J. Product. & Dev., 25(4),453- 470 (2020)

STABILITY OF SOME COMMON BEAN CULTIVARS UNDER DIFFERENT PLANT DENSITIES

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ABSTRACT

A field experiment was carried out during two successive summer season at years 2016 and 2017 at privet farm, in Al-Rahmania district, El-Behira governorate, Egypt, to examine the magnitude of genotype-environment interactions over six different environments. The five commercial cultivars of common bean (Paulista, Valentino, Bronko, Nebraska, and Giza-6) were evaluated under six environments, i.e., combinations of one and two planting sides with densities (25, 20 and 15 cm).

Pooled analysis of variance over all densities (environments) displayed significant to highly significant differences between genotypes and environment relative to studied traits, while significant genotypes × environment (G×E) were shown for each of plant height (cm), number of leaves/plant, number of pods/plant, pod yield/m^2 and pod yield/feddan in both seasons as well as leaf area and each of number of branches, total chlorophyll and pod diameter in 1st and 2nd season, respectively indicating that genotypes responded differently to various environments which indicated a wide range of variability among the genotypes performance. The value of Regression coefficient "bi" approached nearly unity in some genotypes for some traits, indicating average response to the fluctuating environmental conditions prevailed the different densities across both seasons. On the other hand, "bi" value was more than one (bi>1) for some genotypes and on contrary, regression coefficient was less than 1 (bi<1) for 4 genotypes at least two to six studied traits in both seasons.

Conclusively, *high potential response for Nebrasca genotype in favorable environments with adequate water and other input and reverse trend for Paulista cv which exhibited low yield, regression coefficient "b value" was less than 1 for yield and some traits, showing it is more productive under unfavorable environments. The studied cultivars under studied densities might be of prime importance for traditional* *agricultural procedures for high yield and/or some of its important components.*

Key words: Bean, stability, regression coefficient, genotype × environment.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is a herbaceous annual plant (Gentry, 1969) and a main grain legume which is consumed worldwide for its edible seeds and pods (Heuzé *et al.*, 2013). It is considered one of the most important legume crops, in Egypt, because of its high nutritional value where it's grown for local consumption and export. The total area was grown at 2018/2019 for green pod yield was 43,272 feddan which produced 177,029 tons, with an average 4.091 tons/*fed*. As for dry seed yield, the total area was 126,404 feddan which produced 136,046 tons, with an average 1.076 tons/*fed.* in Egypt (MALR Statistics, 2019). The yield of bean varieties varies idely due to variation in climatic and soil factors, which complicates the identification of superior genotypes. Mehaet and Erean (2013) showed that plant height and number of pods/plant is affected by environment and quit effective on the yield. Babar and Tariq (2009), Goa and Hussen (2013), Tamene *et al.* (2013) and Fikere *et al* (2014) reported that pooled analysis of variance over environments displayed highly significant differences between genotypes, environments and genotype × environment interaction. The analysis of variance for seed yield at individual environment showed significant to highly significant differences between genotypes and that pooled analysis of variance for grain yield showed significant ($P < 0.01$) differences among the genotypes, environments and the genotype × environment interaction effects. However, breeding efforts for such environments should give more emphasis to develop widely adapted genotypes, where, breeding for specific localities need to be encouraged using the existing sub centers and, of course, with in the available resources since the latter is more expensive than the former. Also, the genotype × environment interaction has been carried out on various crops (Ivanova and Naidenova, 2006). The stability parameters have been studied in edible legumes to measure phenotypic stability (Arshad *et al.*, 2003 and Cakmakci *et al*., 2006), but still it is very important information that the stability parameters should be available for the accessions of pea varieties.

Therefore, the main objective of the present investigation was to study the performance and stability parameters of yield and its components in some pea cultivars under six environments (densities).

MATERIALS AND METHODS

Five commercial cultivars of common bean *i.e.*, Paulista, Valentino, Bronko, Nebraska and Giza-6 were included in the yield trial to examine the magnitude of genotype-environment interactions over six different environments. These environments were the six densities of D_1: 6.5 plants/m^2 (26000 plants/fed.), $D_{2:}$ 8.5 plants/m^2 (34000 plants/fed.), $D_{3:}$ 11 plants/m^2 (44000 plants/fed.), D_4: 13.5 plants/m^2 (54000 plants/fed.), D_5: 17 plants/m^2 (68000 plants/fed.) and D_6: 22.5 plants/m^2 (90000 plants/fed.). The different densities were resulted from plant spacing of 25, 20 and 15 cm combined with one and two planting sides. The experimental layout was a randomized complete blocks design with three replications for each experiment. Each genotype was sown in four rows (3 m long × 0.7 m wide). Planting dates were February 15th in both 2016 and 2017 growing seasons. The flood irrigation system was followed in all environments and the normal cultural practices were applied according to the recommendation of Ministry of Agriculture for common bean production.

Data were recorded on the vegetative growth traits: Plant height in cm, was measured as an average height of the chosen plants from the surface of the ground to the plant stem apex; Branches/plant, was calculated as average number of branches on the chosen plants; Leaves/plant, was calculated as an average number of leaves on the chosen plants; Leaf area in cm^2, it was measured on the fourth upper leaf from every plant, according to the formula:

Leaf area in cm^2 = [(Fresh weight of leaves/ Fresh weight per disk) × Area per disk (cm^2) as Metwally (1998);

Total chlorophyll were calorimetrically determined (mg/g f.w.) using spectrophotometer according to the method described by Lichtenthaler and Wellburn (1983) as well as pods and yield traits: pod length in cm; pod diameter in cm; number of pods/plant; Pod yield in g/m^2 (it was calculated from all harvested pods/plot until seven picking and then converted as g/m^2); pod yield ton/feddan, it was calculated from all harvested pods/plot and converted as ton per fed. The treatments were arranged in a randomized complete block design (RCBD) with three replicates. Combined analysis of variance was performed across the six environments to detect the genotype by environment interaction effects as described by Steel *et al*., 1997 using SAS software Version 9.1. Stability analysis for the characteristics studied was performed according to the model of Eberhart and Russell (1966) as follow:

$$Y_{ij} = \mu + \beta_i I_j + \delta_{ij}$$

Where: Y_{ij}: is the mean yield of the i^{th} genotype at the j environments (i = 1, 2, 3 … v and j = 1, 2 … n), µ: is the mean of i^{th} genotype across all environments and β_i: is the regression coefficient of the measured response of the i^{th} genotype to several environments.

$$b_i = \Sigma_j Y_{ij} I_j / \Sigma_j I_j^2$$

Where, I_j: is the environmental index obtained as the mean of all genotypes at the j^{th} environment minus the grand mean.

$$[Ij = (\Sigma_i Y_{ij} / v) - (\Sigma_i \Sigma_j Y_{ij} / vn)], \Sigma_j I_j = 0$$

$$S^2_{di} = [\Sigma_j \delta^2_{ij} / (n-2)] - s^2e / r$$

Also, δ_{ij}: is the deviation from regression of the i^{th} genotype at the j^{th} environment.

RESULTS AND DISCUSSION

Combined analysis of variance for studied traits of bean genotypes tested from the combined data of six experiments are presented in Table 1.

Pooled analysis of variance over all densities (environments) displayed significant to highly significant differences between genotypes and environment relative to studied traits (Table 1) while, genotypes × environment interactions were shown for each of plant height (cm), number of leaves/plant, number of pods/plant, pod yield/m^2 and pod yield/feddan in both seasons as well as leaf area and each of number of branches, total chlorophyll and pod diameter in 1^{st} and 2^{nd} season, respectively indicating that genotypes responded differently to various environments which indicated a wide range of variability among the genotypes performance. Previously reports of Zayed *et al* (1999) and Husain and Abd El-Hady, (2015) detected significant environmental effects on the yielding ability of some legume genotypes. Moreover, the G×E interaction was significant and a major portion of this was accounted for the deviation from linear response. Zayed *et al* (1999) stated that a large magnitude of G×E interaction indicating that the tested genotypes fluctuated consistently in yielding ability among environments.

Results in Table (2) showed that the linear response of environments was highly significant for most studied traits. Consequently the regression coefficient (b_i) and deviation from regression (S^2d) pooled over the six environments were calculated for each genotype and presented in Tables 3&4. Eberhart and Russell (1966) confirmed that a need for considering both the linear and non-linear trend in order to evaluate yield and other parameters of stability of genotypes as well as both the linear regression coefficient and deviation from regression for phenotypic stability.

Table 1. Mean squares of combined analysis of variance for the growth, pod and yield studied traits.

S.O.V	d.f	Plant height		Branches/ plant		Leaves/ plant		Leaf area (cm^2)		Total chlorophyll	
		1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Environments (E)	**5**	6.756 **	12.66 **	1.164 **	1.265 **	18.37 **	19.3 **	74.36 **	126.9 *	0.001 **	0.0007 **
R (E)	**12**	0.145	0.13	0.072	0.036	0.988	0.31	4.41	29.9	0.0001	0.0001
Genotypes (G)	**4**	790.6 **	755.1 **	31.77 **	32.27 **	59.10 **	60.9 **	5672.1 **	5693 **	0.056 **	0.0526 **
G×E	**20**	0.920**	2.37 **	0.0627	0.14 **	4.56 **	4.67 **	12.43 **	39.9	0.0001	0.0001**
Error	**48**	0.218	0.33	0.142	0.051	0.118	0.106	3.59	29.2	00004	0.00003
		Pod length (cm)		**Pod diameter(cm)**		**No. of pods /plant**		**Pod yield (g/m^2)**		**Pod yield (ton/fed.)**	
Environments (E)	**5**	0.007 **	0.061 **	0.0004 **	0.00009**	0.151 **	0.08 **	286866**	289913**	45.90 **	46.39 **
R (E)	**12**	0.0002	0.0018	0.00003	0.00001	0.005	0.0003	1.042	0.394	0.00002	0.00001
Genotypes (G)	**4**	4.98**	5.096 **	0.085 **	0.075 **	94.45 **	93.9 **	397157**	406375**	6.355 **	6.502 **
G×E	**20**	0.0004	0.0016	0.00001	0.0003 **	0.018 **	0.01 **	13491 **	14134 **	0.216 **	0.226 **
Error	**48**	0.0003	0.0036	0.00003	0.00001	0.005	0.001	0.705	0.6833	00001	.00001

* & ** Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.

Highly significant mean squares due to E + (G × E) interaction revealed that genotypes interacted considerably with the five environmental conditions.

A major portion of these interactions may be attributed to E (linear) component. Significance of Pooled deviation mean squares for plant height, number of branches, pod diameter and number of pods in 1st season as well as each of number of leaves/plant, pod yield/m^2 and pod yield per feddan in both seasons suggesting deviation mean squares for individual genotypes (Table 3). Such genotypes, *i.e*., Paulista for leaf area in 1st season and both branches and leaves number in 2nd season; Valintino for both plant height and branches in 2nd season; Bronko for leaf area in 1st season, Nebraska for plant height and number of leaves in both seasons and leaf area in 2nd one and Giza-6 for number of leaves in both seasons as well as all genotypes for pod yield/m^2 seemed to be not consistent in its performance over all densities.

On the contrary, all other genotypes shown absence of significance for all studied traits suggesting the consistency of their yielding ability under environmental conditions tested.

Table 2. Stability analysis of variance for all studied traits of 5 common bean genotypes evaluated under six different environmental conditions.

S.O.V	d.f	Plant height		Branches /plant		Leaves /plant		Leaf area (cm2)		Total chlorophyll	
		1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Genotypes (G)	**4**	263.5**	251.7**	10.59**	10.76**	19.68	20.33	1890.7**	1897.7**	0.019**	0.017**
E+ (G×E)	**25**	0.696**	1.475**	0.094**	0.122*	2.44**	2.530**	8.271**	19.10*	0.0001**	0.0001**
E (linear)	**1**	11.26**	21.1**	1.939**	2.108**	30.6**	32.14**	123.92**	211.6**	0.001**	0.0012**
G×E (linear)	**4**	0.985**	2.16**	0.032	0.022	4.36**	5.34**	15.081**	20.10	0.00001	0.00004
P-deviation	**20**	0.110	0.36**	0.014	0.043**	0.65**	0.488**	1.13	9.29	0.00001	0.00002
Paulista	**4**	0.026	0.029	0.017	0.096**	0.66**	0.667**	2.71	6.74	0.00003	0.00002
Valentino	**4**	0.165	0.60**	0.003	0.032	0.180	0.098	0.067	0.208	0.00002	0.00001
Bronko	**4**	0.084	0.290*	0.010	0.015	0.220	0.192**	2.481	6.496	0.00001	0.00001
Nebraska	**4**	0.246*	0.59**	0.005	0.005	1.45**	1.13**	0.109	31.61*	0.000004	0.00003*
Giza-6	**4**	0.026	0.276*	0.037	0.069**	0.74**	0.36**	0.266	1.377	0.00001	0.00003
P-error	**60**	0.068	0.097	0.043	0.016	0.097	0.049	1.252	9.768	0.00002	0.00001
		Pod length (cm)		**Pod diameter(cm)**		**No. of pods/plant**		**Pod yield (g/m2)**		**Pod yield (ton/fed.)**	
Genotypes (G)	4	1.66**	1.70**	0.028**	0.025**	31.48**	31.3**	132385	135458	2.118	2.1673
E+ (G×E)	25	0.001**	0.01**	0.00003**	0.0001	0.015**	0.01**	194841**	197044**	3.118**	3.153**
E (linear)	1	0.01**	0.102**	0.0006**	0.0002	0.251**	0.132**	478110**	4831888**	76.50**	77.31**
G×E (linear)	4	0.0002*	0.002**	0.00001**	0.00001	0.026**	0.003*	22147**	23200**	0.354**	0.371**
P-deviation	20	0.0001	0.0002	0.000001	0.0001**	0.0008	0.001**	67.61**	71.51**	0.001**	0.001**
Paulista	4	0.0001	0.0004	0.000001	0.00001*	0.0014	0.001**	79.12**	64**	0.001**	0.001**
Valentino	4	0.0002	0.0002	0.000001	0.00002**	0.001	0.0004*	80.76**	71.54**	0.001**	0.001**
Bronko	4	0.00001	0.0001	0.000001	0.0002**	0.0003	0.001**	31.25**	68.29**	0.001**	0.001**
Nebraska	4	0.00001	0.0002	0.000002	0.0001**	0.0016	0.002**	55.62**	122.91**	0.001**	0.002**
Giza-6	4	0.0001	0.0002	0.000001	0.0001**	0.0002	0.001*	91.29**	30.79**	0.002**	0.0005**
P-error	60	0.0001	0.0011	0.00001	0.000003	0.0018	0.0002	0.257	0.208	0.000004	0.000003

* and ** Significant and highly significant at 0.05 and 0.01 levels of probability, respectively.

Stability parameters:

The value of regression coefficient "b_i" which measure the genotypes performance on the environmental index (Tables 3-6) approached nearly unity in some genotypes for some traits, *i.e.,* Valintino for total chlorophyll, pod yield/m^2 and pod yield/feddan in both seasons as well as plant height and number of branches in 1st and 2nd season, respectively; Bronko and Giza-6 for pod yield/m^2 and pod yield/feddan in both seasons; Paulista for number of pods in 1st season; both Nebraska and Paulista for pod length in 1st and 2nd season, respectively; and each of Valintino, Nebraska and Giza-6 for number of branches in 2nd season, indicating average response to the fluctuating environmental conditions prevailed the different densities across both seasons.

Table 3. Estimates of stability for plant height, number of branches and leaves/plant of 5 bean genotypes grown under different densities.

Genotypes	Plant height (cm)			Branches/plant			Leaves/plant		
	$\bar{x}$	b_i	S^2d	$\bar{x}$	b_i	S^2d	$\bar{x}$	b_i	S^2d
1st year									
Paulista	34.030	0.842	-0.041	8.361	1.267	-0.026	21.633	1.425	0.5671
Valentino	35.073	1.094	0.0977	6.667	1.298	-0.039	23.067	1.154	0.0832
Bronko	33.380	0.5900	0.0165	7.833	1.020	-0.032	21.056	0.0872**	0.1225
Nebraska	49.370	2.0841**	0.1777**	4.917	0.747	-0.037	23.900	2.1028**	1.3480**
Giza-6	38.932	0.892	-0.042	7.250	0.669	-0.006	19.244	0.2311*	0.6385
Mean	38.157	--	--	7.006		--	21.780	--	--
LSD 0.05	0.4037	--	--	0.1466	--	--	0.9833	--	--
2nd year									
Paulista	34.453	0.873	-0.068	8.500	1.262	0.0800	22.133	1.537*	0.6183**
Valentino	35.877	1.239	0.5017	6.822	1.088	0.0156	23.367	1.167	0.0489
Bronko	33.872	0.3333*	0.1932	7.933	0.642	-0.001	21.283	0.137**	0.1427
Nebraska	49.526	2.1063**	0.4973**	5.006	0.980	-0.011	24.150	2.139**	1.0775**
Giza-6	39.838	0.4479	0.1788	7.333	1.028	0.0532	19.439	0.018**	0.3055
Mean	38.713	--	--	7.119	--	--	22.074	--	--
LSD 0.05	0.7297	--	--	0.2536	--	--	0.8522	--	--

Table 4. Estimates of stability for Leaf area and total chlorophyll of 5 bean genotypes grown under different densities.

Genotypes	Leaf area (cm^2)			Total chlorophyll		
	$\bar{x}$	b_i	S^2d	$\bar{x}$	b_i	S^2d
1st year						
Paulista	1,076.91	2.2690**	1.4579**	1.8107	1.1283	0.00002
Valentino	1,096.36	0.2337**	-1.1840	1.8484	1.0098	0.000003
Bronko	1,050.12	1.1393	1.2290**	1.7378	1.1611	0.000004
Nebraska	1,073.59	0.605	-1.1430	1.7133	0.9651	0.00001
Giza-6	1,059.17	0.7521	-0.9861	1.7524	0.7357	0.000009
Mean	**1,071.23**	--	--	**1.7725**	--	--
LSD 0.05	**1.2938**	--	--	**0.0045**	--	--
2nd year						
Paulista	1,077.75	1.5300	-3.0324	1.8459	0.5105	0.000004
Valentino	1,097.19	0.1697*	-0.5598	1.8693	0.9025	-0.000005
Bronko	1,050.75	0.7235	-1.2722	1.7660	1.1373	0.0000004
Nebraska	1,071.28	1.1744	2.844	1.7451	1.2047	0.00002
Giza-6	1,059.86	0.7024	-8.3909	1.7754	0.7686	0.000014
Mean	**1,071.37**	--	--	**1.8004**	--	--
LSD 0.05	**3.717**	--	--	**0.0053**	--	--

Table 5. Estimates of stability for pod length, pod diameter and No. of pods/plant of 5 bean genotypes grown under different densities.

Genotypes	Pod length (cm)			Pod diameter (cm)			No. of pods/plant		
	$\bar{x}$	b_i	S^2d	$\bar{x}$	b_i	S^2d	$\bar{x}$	b_i	S^2d
				1st year					
Paulista	13.24	0.556	-0.00002	0.6525	1.395	-0.00001	13.71	1.092	-0.00035
Valentino	12.67	0.987	0.000059	0.7497	1.138	-0.00001	14.38	0.817	-0.00117
Bronko	12.73	0.942	-0.00009	0.7207	1.126	-0.00001	12.91	0.649	-0.00149
Nebraska	11.78	1.044	-0.00008	0.8353	0.689	-0.00001	18.5	1.164	-0.00016
Giza-6	12.59	1.4	0.000033	0.7855	0.653	-0.00001	16.61	0.477	-0.00157
Mean	**12.60**	–	–	**0.7487**	–	–	**15.22**	–	–
$LSD_{0.05}$	0.0104	–	–	0.0013	–	–	0.0345	–	–
				2nd year					
Paulista	13.284	1.077	-0.0007	0.6582	0.496	0.00001	13.71	1.367	0.00056
Valentino	12.709	1.156	-0.0009	0.7508	0.992	0.00001	14.38	1.106	0.00027
Bronko	12.762	0.756	-0.0010	0.7327	1.477	0.00023	12.88	0.833	0.00097
Nebraska	11.805	0.670	-0.0009	0.8322	1.744	0.00014	18.46	1.194	0.00186
Giza-6	12.626	1.342	-0.0009	0.7828	0.290	0.00008	16.6	0.501	0.00039
Mean	**12.637**	–	–	**0.7513**	–	–	**15.20**	–	–
$LSD_{0.05}$	**0.0173**	–	–	**0.01195**	–	–	**0.0380**	–	–

On the other hand, "b_i" value was more than one ($b_i > 1$) for some genotypes, such as Paulista for branches and leaf area in both seasons and both total chlorophyll and pod diameter in 1st season as well as both Paulista and Valintino for number of leaves in both seasons and number of pods/plant in 2nd one; Bronko for leaf area in 1st season and both total chlorophyll and pod diameter in both seasons; Nebraska for plant height, leaves, number of pods, pod yield/m^2 and pod yield/fed in both seasons and leaf area, total chlorophyll and pod diameter in 2nd one as well as Giza-6 for pod length in both seasons, indicating high potential response for these genotypes in favorable environments.

Moreover, regression coefficient was less than 1 ($b_i<1$) for 4 genotypes at least two to six studied traits in both seasons, such as Valintino for leaf area and number of pods/ plant; Paulista for plant height, pod yield/m^2 and pod yield per feddan; Bronko for each of plant height, leaves number/plant, pod length and number of pods per plant as well as Giza-6 for plant height, leaves number/plant, leaf area, total chlorophyll, pod diameter and number of pods/plant in both seasons. These genotypes appeared to be more productive under unfavorable environments. Zayed and Asfour (2005), Zayed *et al.*

(2005) and Hussein and Abd El-Hady (2015) reported some genotypes to consider as standard cultivars for faba bean, pea and cowpea cultivation under less favorable conditions.

The different genotypes used in this study did not exhibit uniform stability and responsiveness appeared to be specific for specific characters within a single genotype. However, the performance of a genotype which had non-significant regression coefficients (b_i=1) may be predicted and said to be stable (Eberhart and Russell 1966) and linear regression could be regarded as the measure of response of a particular genotype, whereas the deviation around the regression line (S^2d) is the most suitable measure of stability (Jatasra and Paroda, 1980). Hence, the genotypes with lowest insignificant deviation from regression are most phenotypically stable and *vice versa*. However, data in Tables (3-6) showing that value of deviation from regression (S^2d) was significant in some genotypes for specific traits, indicating the instability of these genotypes regarding these traits. Subsequently, again, the results of stability analysis showed a wide variation among genotypes; some genotypes exhibited wide adaptation, while other showed specific adaptation either to favorable or unfavorable environments. In Table 6, the high yielding genotype Nebraska produced the highest mean yield (4.725; 4.757 ton/fed. in 1st and 2nd season, respectively) over all environments (densities) and had regression coefficient (b_i) more than one (b_i>1) and deviation from regression (S^2_d) not significantly from zero followed by Giz-6, and Valintino close to unity and deviation from regression (S^2_d) not significantly from zero.

Preferred genotypes generally, show low G×E interaction variance, high mean yield potential over environments and below deviation from the expected response within a target environment (Lin and Binns 1988). This indicated its high yielding performance based on wide adaptation and stability of performance over all environments. Paulista showed below regression coefficient (b_i<1) and non-significant deviation from regression (S^2_d), indicated specific adaptability of this genotype to harsh (unfavorable) environments. It is evident that this genotype could be used as stress tolerant genotypes under stressed environments (poor yielding or unfavorable environments)**.**

Again, according to Finlay and Wilkinson (1963) and Eberhart and Russell (1966), genotypes with "b_i" value less than 1.0 and higher S^2_d than zero are said to be specifically adapted to poor or unfavorable environments, while, genotypes having high "b_i" value are specifically adapted to favorable or high yielding environments. Genotypes Paulista and Valintino in 2nd season and Nebraska in both seasons with above average regression coefficient (b_i>1) for

Table 6. Estimates of stability for pods yield (g/m^2) and pods yield (ton/fed.) of 5 bean genotypes grown under different densities.

Genotypes	Pods yield (g)			Pods yield (ton)		
	$\bar{x}$	b_i	S^2d	$\bar{x}$	b_i	S^2d
			1st year			
Paulista	794.67	0.76	78.86**	3.179	0.756	0.0013
Valentino	1055.81	1.00	80.51**	4.223	1.002	0.0013
Bronko	1020.65	0.99	30.99**	4.083	0.991	0.0005
Nebraska	1181.15	1.15	5.36	4.725	1.153	0.0009
Giza-6	1127.23	1.10	9.04	4.509	1.099	0.0015
Mean	**1035.90**	--	--	**4.144**	--	--
LSD $_{0.05}$	**10.029**	--	--	**0.040**	--	--
			2nd year			
Paulista	797.15	0.75	63.79**	3.189	0.752	0.0010
Valentino	1059.26	1.00	71.33**	4.237	1.003	0.0011
Bronko	1021.92	0.99	38.09**	4.088	0.991	0.0011
Nebraska	1189.24	1.16	12.70	4.757	1.162	0.0020
Giza-6	1131.43	1.09	10.58	4.526	1.092	0.0005
Mean	**1039.8**	--	--	**4.159**	--	--
LSD $_{0.05}$	**10.315**	--	--	**0.0412**	--	--

number of pods/plant, it indicated that these genotypes could produce the largest number of pods at favorable environments with fertile soil, adequate water and other inputs.

Brief comparison for results:

Field experiments were carried out to examine the magnitude of genotype-environment interactions over six different densities (Table 7). Accordingly, comparing the performance of the cultivars on the basis of yield (ton/fed.) under highest desirable response for yield under various treatments (densities) as well as desirable significant regression coefficients of other traits was done. The best cultivars, which classified on the basis of these parameters, are shown in Table 7. Four out of the five studied cultivars were classified as a good yielded genotypes (>4 t/fed average of all densities).

As for b value, three out of these 4 cvs approached nearly unity for yield, *i.e.,* Giza-6, Valintino and Bronko indicating average response to the fluctuating environmental conditions prevailed the different densities across both seasons. One out of the highest four cvs, Nebrasca, exhibited b value >1 for yield as well as each of plant height, leaves/plant, pods/plant and yield/m^2

Table 7. The best cultivars chosen on the basis of mean yield along with desirable significant b value for other traits under different densities.

CV	Y (t/f)	Stability index of yield/fed: b 1st	b 2nd	S^2d 1st	S^2d 2nd	Regression coefficient for other traits: bi>1 1st	bi>1 2nd	bi<1 1st	bi<1 2nd	b=1 1st	b=1 2nd	Desirable significant "b" for other traits 1st	2nd
G1	4.74	1.15	1.16	0.001	0.002	a,chi	a,cdeghi	b,deg	f	f	B	b,defghi	b,defghi
G2	4.52	1.10	1.09	0.002	0.001	F	fi	a,bcdegh	a,cdegh	i	B	a,b, defghi	a,bdefghi
G3	4.23	1.00	1.00	0.001	0.001	b,cg	a,cfh	dh	dg	a,efi	bei	a,bcefgh	a,bcefgh
G4	4.09	0.99	0.99	0.001	0.001	deg	eg	a,cfh	a,bcd fh	bi	I	a,befgh	b,defgh
G5	3.18	0.76	0.75	0.001	0.001	b,cdfg	b,cdh	a,ei	a,egi	fh	F	a,bcefgh	a,bdefgh

a: Plant height, b: Branches, c: Leaves/plant, d: Leaf area, e: Chlorophyll, f: Pod length, g: Pod diameter, h: pods/plant, i: Yield/m^2.

*Y: Average yield over both seasons. G1: Nebraska G2: Giza6 G3: Valentino, G4: Bronko G5: Paulista in both seasons as well as each of leaf area, chlorophyll and Pod diameter in 2^{nd} season, indicating high potential response for this genotype in favorable environments with adequate water and other input.

As for Paulista cv which exhibited low yield (<4 t/fed), regression coefficient "b value" was less than 1 ($b_i<1$) for yield and each of plant height and yield/m^2 in both seasons as well as both total chlorophyll and pod diameter in 2^{nd} season, showing it is more productive under unfavorable environments. However, treatment with high yield effects did not necessarily produce high other traits, especially qualitative traits and vice versa.

Results revealed that the abovementioned cvs under studied densities might be of prime importance for traditional agricultural procedures for high yield and/or some of its important components.

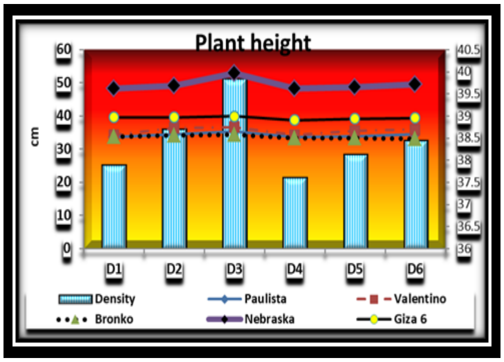
Mean performance of genotypes:

For plant height, Fig. 1a shows that Nebraska cv. was the tallest (49.45 cm) plant in all plant densities (environments) followed by Giza-6 cv. (39.39 cm), while Bronko cv. was the shortest (33.63 cm) one. The best density for plant height was D_3 (39.84 cm) followed by D_2 (38.70 cm) and D_6 (38.45 cm), while the lowest one was D_4 (37.61 cm).

For number of branches/plant (Fig. 1b), Paulista cv. had the highest Branches number per plant (8.43 branches) in all plant densities (environments) followed by Bronko cv. (7.88 branches), while Nebraska cv. was the lowest one (4.96 branches). The best density for Branches/plant was D_1 (7.33 branches) followed by D_3 (7.27 branches) and D_2 (7.22 branches), while the lowest density for Branches/plant was D_5 (6.58 branches).

For Total chlorophyll (Fig. 1c), Valentino cv. was the highest total leaf chlorophyll content (1.86 mg/g) in all plant densities (environments) followed by Paulista cv. (1.83 mg/g), while Nebraska cv. was the lowest (1.73 mg/g). The best density for total chlorophyll was D_1 (1.80 mg/g) followed by D_2 and D_4 (1.79 mg/g), while the bad density for Total chlorophyll was D_3, D_5 and D_6 (1.78 mg/g).

On the other hand, Fig. 1d showing that Nebraska cv. was the best cultivar for number of leaves/plant (24.03 Leaves) in all plant densities (environments) followed by Valentino cv. (23.22 Leaves), while Giza-6 cv.



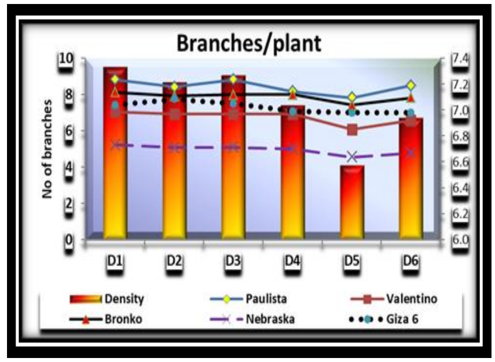


Fig.: a **Fig.: b**

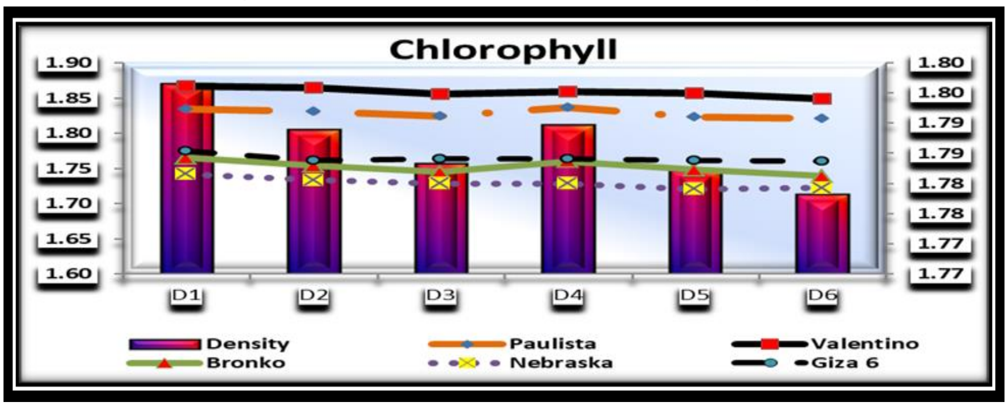
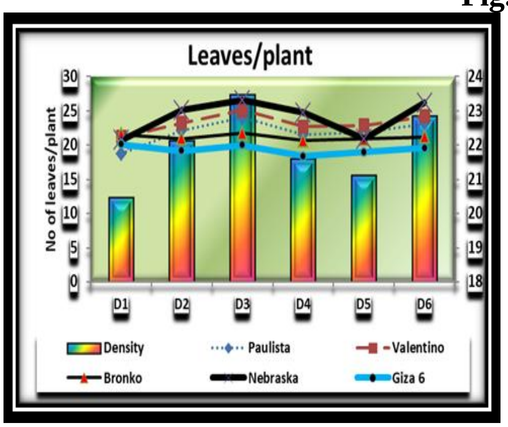


Fig.: c



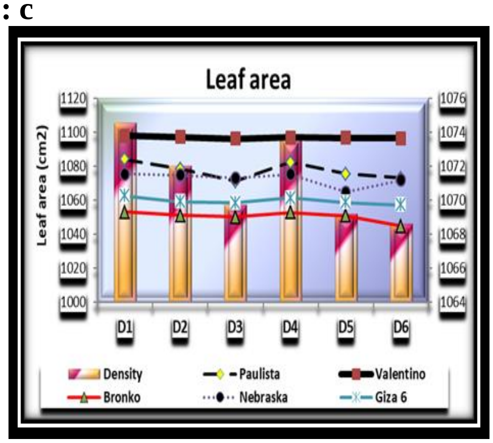


Fig.: d **Fig.: e**

Fig. 1: Genotypes and denisities average mean performance for growth traits combined over both seasons.

was the lowest leaves/plant (19.34 Leaves). The best density for leaves/plant was D_3 (23.48 Leaves) followed by D_6 (22.84 Leaves) and D_2 (22.11 Leaves), while the lowest density for leaves/plant was D_1 (20.45 Leaves).

For Leaf area (Fig. 1e), Valentino cv. was the biggest Leaf area (1,096.78 cm^2) in all plant densities (environments) followed by Paulista cv. (1,077.33 cm^2), while Bronko cv. was the smallest one (1050.44 cm^2). The best density for leaf area was D_1 (1074.56 cm^2) followed by D_4 (1073.68 cm^2) and D_2 (1072.01 cm^2), while the bad density for Leaf area was D_6 (1068.21 cm^2).

As for pod length (cm), Fig. 2a illustrated that Paulista cv. was the longest pod length (13.26 cm) in all plant densities (environments) followed by Bronko cv. (12.75 cm), while Nebraska cv. was the shortest pod length (11.80 cm). The best density for pod length was D_4 (12.69 cm) followed by D_1 (12.64 cm) and D_2 (12.62 cm), while the negative density for pod length was D_6 (12.58 cm).

For pod diameter (cm), Nebraska cv. was the widest pod diameter (0.84 cm) in all plant densities (environments) followed by Giza-6 cv. (0.79 cm), while Paulista cv. was the narrowest pod diameter (0.66). As for densities effect for pod diameter (Fig. 2b), no significant differences between D_1, D_2, D_3, D_4 and D5 (0.75 cm) were observed, while the lowest diameter was found in D_6 (0.74 cm^2).

For number of pods/plant in Fig. 2c, Nebraska cv. had the highest number of pods/plant (18.48 pods) in all plant densities (environments) followed by Giza-6 cv. (16.61 pods), while Bronko cv. was the fewest number of pods/plant (12.90 pods).

The best density for number of pods/plant was D_1 (15.29 pods) followed by D_2 (15.26 pods) and D_5 (15.24 pods), while the bad density for number of pods/plant was D_6 (15.06 pods).

For pod yield ton/feddan (Fig. 2d), Nebraska cv. was the highest pod yield /feddan (4.74 ton) over all plant densities (environments) followed by Giza-6 cv. (4.52 ton), while Paulista cv. was the lowest cultivars (3.18 ton). The best density for pod yield/feddan was D_6 (6.89 ton) followed by D_5 (5.33 ton) and D_4 (4.32 ton), while the bad density for pod yield/feddan was D_1 (2.17 pods).

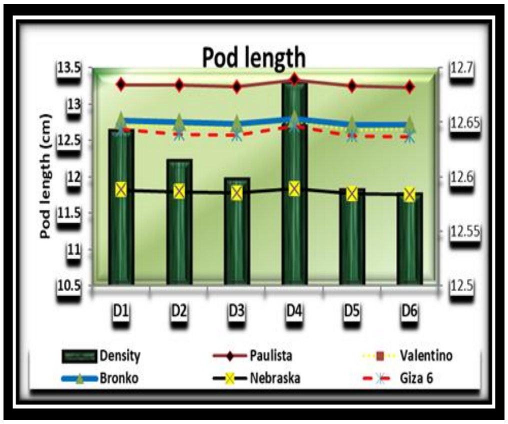


Fig.: a

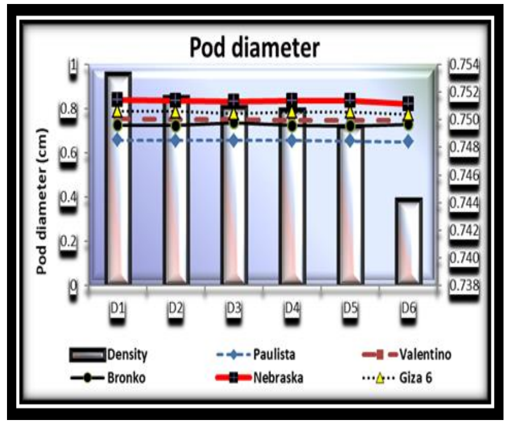


Fig.: b

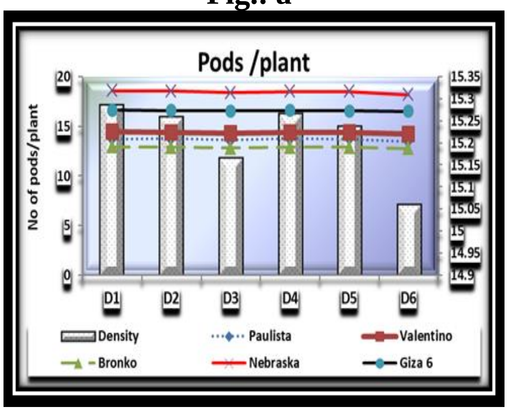


Fig.: c

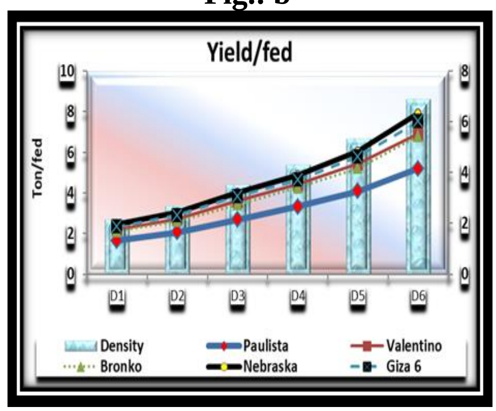


Fig.: d

Figure 2: Genotypes and denisities average mean performance for pod qualitative and yield traits combined over both seasons.

Conclusively,

High potential response for Nebrasca genotype in favorable environments with adequate water and other input and reverse trend for Paulista cv which exhibited low yield (<4 t/fed), regression coefficient "b value" was less than 1 (b_i<1) for yield and each of plant height and yield/m^2 in both seasons as well as both total chlorophyll and pod diameter in 2^{nd} season, showing it is more productive under unfavorable environments. Results revealed that the abovementioned cvs under studied densities might be of prime importance for traditional agricultural procedures for high yield and/or some of its important components.

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الثبات الوراثي لبعض اصناف الفاصوليا تحت كثافات نباتية مختلفة

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أجريت هذه الدراسة خلال موسمى 2016 و2017 لإختبار حجم التفاعل الوراثي البيئي. قيمت خمسة أصناف تجارية من الفاصوليا تحت ستة بيئات كتوليفات من الزراعة علي ريشة أو ريشتين, وثلاث مسافات زراعة.

أظهر تحليل التباين المشترك وجود إختلافات معنوية بين التراكيب الوراثية والبيئات للصفات المدروسة بينما اظهرت معنوية التفاعل بين التراكيب الوراثية والبيئة في كلا الموسمين أن أداء التركيب الوراثى يستجيب بصورة مختلفة للبيئات المختلفة. وعلي العكس أظهرت باقي التراكيب الوراثية ثبات محصولها تحت ظروف البيئات المختبرة. قيمة معامل الإنحدار كانت قريبة من الوحدة في بعض التراكيب الوراثية لبعض الصفات, مما يدل علي إستجابة متوسطة للتغير للظروف البيئية السائدة (الكثافات النباتية) خلال الموسمين. وقد أظهرت قيم الثبات بالنسبة لصفة محصول القرون الخضراء أن b_i لجميع الاصناف كان غير معنوياً عن الواحد كما كانت قيمة $S^2{}_d$ غير معنوية عن الصفر. تم تصنيف أربعة أصناف من أصل خمسة أصناف مدروسة على أنها طرز وراثية جيدة الإنتاج (< 4 طن / فدان فى متوسط السنوات والكثافات). أما بالنسبة لـ "قيمة b"، فقد اقتربت ثلاثة من هذه الاصناف الأربعة تقريبًا من الواحد للمحصول، مما يشير إلى متوسط الاستجابة للظروف البيئية المتقلبة التي سادت الكثافات المختلفة في كلا الموسمين.

التوصية:

تشير النتائج إلى استجابة محتملة عالية لصنف النبراسكا للزراعة تحت الكثافات النباتية فى الظروف القياسية للزراعة من رى وتسميد وصلاحية المياه والتربة. أما بالنسبة لـبوليستا (< 4 طن / فدان)، فإن معامل الانحدار كان أقل من 1 للمحصول مما يدل على صلاحيته للبيئات غير المواتية او تحت الاجهاد البيئى.