928	0.864
	GR	0.864	1.026	0.890	0.957	0.946	0.910	0.902
FLIP 03-87C	H	0.910	0.951	0.879	0.936	0.965	0.908	0.798
	GR	0.887	1.025	0.878	0.860	0.957	0.943	0.752
FLIP 05-74C	H	0.931	0.929	0.793	0.855	0.958	0.858	0.879
	GR	0.963	0.942	0.804	0.725	0.947	0.832	0.815
FLIP 05-87C	H	0.886	0.808	0.817	0.910	0.987	0.877	0.885
	GR	0.849	0.738	0.805	0.792	0.960	0.856	0.760
FLIP 05-110C	H	0.848	0.772	0.843	0.880	0.859	0.891	0.917
	GR	0.819	0.707	0.790	0.764	0.917	0.832	0.871
FLIP 05-142C	H	0.863	0.764	0.844	0.925	0.948	0.888	0.838
	GR	0.837	0.714	0.816	0.847	0.934	0.866	0.872
FLIP 05-150C	H	0.984	0.954	0.746	0.951	0.977	0.973	0.930
	GR	1.109	1.020	0.781	1.427	1.001	1.095	1.150
Means	***H***	***0.902***	***0.876***	***0.826***	***0.906***	***0.953***	***0.903***	***0.873***
	GR	***0.904***	***0.882***	***0.823***	***0.910***	***0.952***	***0.905***	***0.875***

Regarding table (2), plant height was stable because it had a highest homeostasis and genotypic resultant.Thegenotypes (FLIP 05-150C), (FLIP 05-74C) and (FLIP 03-87C) have the greatest homeostasis values with 0.984, 0.931 and 0.910 respectively.

Plant weight exhibited stable for the genotypes (FLIP 97-706C), (FLIP 05-150C), (FLIP 03-87C) and (FLIP 05-74C) showed height homeostasis and genotypic resultant with (0.954 and1.026), (0.954 and1.020), (0.951 and1.025) and (0.929 and 0.942) respectively. It means these genotypes have more stability and high performance across different environments.

The table (2) reveled no. of branches/plant should be not stable across environments due to low homeostasis and genotypic resultant means values. The genotypes (FLIP 03-87C) and (FLIP 97-706C) represented more stable than the other genotypes. They showed height homeostasis with (0.879, 0.858).

The genotypes (FLIP 05-150C), (FLIP 03-87C), (FLIP 05-142C) and (FLIP 05-87C) with their character no. of pod/plant obtained greatest stability, with the values 0.951, 0.936, 0.925 and 0.910 respectively. This ratifying that this character has more homeostasis performance among the environments.

No. of seeds/pod possessed high homeostasis across environments due to high genotypic resultant values compare to other characters. Moreover, all genotypes showed highest stability and high performance whichconfirming more stability for this character across environments.

There were high homeostasis and genotypic resultant values for 100 seed weight (g). High homeostasis and genotypic resultant were showed by (FLIP 05-150C), (FLIP 97-706C) and (FLIP 03-87C) with (0.973 and 1.095), (0.928 and 0.910) and (0.908 and 0.943) respectively, this could be considered as evidence ofthese genotypes which possess more homeostasis among diverse environments than other genotypes.

The results in table (2) showed high homeostasis and high genotypic resultant values for all genotypes this result agree with [5, 23, and 25], Elsahookie and Al-Rawi who mentioned that if the value of homeostasis higher than 85% and the value of genetic resultant was high, it means that the genotype more stable across the environments, because the stability of genotypes depending on homeostasis and genetic resultant., it means that the genotype has a good performance across different environments [5, 23, and 25].

Conclusions

Despite the different homeostasis methods are expressive; Elsahookie [23], method provides useful information for achieving definitive results and the identification of mega-environments and wining genotypes essentially. this experiment showed that genotypes (FLIP 05-150C) possess the maximum values for most of the desirable characters such as plant height, plant weight (g), no. of pods/plant, no. of seeds/pod, 100 seed weight (g) and seed weight/plant (g) with the best homeostasis and genotypic resultants across the investigated seasons.

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Appendix 1: Soils physical and chemical properties at Sulaimani environments in the date of sowing season 2016-2018

Soil Properties	***Sulaimani – Qlyasan***
PSD	Silty Clay
Sand %	5.83
Silt %	42.07
Clay %	52.10
pH	7.13
Organic Matter %	2.13
Total Nitrogen %	0.15
Available Phosphate (ppm)	4.49

Appendix 2: The Metrological data in Sulaimani environments during the growing season 2015-2018.

Period	***2015 - 2016***			***2016 - 2017***			***2017 - 2018***		
	Temp. C°		***Rainfall mm***	***Temp. C°***		***Rainfall mm***	***Temp. C°***		***Rainfall mm***
	Max.	***Min.***		***Max.***	***Min.***		***Max.***	***Min.***	
Nov	13.3	6.1	197.2	24.3	80.	6.0	23.9	7.6	114.6
Dec	12.1	2.2	75.8	18.0	-2.9	149.4	17.8	-2.5	22.2
Jan	16.6	-3.2	110.6	13.8	1.8	39.8	15.6	1.4	72.4
Feb	19.8	0.2	76.2	30.1	-2.5	105.0	20.9	-2.3	323.0
Mar	22.0	3.2	171.8	24.8	1.2	121.0	24.4	1.0	44.6
Apr	32.2	5.0	57.6	32.4	2.8	70.0	31.6	2.2	98.6
May	36.9	11.2	12.2	39.2	14.4	20.0	38.1	13.0	40.4
Jun	41.3	17.2	-	43.4	18.9	-	42.4	17.6	-
Total	—	—	***701.4***	—	—	***511.2***	—	—	***715.8***

Appendix 3: Mean squares of combined analysis of variance across environments

		MS						
S.O.V	***d.f***	***Plant height (cm)***	***Plant weight (g)***	***No. of branches plant^{-1}***	***No. of pods plant^{-1}***	***No. of seeds pod^{-1}***	***100 seed weight (g)***	***Seed weight plant^{-1} (g)***
Seasons	2	6900.000 **	43017.207 **	12.064 **	3662.470 **	1.774 **	1381.098 **	321.349 **
Block / Seasons =E(a)	6	5.254	94.772	0.172	5.761	0.034	6.370	2.177
Genotypes / environments	18	68.265 **	715.587 **	0.186 n.s	359.170 **	0.013 n.s	22.293 **	11.634 **
Genotypes	6	134.868 **	1221.381 **	0.371 *	1046.660 **	0.012 n.s	30.003 **	24.633 **
Genotypes × Seasons	12	34.963 **	462.690 **	0.094 n.s	15.425 *	0.014 n.s	18.438 **	5.135 **
Error / Seasons =E(b)	36	8.439	105.962	0.117	7.380	0.035	4.368	1.634