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DROUGHT RESPONSE OF BEAN (*Phaseolus vulgaris* L.) CULTIVARS USING DIFFERENT SELECTION INDEXES

Respuesta de cultivares de frijol (*Phaseolus vulgaris* L.) a la sequía utilizando diferentes índices de selección

Wilfredo Estrada Prado[1]✉, Eduardo Jerez Mompie[2], María C. Nápoles García[2], Ariel Sosa Rodríguez[1], Yariuska C. Maceo Ramos[1] and Cristóbal Cordoví Dominguez[1]

ABSTRACT. The response of 15 bean cultivars the hydric defficit tolerance was evaluated in an experiment carried out between the years 2012-2013 at CCSF "Roberto Aguilar", Bayamo municipality, Granma province, Cuba. Two treatments were used: cultivars of bean under watering and cultivars of bean low drought, distributed in a random block design. Ten plants were selected at random from each treatment where indicators were evaluated: number of sheaths for plants, weight of the sheaths (g), lenght of the sheaths (cm) and wide of the sheaths (mm). Also to determine the tolerance the following indexes were evaluated: yield losses (YL), geometrical mean productivity (GMP), mean productivity (MP), relative efficiency index (REI), drought tolerant tndex (DTI), stability yield index (SYI), susceptibility drought index (SDI), harmonic mean (HM) and tolerance (T). The results showed that the soil hydric defficits evaluated have an influence (p≤0,05), in the behavior of the cultivars, where CC-25-9R variety showed the most tolerant hydric defficit, while Tomeguín-93 was the most susceptible variety.

Key words: varieties, drought susceptibility, drought tolerant

RESUMEN. Se evaluaron 15 cultivares de frijol para determinar la tolerancia al déficit hídrico en un experimento que se desarrolló en el período 2012-2013 en la CCSF "Roberto Aguilar", municipio Bayamo, provincia Granma, Cuba. Se emplearon dos tratamientos: cultivares de frijol bajo riego y cultivares de frijol bajo sequía, distribuidos en un diseño de bloque al azar. Se seleccionaron diez plantas al azar en cada tratamiento donde se evaluaron los siguientes indicadores: número de vainas por plantas, peso de las vainas (g), longitud de las vainas (cm) y ancho de las vainas (mm). Además, para determinar la tolerancia se evaluaron los siguientes índices: pérdida del rendimiento (PR), productividad media geométrica (PMG), productividad media (PM), índice de eficiencia relativa (IER), índice de tolerancia a la sequía (ITS), índice de rendimiento (IY), índice de estabilidad del rendimiento (IEY), índice de susceptibilidad a la sequía (ISS), media harmónica (MH) y tolerancia (TOL). Los resultados mostraron que el déficit de humedad evaluado, influyó significativamente (p≤ 0,05), en el comportamiento de los cultivares donde la variedad CC-25-9R mostró mayor tolerancia al déficit hídrico mientras que la variedad Tomeguín-93 fue la más susceptible.

Palabras clave: variedades, susceptibilidad a la sequía, tolerancia a la sequía

INTRODUCTION

Among all food grain legumes, the bean (*Phaseolus vulgaris* L.) is one of the most important species for human consumption. Its production includes various agroecological areas. This legume is grown almost everywhere in the world (1).

It is one of the main sources of protein in Latin America and Africa (2), as well as a significant source of vitamins, minerals and dietary fiber widely consumed by inhabitants from developing countries (3).

Climatic change is a progressive and every time more intense threat to food production, especially in less developed regions. Severe droughts and frequent

[1] Instituto de Investigaciones Agropecuarias "Jorge Dimitrov", carretera Vía Manzanillo, km 16 1/2, Bayamo, Granma, Cuba.

[2] Instituto Nacional de Ciencias Agrícolas (INCA), gaveta postal 1, San José de las Lajas, Mayabeque, Cuba, CP 32700.

✉ estrada@dimitrov.cu

floodings are threats that favor the appearance of new pests and diseases or increase the existing ones (4).

Drought is one of the most significant stress factors, as it inhibits plant growth and yield. There are many reports about the mechanisms of perception, transduction and plant response against drought stress (5).

Among all environmental constraints, drought stress is the most limiting factor for plant productivity and distribution in agricultural and natural systems (6, 7). A recent proposal to mitigate climatic change effects and reduce water consumption in agriculture is to obtain varieties that make efficient use of water (UEA) (8).

Therefore, the fact that the eastern region of Cuba has difficulties with rainfall distribution and frequency makes some crops, such as bean, do not reach its full productive potential, because there are not enough varieties adapted to water stress.

Consequently, an experiment was carried out with the aim of evaluating the response of 15 bean (*Phaseolus vulgaris* L.) varieties under different soil moisture conditions using several selection indices.

MATERIALS AND METHODS

This work was developed at "Roberto Aguilar" SSCC of Bayamo, Granma province, within 2012-2013 period, using commercial bean (*Phaseolus vulgaris* L.) seeds from the following varieties: Velasco Largo, CC-25-9R, CC-25-9N, Tomeguin-93, Cabriole, Holguin-518, Delicias-364, Pilon, INIFAT-8, Lagrima Roja, Bonita-11, Engañador, P-219, P-1127 and P-3047 (9).

The experiment was carried out on a non-carbonated Brown soil or Cambisols, according to the latest genetic classification of soils in Cuba (10), with the chemical characteristics listed in Table I. Soil was prepared by employing Yunz-6 KM tractor in the following order: harrowing, raking and furrowing. Mineral fertilizer at a rate of 120 kg ha^{-1} NPK formula 7,5-6-12 was spread at the bottom of the furrow and covered with a soil layer to avoid seed contact directly with fertilizer (11).

Seeding was done by hand within the second fortnight of December, 2012, in a frame made up of 0,70 m between rows and 0,05-0,07 m between plants. Plots were 5 m long and 2,8 m wide for a total area of 14,00 m^2 with a calculation area of 6,30 m^2 discounting both lateral rows and 0,25 m at the beginning and the end of each row. All varieties were subjected to two irrigation treatments:

T_1- Irrigation (irrigation applied throughout the whole crop cycle).

T_2- Drought (irrigation interrupted at flowering and pod formation stage).

Evaluations were performed to pod number per plant, pod weight (g), pod length (cm) and pod width (mm).

To determine varietal sensitivity and tolerance in both treatments, yield losses were calculated at different soil moisture levels using the formula:

$$PR= 1-(Rs/Rr).100$$

where:

Rs: T_1 yield

Rr: T_2 yield and drought tolerance indices as shown in Table II (12).

Table II. Tolerance indices studied in both moisture conditions

Tolerance indices	Formulae
Drought sensitivity index	ISS= [1-(Rsi/Ryi)] / ITS
Mean geometric productivity	PMG= √Rsi . Ryi
Mean productivity	PM= (Rsi + Ryi) / 2
Harmonic mean	MH= 2(Ry+Rs)/(Ry+Rs)
Tolerance	TOL= Ryi-Rsi
Drought tolerance index	ITS= (Ry . Rs)/ (Ry)^2
Yield index	YI= Rsi/Rs
Yield stability	YSI= Rsi / Ryi
Relative efficiency index	IER= (Rsi /Rs)/Ryi/Ry)

Rsi: Mean yield of all varieties under stress conditions; Ryi: Mean yield of all varieties under irrigation; Rs: crop yield under stress conditions; Ry: crop yield under irrigation conditions

Table I. Chemical characteristics of a non-carbonated Brown soil (Cambisols)

Depth (cm)	OM (%)	pH KCl	P_2O_5	K_2O	Ca^{2+}	Mg^{2+}	K^+	Na^+
			mg 100g^{-1}		cmol kg^{-1}			
0-25	3,00	6,5	2,77	35,75	26,81	6,36	1,15	0,75

A factorial variance analysis was performed in a randomized block design with split plot arrangement, where large plots were both irrigation treatments and small plots were all varieties evaluated. Means were compared through Tukey test with a probability of p<0,05. Statistical processing used Statistica package version 8.0 for Windows (13).

RESULTS AND DISCUSSION

When analyzing pod production and its components in Table III, it was observed that where irrigation was applied, all indicators showed significant differences among varieties, CC-25-9R achieving more pods (27,0) per plant, without significant differences from Holguin 518, Engañador and Velasco Largo, which in turn showed differences from the other varieties. Meanwhile Tomeguin-93 and Bonita-11 reached 15,9 and 15,7 pods per plant, without statistical differences between them. Regarding pod weight, there was a similar behavior among varietal length and width, CC-25-9R being the best again with 8,49 cm and 9,1 mm respectively.

Under drought conditions, the best results were also achieved by CC-25-9R with 23,6 pods per plant, without differing from Holguin-518, Engañador and Velasco Largo, and a similar result was recorded in pod weight with 295 g, it being much better than the other varieties. The greatest pod length and width was attained by the same variety with values of 7,4 cm and 8,2 mm respectively. In addition, Tomeguin-93 and Bonita-11 reached lower values of such indicators, without significant differences between them. It is evident that when plants suffered from drought, all measured indicators were reduced in relation to those obtained under irrigation conditions.

Either drought or poor water availability is the main factor limiting crop production (14).

Undoubtedly, when drought occurs at flowering, pod formation and grain filling stages, common bean yield decreases. For some researchers studying bean crop, pod number and yield decrease from 50 to 72 %, depending on water deficit intensity and cultivar tolerance (15). According to other authors, depending on drought lengthening and its magnitude, it can cause yield losses from 20 to 100 % in bean fields (16).

Table III. Pod production under both moisture conditions

Varieties	Indicators							
	Irrigation				Drought			
	Pods per plant	Pod weight (g)	Pod length (cm)	Pod width (mm)	Pods per plant	Pod weight (g)	Pod length (cm)	Pod width (mm)
Velasco Largo	23,8 b	420 b	8,13 b	8,3 b	22,7 b	283 b	7,4 b	7,8 b
CC-25-9R	27,0 a	482 a	8,49 a	9,1 a	23,6 a	295 a	7,4 a	8,2 a
CC-25-9N	20,2 d	405 cd	7,82 cd	8,8 cd	16,3 cd	180 cd	7,28 cd	8,1 cd
Tomeguín-93	**15,9 e**	**364 e**	**6,95 e**	**6,5 e**	**13,9 e**	**162 e**	**6,37 e**	**6,4 e**
Cabriole	18,6 de	357 de	7,68 de	7,6 de	18 de	187 de	6,59 de	7,2 de
Delicias-364	21,4 d	370 d	8,26 d	8,5 d	20 d	269 d	6,82 d	7,3 d
Holguín-518	26,2 ab	450 ab	8,34 ab	8,4 ab	21 ab	274 ab	7,0 ab	7,5 ab
Pilón	19,4 d	389 d	7,57 d	7,7 d	17 d	213 d	6,81 d	7,3 d
Bonita-11	**15,7 e**	**376 e**	**7,00 e**	**7,3 e**	**16 e**	**175 e**	**6,44 e**	**6,5 e**
INIFAT-8	16,5 cd	394 cd	8,20 cd	8,4 cd	18 cd	218 cd	6,89 cd	7,0 cd
Lagrima Roja	19,3 de	382 de	7,29 de	7,4 de	20 de	206 de	6,75 de	6,9 de
Engañador	25,5 b	437 b	7,76 b	8,2 b	19 b	247 b	6,94 b	7,4 b
P-219	17,6 cd	378 cd	7,28 cd	7,0 cd	16 cd	194 cd	6,67 cd	6,7 cd
P-1127	18,3 c	394 c	7,41 c	7,9 c	20 c	238 c	6,80 c	6,8 c
P-3047	17,9 c	390 c	7,54 c	7,5 c	17 c	224 c	7,04 c	7,1 c
Es_x	0,92	4,56	0,04	0,02	1,00	4,98	0,02	0,05

Means with the same letters are not significantly different for p<0,05

Some authors stated drought sensitivity rate (ISS) can be considered an acceptable criterion to discriminate varieties (14) under water stress conditions. However, other characteristics should be taken into account, since varieties with higher drought tolerance (lower ISS) are not necessarily more productive under such conditions, but they are the least yield reducers when transferring from irrigation to drought conditions.

Other authors noted that while ISS is an acceptable criterion to select varieties that less reduce yield under water stress conditions, they are not necessarily the highest yielding ones (14).

Based on the authors' criteria above mentioned, it is observed that varietal response was different in every index evaluated (Table IV).

Observe how yield losses (PR), tolerance (TOL) and drought sensitivity index (ISS) reached the lowest values in CC-25-9R, Delicias-364, Holguin-518 and INIFAT-8; hence, they turn out to be the most water stress tolerant varieties. Also, there is agreement on these four varieties, where MP, MPG, IER, IST, YI and YSI values are above the mean of all varieties, so confirming the results already described. On the contrary, the highest values of these indices were recorded in Tomeguin-93, Bonita-11, Cabriole, Pilon and P-3047 that are considered the most sensitive ones.

Relative yields measured in varieties under drought and favorable environments seem to be a common starting point to identify desirable varieties for environmental conditions with unpredictable rainfall (17).

Tolerance indices provide a drought measurement based on yield loss under drought conditions compared to normal conditions. Therefore, drought sensitivity of a variety is often the measure of yield reduction under drought stress conditions. According to several authors, such tolerance indices are important to evaluate varietal responses under stress vs non-stress conditions, as well as to know yield adaptation and stability (17).

Selection based on a combination of indices is a useful criterion for plant breeders to drought tolerance, but the study of correlation coefficients is also useful to find the global linear degree of association between any attribute (18).

Table IV. Selection indexes of water stress tolerant bean varieties

Varieties	Rr	Rs	PR (%)	PMG	PM	IER	ITS	YI	YSI	ISS	MH	TOL
Velasco Largo	1,67 b	1,31 b	21,56	1,48	1,49	1,5234	2,19	1,2710	0,78	1,0	1,47	0,36
CC-25-9R	2,15 a	1,92 a	10,70	2,03	2,04	2,8745	4,13	1,8628	0,89	0,50	2,03	0,23
CC-25-9N	1,24 d	0,93 cd	25,00	1,07	1,09	0,8030	1,15	0,9023	0,75	1,16	1,06	0,31
Tomeguín-93	1,21 d	0,69 e	42,98	0,91	0,95	0,5813	0,83	0,6694	0,57	1,99	0,88	0,52
Cabriole	1,04 e	0,63 e	39,42	0,81	0,84	0,4562	0,66	0,6112	0,61	1,83	0,78	0,41
Delicias-364	1,1 e	0,86 d	21,82	0,97	0,98	0,6587	0,95	0,8344	0,78	1,01	0,97	0,24
Holguín-518	1,75 ab	1,46 ab	16,57	1,60	1,61	1,7791	2,56	1,4165	0,83	0,77	1,59	0,29
Pilón	1,15 de	0,73 de	36,52	0,92	0,94	0,5845	0,84	0,7082	0,63	1,69	0,89	0,42
Bonita-11	1,12 de	0,64 de	42,86	0,85	0,88	0,4991	0,72	0,6209	0,57	1,99	0,81	0,48
INIFAT-8	1,33 cd	1,05 c	21,05	1,18	1,19	0,9724	1,40	1,0187	0,79	0,98	1,17	0,28
Lagrima Roja	1,27 d	0,89 d	29,92	1,06	1,08	0,7870	1,13	0,8635	0,70	1,39	1,05	0,38
Engañador	1,65 b	1,34 b	18,79	1,49	1,50	1,5391	2,21	1,3001	0,81	0,87	1,48	0,31
P-219	1,30 cd	0,91 cd	30,00	1,09	1,11	0,8237	1,18	0,8829	0,70	1,39	1,07	0,39
P-1127	1,46 c	1,10 c	24,66	1,27	1,28	1,1183	1,61	1,0672	0,75	1,14	1,25	0,36
P-3047	1,46 c	1,00 cd	31,51	1,21	1,23	1,0166	1,46	0,9702	0,68	1,46	1,19	0,46
Average	1,39	1,03	27,56	1,20	1,21	1,07	1,53	1,00	0,72	1,28	1,18	0,36
sEx	0,07	0,09										

Rr= Yield with irrigation (t ha^{-1}) Rs= Yield in drought (t ha^{-1}) PR(%)= Yield loss
PMG= Mean geometric productivity PM= Mean productivity IER= Relative efficiency index
ITS= Drought tolerance index YI= Yield index YSI= Yield stability index
ISS= Drought sensitivity index MH= Harmonic mean Tol= Tolerance
Means with the same letters do not differ significantly according to Tukey multiple range test for p<0,05

Other authors explained that among tolerance indicators, the highest TOL and ISS values relatively represent more drought sensitivity, whereas the smallest TOL and ISS values are favorable (19). In addition, they added that varieties with a lower ISS value than the unit are drought tolerant. A selection based on these two criteria favors varieties with low yield under non-stress conditions and high yield under stress conditions (20).

CONCLUSIONS

- ♦ Yield is markedly influenced by soil moisture level and CC-25-9R showed the best varietal response under such conditions, with yields of 2,15 and 1,92 t ha^{-1}, respectively.
- ♦ CC-25-9R showed a higher water stress tolerance, whereas Tomeguin-93 was the most susceptible one.
- ♦ All selection indices used enable to characterize varietal behavior under different soil moisture conditions.

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