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Yield evaluation of guar genotypes (*Cyamopsis tetragonoloba* L. Taub.) selected for high-density planting and mechanical harvesting

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Abstract

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Guar (*Cyamopsis tetragonoloba*) is an annual and self-pollinated crop with a spring-summer cycle that belongs to Fabaceae family. Guar has been assuming increasing importance among agro-industrial crops due to the high galactomannan content of its seeds. Fifteen unbranched genotypes selected for a high-density planting and mechanical harvesting were evaluated for agronomic and yield traits. Ten morphological traits were studied for the analysis of variance, correlation, path coefficient analysis and principal components. The analysis of variance exhibited statistically significant differences among genotypes for all traits studied. The seed plant yield ranged from 13.5 to 25.0 g with mean 19.2 g. The highest significant positive correlation was observed between seed plant yield and number of pods per plant (r=0.806). Likewise, the path coefficient analysis showed that the number of pods per plant (0.72) exerted significantly positive direct effect on seed yield per plant. The PCA showed three components with eigenvalues greater than one, which explained 80.7% of the total variation. Among the fifteen genotypes studied, CB06, CB09, CB12 and CB14 were the most promising for a high-density planting and mechanical harvesting. The information presented in this manuscript is useful in breeding and development of guar genotypes for high-density planting and mechanical harvesting in Mediterranean environment.

Keywords: clusterbean; morphological traits; principal component analysis; seed yield

Introduction

Guar or clusterbean (*Cyamopsis tetragonoloba* L. Taub.) is an annual and self-pollinated plant with a spring-summer cycle that belongs to Fabaceae family. Guar is a multipurpose crop that has been cultivated for generations in India and Pakistan (Chudzikowski, 1971; Whistler & Hymowitz, 1979). There is lack of general consensus with regard to the origins of this plant (Whistler & Hymowitz, 1979), although the trans-domestication concept is accepted as a plausible explanation for the domestication of guar. The African wild species *C. senegalensis* appears to be the ancestor of the west-Asian domesticates *C. tetragonoloba* (Hymowitz, 1972).

Guar, generally a 50-150 cm tall and deep-rooted plant, is hardy and drought resilient and is grown on sandy soils of arid and semi-arid regions. Branching habit in this species may be erect, basal branching and branched. The erect category has predominantly zero to two branches (Pathak, 2015).

Guar has been assuming increasing importance among agro-industrial, due to the high galactomannan content of its seeds. Because of its unique rheological properties, guar gum has a wide range of applications in various industries like food, pharmaceutical, textile, oil, paint, paper, explosive, cosmetics and oil and methane extraction by hydraulic fracturing (Mathur, 2012; Mudgil et al., 2014).

Guar growing could be economically sustainable and an important opportunity for diversification or integration of incomes in Mediterranean areas (Gresta et al., 2014). However, mechanical harvesting requires a specific model plant: high seed yield combined with plant favorable architecture. According to Chaudhary & Singh (1976), a model guar plant should have few branches, high number of clusters with pods, bold seeds and long peduncle for higher seed yield. Besides, early maturing, determinate growth habit, photo insensitivity, moderate number of branches and height are also expected as efficient plant type for higher yields of this crop (Pathak, 2015). A short crop cycle, an elevated height of the first fertile node, a lack of branches and a high seed production were considered the best morpho-productive traits for cultivation in the Mediterranean environment (Gresta et al., 2016). According to the same authors, despite strong branching habit leads to a great number of pods per plant, it induces a greater loss of production at harvest, as the branches spread from the base of the stem and pods cannot be collected by the combine harvester (Gresta et al., 2016).

Several studies showed high level of genetic variability and high level of broad sense heritability (h^2) in the guar plant traits, that determine productivity and morphological architecture, e.g. seeds per pod ($h^2 = 0.54$), 100-seed weigh ($h^2 = 0.98$), pods per plant ($h^2 = 0.94$), yield per plant ($h^2 = 0.98$), branches per plant ($h^2 = 0.72$), plant height ($h^2 = 0.85$) (Jitender et al., 2014). Therefore, classical methods of plant breeding can be used to obtain cultivars more adapted to agro-industrial crop.

At Idanha-a-Nova region, in Portugal, the irrigated area perimeter (about 8200 ha), has been almost abandoned. One major cause was irregular water availability for the major cash-crops, due to insufficient rainfed charge of Marechal Carmona Lake, most likely due to climate change induced drought. Therefore, guar might have a potential to be an alternative to cash-crops in this area, because it's lower water requirements and drought resilience. A large project was established with the aim to study the Guar adaptation and feasibility for this Mediterranean area. The present research is a part of these studies.

The main objective was the morphological characterization and preliminary yield evaluation of fifteen unbranched guar genotypes for a high-density planting and mechanical harvesting in Mediterranean environment. Furthermore, it was intended the seed multiplication of the studied "promising" genotypes.

Materials and Methods

Plant material and experimental design

Fifteen genotypes of guar (14 from India origin and one from US) previously selected for reduced branching (our unpublished data) were studied. The trial was carried out at the School of Agriculture of Castelo Branco, Portugal (39º49′ N; 7º27′ W, elev. 365 m a.s.l.); it was established in a medium-sandy textured soil with pH 5.9 and medium organic matter content. The genotypes were sown on 23 May in a plot of 10 m length at spacing of 50 × 30 cm (one row per genotype) under optimum management practices. The plot was irrigated (sprinklers) to maintain field capacity (May-June ca. 4,25mm each two days, depending on rainfed; July-September, 4.25 – 8.25 mm, each day). Harvest was carried from September to October, when most of the pods were ripe.

The Köppen-Geiger climate classification of Castelo Branco is Csa. The annual mean temperature in 2018 was 15.7ºC. The driest and hottest months were July, August and September, with mean temperatures ranging between 24 and 27ºC and absolute values reaching 36ºC. The accumulated precipitation in the period May to September 2018 was 77.1 mm. These values were lower from the mean over the last 30-years of 121.8 mm for the same period.

Morphological characterization and yield evaluation

Morphological characterization was based on the following quantitative traits: plant height (PLH, cm), first fertile nod insertion (FFNI, cm), clusters per plant (CLPL), pods per cluster (PodCL), pods per plant (PodPL), pod length (PodL, cm), seeds per pod (SPod), 100-seed weight (100SW, g) and seed yield per plant (PYield, g). All pods were counted as pods per cluster and pods per plant. The number of seeds per pod and pod length were evaluated in the 10 largest pods of each plant. The length of biological cycle from sowing until seed maturation was also evaluated and three categories were considered: early (1st, 60-90 days), medium (2nd, 91-120 days) and late (3rd, > 120 days). Data was recorded on ten individual plants, randomly selected from each genotype.

Variability was calculated intra genotype and among all, to each trait, by the Phenotypic coefficient of variation

(PCV), according to Singh and Chaudhary (cit. by Jitendet et al., 2014).

Statistical Analysis

The data was analysed using one-way ANOVA and Bonferroni post-hoc tests; normality and homogeneity was as assessed by Shapiro-Wilk test (p > 0.05) and Levene's test, respectively. In cases of Anova assumptions failure, Welch ANOVA was used instead and Games-Howell post-hoc test. Statistical significance was accepted with 5% as the probability of type I error for both the omnibus test and the multiple comparisons test. Pearson's correlation, path coefficient analysis and principal component analysis (PCA) were conducted using the data from the morphological descriptors. The suitability of PCA was assessed prior to analysis by checking the linearity between all variables and the sampling adequacy. Inspection of the correlation matrix was conducted to select the variables with, at least, one correlation coefficient greater than 0.3. The overall Kaiser-Meyer-Olkin (KMO) measure was 0.63 with individual KMO measures all greater than 0.54 meeting the minimum requirements for sampling adequacy according to the Kaiser method (1974). Bartlett's test of sphericity was statistically significant ($p < 0.05$), which indicated that the data were likely factorable. The statistical analyses were performed using IBM SPSS Statistics software v.24 (IBM Corp., Armonk, NY, USA).

Table 1. Analysis of variance (ANOVA) statistic for the morphological and yield traits studied in guar (*Cyamopsis tetragonoloba*) genotypes. [a]One-way ANOVA; [b]one-way Welch ANOVA

Morphological parameters	F	df_1	df_2	Sig.
Plant height (PLH)	57.34[a]	14	147	$p < 0.05$
First fertile Node (FFNI)	25.12[b]	14	50.28	$p < 0.05$
Clusters per plant (CLPL)	6.99[b]	14	50.34	$p < 0.05$
Pods per cluster (PodCL)	1.94[a]	14	147	$p < 0.05$
Pods per plant (PodPL)	13.14[b]	14	50.43	$p < 0.05$
Pod length (PodL)	25.55[a]	14	147	$p < 0.05$
Seeds per pod (SPood)	10.54[a]	14	147	$p < 0.05$
100-seed weight (100SW)	11.80[b]	14	50.49	$p < 0.05$
Seed yield (PYield)	7.91[b]	14	50.41	$p < 0.05$

Results

Morphological characterization and yield evaluation

All morphological traits exhibited statistically significant differences (p < 0.05) among genotypes (Table 1). The means from morphological traits of the fifteen unbranched guar selected genotypes are shown in Table 2.

Differences in the biological cycle from sowing to seed maturity were found. Genotypes CB06, CB09 CB10 and CB15 showed early cycles, medium cycles were observed in genotypes CB01, CB05, CB07, CB08, CB12, CB13 and CB14, while later cycles were observed in genotypes CB02, CB03 CB04 and CB011 (Table 2).

Table 2. Means of morphological traits and yield of selected guar (*Cyamopsis tetragonoloba*) genotypes. Different letters indicate significant differences for $p < 0.05$

Genotype	Origin	Cycle	PLH, cm	FFNI, cm	CLPL	PodCL	PodPL	PodL cm	SPood	100SW, g	PYield, g
CB01	India	2	121.6[c]	9.1[a]	11.3[abc]	8.9[b]	96.3[fg]	5.6[bcde]	7.8[a]	2.79[g]	13.5[g]
CB02	India	3	146.8[a]	9.5[a]	11.8[abc]	10.7[ab]	126.2[bcdef]	5.5[de]	7.6[a]	2.93[fg]	19.4[bcdefg]
CB03	India	3	141.1[ab]	10.6[a]	13.7[ab]	12.3[a]	161.4[a]	5.4[ef]	7.5[ab]	3.09[defg]	25.1[a]
CB04	India	3	141.1[ab]	9.6[a]	14.8[a]	10.8[ab]	155.7[ab]	5.5[e]	7.8[a]	2.99[efg]	21.9[abcd]
CB05	India	2	128.1[bc]	9.7[a]	14.9[a]	9.9[ab]	146.3[abc]	5.8[bcd]	7.9[a]	3.23[bcdef]	22.9[abc]
CB06	India	1	82.8[ef]	8.65[ab]	12.7[abc]	11.8[a]	149.2[ab]	5.4[ef]	7.0[bc]	3.23[bcdef]	19.6[abcdefg]
CB07	India	2	135.5[abc]	9.1[a]	10.1[bc]	9.9[ab]	100.1[efg]	5.6[bcde]	7.8[a]	3.15[cdefg]	16.7[defg]
CB08	India	2	123.7[c]	11.5[a]	10.0[bc]	9.8[ab]	95.9[fg]	5.8[bc]	8.0[a]	3.01[defg]	15.4[efg]
CB09	India	1	100.7[d]	5.0[c]	11.4[abc]	9.7[ab]	107.9[defg]	5.4[ef]	7.6[a]	3.54[ab]	18.7[abcdefg]
CB10	India	1	123.4[c]	9.6[a]	9.8[bc]	10.0[ab]	96.9[fg]	6.2[a]	7.9[a]	3.54[ab]	18.3[bcdefg]
CB11	USA	3	123.7[c]	8.9[a]	9.4[c]	9.8[ab]	91.8[g]	5.6[cde]	8.0[a]	3.33[bcde]	16.0[defg]
CB12	India	2	102.3[d]	5.6[bc]	13.2[abc]	10.4[ab]	132.5[abcde]	5.5[e]	8.0[a]	3.36[bcde]	21.5[abcde]
CB13	India	2	126.5[c]	10.0[a]	11.9[abc]	9.8[ab]	115.0[cdefg]	5.9[ab]	8.0[a]	3.87[a]	23.3[ab]
CB14	India	2	91.1[de]	4.4[c]	14.8[a]	9.8[ab]	139.5[abcd]	5.2[fg]	7.7[a]	3.39[bcd]	21.1[abcdef]
CB15	India	1	75.8[f]	4.7[c]	9.5[c]	10.2[b]	96.4[fg]	4.9[g]	6.8[c]	3.59[ab]	14.8[fg]
Mean ± SD			117.6 ± 23.0	8.4 ± 3.0	12.0 ± 3.1	10.3 ± 1.7	120.7 ± 31.7	5.6 ± 0.35	7,7 ± 0.5	3,27 ± 0.37	19.2 ± 5.1

Cycle: 1 – early; 2 – medium; 3 – late. PLH – plant height (cm); FFNI – first fertile node insertion (cm); CLPL – clusters per plant; PodCL – pods per cluster; PodPL – pods per plant; PodL – pod length (cm); SPod – seeds per pod; 100SW – 100-seed weight (g); PYield – seed yield per plant yield (g)

Plant height ranged from 75.8 (CB15) to 146.8 cm (CB02) with overall mean 117.6 cm (Table 2) and PCV was 20% (Table 3). Only five genotypes (CB06, CB09, CB12, CB14 and CB15) had height close to or below 100 cm (Table 2). PCV was higher than 10% only in two genotypes (CB09 and CB15).

The height of first fertile node insertion ranged from 4.4 (CB14) to 11.5 cm (CB08) with mean 8.4 cm (Table 2) and PCV 36% (Table 3); genotype CB11 had lower variability, ca. 10%. The mean number of clusters per plant was 12.0, ranging from 9.4 (CB11) to 14.9 (CB05) (Table 2) and the PCV was 26%; variability was higher on 4 genotypes (CB01, CB03, CB09 and CB14, ranging from 27 to 31%. The number of pods per cluster varied from 8.9 (CB01) to 12.3 (CB03) with mean 10.3 (Table 2) and PCV 18%; CB09 showed the highest variability (PCV of 33%). The number of pods per plant ranged from 91.8 (CB11) to 161.4 (CB03) with mean 120.7 (Table 2) and PCV 26%. The pod length ranged from 4.9 (CB15) to 6.2 cm (CB10) with mean 5.6 cm (Table 2) and PCV 6%. The number of seeds per pod ranged from 6.8 (CB15) to 8.0 (CB08, CB11, CB12 and CB13) with mean 7.7 (Table 2) and PCV 6%. The 100 seed weight varied from 2.79 to 3.87 g with mean 3.27 g (Table 2) and PCV 11%. The mean seed yield per plant for the set of studied genotypes was 19.2 g, ranging from 13.5 (CB01) to 25.0 g (CB03) (Table 2) and PCV was 27%; the highest variability was observed on CB05 (PCV 35%) and a plant seed yield mean of 22.9 g.

The genotype CB03 had the highest yield per plant. However, this genotype had a long biological cycle, plant height (141.1 cm) within the tallest group as well the number of clusters per plant (CLPL) which means a high plant lodging risk. The CB13 and CB05 genotypes presented the second and third highest yield per plant. Comparing with CB03, these two genotypes, had both a medium biological cycle, shorter plant height (126.5 cm and 128.1cm, respectively), and lower (CB13) or higher (CB05) cluster per plant. CB05 showed higher variability in all these traits that could suggest a higher potential to increase plant yield and reduce number of clusters per plant, trough plant selection. The genotypes CB06, CB09, CB012 and CB014 stand out among the shortest group.

Correlation, path coefficients and PCA

Correlation coefficients and statistical significance, between the studied traits are presented in Table 4. The highest significant positive correlation was observed between plant yield *vs* number of pods per plant (r = 0.805) followed by plant yield *vs* number of clusters per plant (r = 0.648). Low positive and significant correlations occurred between, plant yield *vs* 100-seed weight (r = 0.362), plant yield *vs* number of pods per cluster (0.298), plant yield *vs* number of seeds per pod (0.271). Furthermore, positive significant correlations were observed between cycle *vs* plant height (r = 0.734), first fertile node insertion *vs* plant height (r = 0.543), number of clusters per plant *vs* number of pods per plant (r = 0.757), pod length *vs* number of seeds per pod (r = 0.686). Low negative significant correlations occurred between 100-seed weight *vs* cycle (r = −0.388), 100-seed weight *vs* plant height (r = −0.312), 100-seed weight *vs* first fertile node insertion

Table 3. Phenotypic coefficient of variation – PCV (%), of selected guar (*Cyamopsis tetragonoloba*) genotypes

Genotype	Plant height	First fertile nod	Clusters/ plant	Pods/ cluster	Pods/ plant	Pod length	Seeds/ pod	Plant yield	100-seed weight
CB01	7	26	31	17	17	2	3	17	12
CB02	7	19	17	15	23	3	4	16	6
CB03	9	30	27	19	24	3	5	24	6
CB04	4	19	20	15	12	3	5	17	7
CB05	8	18	21	11	22	3	6	35	5
CB06	9	27	10	13	15	4	6	11	5
CB07	9	17	14	15	23	3	4	25	5
CB08	6	38	22	12	12	3	4	16	6
CB09	12	30	29	33	17	5	5	22	7
CB10	5	14	16	10	13	3	5	19	5
CB11	7	11	12	14	14	4	5	18	12
CB12	9	27	23	22	14	4	2	18	6
CB13	7	24	16	19	14	3	5	17	8
CB14	9	22	29	20	15	3	5	23	9
CB15	11	15	15	10	19	5	6	23	11
All	20	36	26	18	26	6	6	27	11

Table 4. Pearson correlation coefficients between different traits of 15 fifteen selected guar (*Cyamopsis tetragonoloba*) genotypes

	Cycle	PLH	FFNI	CLPL	PodCL	PodPL	PodL	SPod	100SW
Plant height (PLH)	0.734[b]								
First fertile node (FFNI)	0.462[b]	0.543[b]							
Clusters per plant (CLPL)	0.058	0.080	-0.118						
Pods per cluster (PodCL)	0.043	0.056	0.064	-0.263[b]					
Pods per plant (PodPL)	0.093	0.118	-0.031	0.757[b]	0.374[b]				
Pod length (PodL)	0.264[b]	0.493[b]	0.457[b]	-0.047	-0.025	-0.084			
Seeds per pod (SPod)	0.398[b]	0.413[b]	0.199[a]	0.112	-0.053	0.014	0.686[b]		
100-seed weight (100SW)	-0.3884[b]	-0.312[b]	-0.235[b]	-0.004	0.118	0.024	0.129	-0.015	
Seed yield (PYield)	0.107	0.200[a]	0.004	0.648[b]	0.298[b]	0.805[b]	0.197[a]	0.271[b]	0.362[b]

[a]Significance at 5% level; [b]significance at 1% level

(r = −0.235), number of pods per cluster *vs* number of clusters per plant (r = −0.263).

The path coefficients based on phenotypic correlation showed that the trait number of pods per plant (0.71) exerted significantly positive direct effect on seed yield per plant, followed by 100-seed weight (0.40), number of seeds per pod (0.20) and plant height (0.15). The traits 100-seed weight (−0.13) and seeds per pod (−0.12) exerted significantly negative direct effect on number of pods per plant.

The PCA revealed three components with eigenvalues greater than one, which explained 80.7% of the total variance (Table 5). The screen plot indicated that three components should be retained (Cattell, 1966), and Varimax orthogonal rotation was employed to interpret these results (Table 6). The first component was represented by seed yield, number of pods and number of clusters per plant (37.9%), the second was represented by the length of biological cycle plant height and first fertile node insertion and (29.7%), and the third was represented by number of seeds per pod and pod length (13.1%).

Table 5. Eigenvalues and the proportion of total variability among guar (*Cyamopsis tetragonoloba*) genotypes as explained by the principal components

	Eigenvalues	Variance, %	Cumulative var., %
Component 1	3.033	37.908	37.908
Component 2	2.373	29.665	67.573
Component 3	1.047	13,093	80.666
Component 4	0.644	8.045	88.711
Component 5	0.336	4.204	92.915
Component 6	0.293	3.658	96.573
Component 7	0.152	1.902	98.475
Component 8	0.122	1.525	100.000

Discussion

Fifteen genotypes of guar previously selected for reduced branching were studied. The analysis of variance indicated significant differences among the genotypes for all traits studied, in pace with high values of PCV. These suggested the presence of substantial morphological diversity among the genotypes under study which offers an opportunity for selection among the traits.

There are several published studies on the morphological characterization of guar genotypes, including branched and unbranched plants (Morris et al., 2010; Manivannan et al., 2015; Boghara et al., 2016; Gresta et al., 2016). Gresta et al. (2016) studied eight branched and unbranched genotypes

Table 6. Rotated structure matrix for PCA with Varimax rotation

	Rotated components coefficients			
	Component 1	Component 2	Component 3	Communalities
Pods per plant	<u>0.943</u>	0.076	-0.110	0.907
Clusters per plant	<u>0.886</u>	-0.028	-0.006	0.786
Seed yield	<u>0.886</u>	0.041	0.239	0.843
Length of cycle	0.094	<u>0.862</u>	0.120	0.767
Plant height	0.126	<u>0.849</u>	0.289	0.820
First fertile node insertion	-0.116	<u>0.772</u>	0.163	0.636
Number of seeds per pod	0.113	0.189	<u>0.889</u>	0.838
Pod length	-0.045	0.288	<u>0.878</u>	0.856

from different origin and concluded that Monument, and to a lesser extent Lewis varieties, showed the best morpho-productive traits suitable for cultivation in the Mediterranean environment. According to these authors, a shorter growing cycle, a growth habit with higher first insertion node and an absence of branches allowing for a higher sowing density, are features of great importance for crops cultivated in the Mediterranean area, where they must be threshed in late summer before the rainy period begins.

In our study, the genotypes CB06, CB09, CB12 and CB14 showed a short to medium growing cycle and a plant height inferior or close to 100 cm. The option to select for non-branched plants allows increasing the sowing density; besides, short to moderate plant height decrease the risks of losses due to waterlogging. In these group of genotypes plant height ranged from 82.8 to 102.3 cm, insertion of the first fertile node 4.4-8.7 cm, number of cluster per plant 11.4-14.8, number of pods per plant 108-149, pod length 5.2-5.5 cm, number of seeds per pod 7.0-8.0, 100 seed weight 3.2-3.5 g and plant yield 18.7-21.5 g. The range of values we found is in accordance with the findings of some previous studies (Morris et al., 2010; Jukanti et al., 2015; Manivannan et al., 2015). For example, Manivannan et al. (2015) studied the genetic diversity of 42 guar accessions based on agro-morphological traits and reported values ranged from 45.4 to 94.6 cm for plant height, 10.8-32.90 for clusters per plant, 21.2-132.1 for pods per plant, 5.3-12.9 cm for pod length, 6.6–9.2 for seeds per pod, 5.7–26.0 g for plant yield and 3.3–5.0 g for 100-seed weight. It should be noted the values for plant height, number of pods per plant and 100-seed weight we found were higher than the values reported by Gresta et al. (2016) for the unbranched Monument variety (75.9 cm, 56.5 and 3.0 g).

Correlations among traits are useful in effective breeding program for any crop (Atanassova & Georgiev, 2007); the correlation at the genotypic and phenotypic level has the same trend, although the phenotypic expression of the correlation is influenced by environment (Boghara et al., 2016). Path analysis is an efficient method of separating direct and indirect effects and measuring the relative importance of the causal factors involved (Wright, 1934). This method has been used to assist in identifying traits that are useful as selection criteria to improve crop yield (Canci & Toker 2009). Among studied traits, number of pods per plant had the highest positive correlation with plant yield followed by the number of clusters. High positive correlations between plant yield and number of pods per plant were previously reported (Gresta et al., 2013; Jukanti et al., 2015; Manivannan et al., 2015; Boghara et al., 2016). In our study, the path coefficient analysis showed that the traits number of pods per plant followed by seed weight exerted significantly positive direct effect on seed yield per plant. Similar results were reported by Boghara et al. (2015) who suggest that maximum weightage should be given to easily scorable traits like number of pods and test weight in selection. However, according to the same authors, for large scale screening clusters per plant would be more appropriate. Ibrahim et al. (2012) and Raghuprakash et al. (2009), adopting path coefficient analysis, concluded that the number of pods per plant and the number of seeds per pod were important components in formulating selection criteria for improvement of seed yield in guar. Contrary to what is reported by several authors (Manivannan, 2015; Gresta et al., 2016), in our study no negative correlation was found between the 100-seed weight and number of pods and between seeds per pod and number of pods. The height of the first fertile node insertion is an important aspect regarding mechanical harvest. In our study, a positive correlation (0.543) occurred between first fertile node insertion and plant height. Similar results were reported by Gresta et al. (2016) although higher values were found (0.709).

Conclusions

Among the fifteen genotypes studied the genotypes CB06, CB09, CB12 and CB14 were the most promising for a high-density planting and mechanical harvesting. These genotypes had a plant height inferior or close to 100 cm, showed a short to medium growing cycle and are unbranched allowing for a higher sowing density. The CB05 genotype should be maintained given the high seed production per plant, medium cycle and high variability in all traits, although the plants are tall than 100 cm. Among yield components, the number of pods per plant was the trait most closely related to the seed yield. The information presented in this manuscript is useful in breeding and development of guar genotypes for the Mediterranean environment.

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