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DROUGHT RESPONSE OF ONION (*Allium cepa* L.) VARIETIES USING DIFFERENT SELECTION INDEXES

Respuesta a la sequía de variedades de cebolla (*Allium cepa* L.) utilizando diferentes índices de selección

Wilfredo Estrada Prado✉, Elio Lescay Batista, Alexander Álvarez Fonseca and Yariuska C. Maceo Ramos

ABSTRACT. The water deficit tolerance of five onion varieties was evaluated in an experiment carried out between the years 2009-2010 at "Jorge Dimitrov" Agricultural Research Institute, Bayamo municipality, Granma province, Cuba. Three soil moisture levels were evaluated: 100, 75 and 50 %. 15 treatments were used, distributed in a completely randomized design and 30 plants were selected at random from each treatment where indexes were evaluated: Yield losses (YL), geometrical mean productivity (GMP), mean productivity (MP), relative efficiency index (REI), drought tolerant index (DTI), stability yield index (SYI), susceptibility drought index (SDI), harmonic mean (HM) and tolerance (TOL). The results showed that the soil water deficits evaluated have a significative ($p \leq 0,05$), where Grano-2000 F_1 showed the most tolerant water deficit variety, while H-222 was the most susceptible variety. All the drought indexes evaluated have a high contribution on the total phenotypic variability.

Key words: *Allium cepa*, drought susceptibility, drought tolerant, varieties

RESUMEN. Se evaluó la tolerancia al déficit hídrico de cinco variedades de cebolla en un experimento que se desarrolló en el período 2009-2010 en el Instituto de Investigaciones Agropecuarias "Jorge Dimitrov", municipio Bayamo, provincia Granma, Cuba. Se evaluaron tres niveles de humedad en el suelo (100, 75 y 50 %). Se emplearon 15 tratamientos, distribuidos en un diseño completamente aleatorizado y se seleccionaron 30 plantas al azar en cada tratamiento donde se evaluaron los 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 los déficit de humedad evaluados, influyeron significativamente ($p \leq 0,05$), donde la variedad Grano-2000 F_1 mostró mayor tolerancia al déficit hídrico mientras que la variedad H-222 fue la más susceptible. Todos los índices evaluados tuvieron una alta contribución a la variabilidad total.

Palabras clave: *Allium cepa*, susceptibilidad a la sequía, tolerancia a la sequía, variedades

INTRODUCTION

Climate change is a progressive and increasingly latent threat to food production, especially in less developed regions. These threats are frequent and severe droughts and floods that favor the emergence of new pests and diseases and the increasing of existing ones (1).

Drought stress is abiotic factor affecting a greater extent the global crop production and consequently food. Drought tolerance in plants is a complex process involving morphological and anatomical differences that contribute to the adaptation of the plant to restricted moisture conditions (2).

In traditional agriculture, in the Eastern region of Cuba, the main problem is variations in the quantity and distribution of rainfall which causes a drought period that affects crop production and sustainability (3).

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

✉ estrada@dimitrov.cu

A decent proposal to mitigate the effects of Climate change and reduce water consumption in agriculture is the generation of varieties that make efficient use of water (UEA) (4).

The use of adapted varieties with a certain degree of tolerance to water deficit conditions and the improvement of water management technologies, are important alternatives to minimize the effects of lack of water in the soil.[A]

Onion (*Allium cepa* L.) belongs to the Liliacea family, is one of the most known vegetables in the world since ancient times, not to be missed in meals and of a high value for its nutritive and medicinal properties. The bulb is consumed fresh and also the aereal part (leaves) as greening onion. It is also industrialized as preserve in brine and it is dehydrated for soups or powder (onion salt) (5).

Water restrictions during the filling of the bulb probably cause low yields. Additionally, the lack of water usually causes advanced crop cycles that in this case could be beneficial. A moderate water restriction in onion growing would bring forward the start of bulb formation. However, yields go down when water deficit coincide with the "critical period" at the start of bulb formation (6).

For all the above, a trial was done to evaluate the response of five onion varieties (*Allium cepa* L.) under different conditions of soil moisture using different selection indexes.

MATERIALS AND METHODS

The trial was done during the 2009-2010 season at the "Jorge Dimitrov" Agricultural Research Institute, Bayamo municipality, Granma province, Cuba. Commercial onion (*Allium cepa* L.) seeds of the varieties Caribe-71, H–222, Texas, Sivan and Grano–2000 F[B] were used. The transplanting method was practiced. For seedling production, the seedbed was made in October 2009, on 10 m long by 1 m width beds using a substrate made up of the tillable layer of a little-differentiated Fluvisol soil (7) with the addition of decomposed ovine manure at a rate of 3:1 with the physical and chemical characteristics shown in Table I

.

Seeds were sown in small rows perpendicular to the length of the beds, at a distance of 15 cm between them and at a depth of 1,5 cm. Seven days postgermination, plantlets were thinned out to avoid grouping and weakening for the transplant. Seedlings were transplanted when they had between 45 and 50 days with a height of 16 to 18 cm, a root length of 9 cm and a diameter of the false stem from 5 to 6 mm. Cultural attentions were carried out during this stage were implemented as set out in the instructional coach culture[C].

The trial was conducted in pots under semicontrolled conditions. A greenhouse with transparent polyethilene was used to avoid the effect of rains and dew. Pots were plastic containers of 6 liters, diameter above 21,5 cm, base diameter of 15 cm and a height of 21,5 cm. Each pot contained the compound substrate as explained before. Three substrate moisture levels were used consisted in: N_1: Moisture atl 100 % field capacity, N_2: Moisture at 75 % field capacity and N_3: Moisture at 50 % field capacity.

[A] García, A. *Efectos fisiológicos del déficit hídrico inducido en fases tempranas del crecimiento de plantas de arroz (Oryza sativa L.) y su aplicación en la selección de variedades tolerantes* [Tesis de Doctorado], Instituto Nacional de Ciencias Agrícolas, Mayabeque, Cuba, 2009, p. 124.

[B] MINAG. *Listado oficial de variedades comerciales*, Centro nacional de sanidad vegetal. Registro de variedades comerciales Subdirección de Certificación de Semillas, La Habana, Cuba, 2014, p. 42.

[C] Dirección Nacional de Cultivos Varios. *Instructivo técnico del cultivo de la cebolla*, Ministerio de la Agricultura, La Habana, Cuba, 1983, p. 60.

Table I. Physical and chemical analysis of the soil

Results of the chemical analysis									
Soil	Depth (cm)	P_2O_5 (mg 100 gr)	K_2O (mg 100 gr)	pH KCl	pH H_2O	M O (%)	K^+ (cmol kg^{-1})	Ca^{2+} (cmol kg^{-1})	Mg^{2+} (cmol kg^{-1})
Little-differentiated Fluvisol	0-20	25,65	58,81	6,3	7,0	2,51	0,45	9,0	3,9

Results of the physical analysis										
Soil	Depth (cm)	ECmm	LSP %	LIP %	Percent of air humidity	Specific weight (G cm^3)	Gross sand (Texture %)	Fine sand (Texture %)	Lime (Texture %)	Clay (Texture %)
Fluvisol	0-20	144	86,3	28,7	5,4	2,73	0,48	35,8	32,28	31,4

EC = Capilar elevation; LSP= Superior plasticity limit; LIP= Inferior plasticity limit

Pots were weighed every three days on a technical scale, and the moisture levels of each treatment were controlled by the gravimetric method. Treatments were formed by the combination of each of the varieties under study with different moisture levels. In each of them 10 posts with three plants each were used, for a total of 30 plants per treatment. A complete randomized design was used.

Data were processed by the software package STATISTICA. The determination of yield responses and some of its components at different soil moisture levels was also made and in addition, a bifactorial analysis of variance using varieties and soil moisture levels was practiced. The multiple comparison of the means was done through Tukey's test for p≤0,05.

In order to determine the susceptibility and tolerance of varieties to water deficit, 30 repetitions per treatment were used (Table II), yield losses of the varieties at 75 and 50 % soil moisture levels were calculated by the formula PR= 1-(Rs/Rr) x 100 (8,9).

Table II. Tolerance indexes used

Tolerance indexes	Formulate
Drough susceptibility index	ISS= [1-(Rsi/Ryi)] / ITS
Geometrical mean 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	IY= Rsi/Rs
Stability yield index	IEY= Rsi / Ryi
Relative efficiency index	IER= (Rsi /Rs)/Ryi/Ry)

Rsi: Medium yield of the varieties under stress conditions
Ryi: Medium yield of all varieties under irrigation conditions
Rs: Crop yield under stress conditions
Ry: Crop yield under irrigation conditions

Moreover, a biplot analysis was done to determine the interaction between studied varieties and the moisture levels and varieties between the studied tolerance indexes.

RESULTS AND DISCUSSION

Selection of onion varieties tolerant to water deficit

Based on the statements of some authors, the evaluated indexes and the response of the varieties were different (Table III and IV).

Look how yield losses (PR), Tolerance (TOL) and susceptibility index to drought (ISS) reached lower values in the varieties Grano-2000 F_1, Sivan and Texas, so these are the most tolerant varieties to water deficit.

There is also coincidence in the fact that these varieties have MP, MPG, IER, ITS, IY and IEY values above the mean which confirm the already described results. On the contrary, the highest values of these indexes were recorded in the varieties H-222 and Caribe-71, so they are considered the most susceptible varieties.

It can also be observed that both at 75 and 50 % of moisture, the behavior of the varieties was similar; however, the index value was higher at 50 %, which indicates that as moisture goes down, the susceptibility of the varieties to the stress is increased.

According to some authors, depending on the duration of the drought and its magnitude, this can cause yield losses of 20 to 100 % (10)

According to some authors, the susceptibility index to drought (ISS) can be considered acceptable to discriminate varieties (9) under water stress conditions. Nevertheless, other characteristics should be taken into account, since it could happen that varieties with the highest tolerance to drought (lower ISS), not necessarily be the most productive ones under drought conditions, but for sure, they reduce yield less by passing from irrigation to drought. Other authors pointed out that although ISS is an acceptable criterion to select varieties that reduce yield less under water stress conditions, not necessarily they will show the highest yield (9).

Other authors as well, have said that in this type of trials, it is necessary the combined use of at least one index of each group, and thus combine the high yield potential with drought tolerance since each group of indexes evaluate different biological phenomena (tolerance vs adaptation and productivity) (11).

Tolerance indexes are based on the yield loss under drought conditions compared to normal conditions, for that reason, the drought susceptibility of a variety is given by the yield reduction for drought stress. These indexes are important in the evaluation of responses to varieties under stress and without stress conditions, as well as for knowing adaptation and yield stability (12).

Among tolerance indicators, higher TOL and ISS values, relatively represents more susceptibility to drought, while lower TOL and ISS values are favorable. They also added that varieties with an ISS lower to the unit are drought tolerant. The selection based on two criteria favor low-yielding varieties under no stress conditions, and high-yielding varieties under stress conditions (13).

Table III. Selection indexes of onion varieties tolerant for 75 % of soil moisture

Varieties	Rr (100 %)	Rs (75%)	PR (%)	PMG	PM	IER	ITS	IY	IEY	ISS	MH	TOL
Caribe-71	136,3 ab	75,9 c	44,3	101,71	106,10	0,78	0,50	0,82	0,55	1,22	97,50	60,4
H-222	133,3 b	72,0 c	46,0	97,97	102,65	0,72	0,46	0,78	0,54	1,26	93,49	61,3
Texas	147,6 ab	91,2 b	38,2	116,02	119,40	1,02	0,65	0,99	0,61	1,05	112,73	56,4
Sivan	149,3 ab	99,4 b	33,4	121,82	124,35	1,12	0,72	1,08	0,66	0,92	119,34	49,9
Grano-2000 $_{F1}$	153,2 a	119,3 a	22,1	135,19	136,25	1,38	0,88	1,30	0,77	0,61	134,14	33,9
Average	143,94	91,56	36,4	114,54	117,75	1,00	0,64	0,99	0,63	1,01	111,44	52,38
Esx	0,01	0,05										

Rr= Yield with irrigation (g.plants^{-1}); Rs= Yield under drought conditions (g.plants^{-1}); PR (%) =Yield loss; PMG= Mean geometrical productivity; PM= Mean productivity; IER= Relative efficiency index; ITS= Drought tolerance index; YI= Yield index; IEY= Yield stability index; ISS= Drought susceptibility index; MH= Harmonic mean; Tol= Tolerance
Means with equal letters do not significatively differ according to Tukey's multiple range test for p≤0,05

Table IV. Selection indexes of onion varieties tolerant for 50 % of soil moisture

Varieties	Rr (100 %)	Rs (50 %)	PR (%)	PMG	PM	IER	ITS	IY	IEY	ISS	MH	TOL
Caribe-71	136,3 ab	55,2 c	59,5	86,74	95,75	0,69	0,44	0,72	0,40	1,64	78,57	81,1
H-222	133,3 b	50,1 c	62,4	81,72	91,70	0,61	0,39	0,66	0,37	1,72	72,82	83,2
Texas	147,6 ab	77,3 b	47,6	106,82	112,45	1,04	0,67	1,02	0,52	1,31	101,46	70,3
Sivan	149,3 ab	87,8b	41,2	114,49	118,55	1,20	0,77	1,16	0,58	1,13	110,57	61,5
Grano-2000 $_{F1}$	153,2 a	107,7a	29,7	128,45	130,45	1,51	0,96	1,42	0,70	0,82	126,48	45,5
Average	143,94	75,62	48,08	103,64	109,78	1,01	0,64	0,99	0,51	1,32	97,98	68,32
Esx	0,01	0,09										

Rr= Yield with irrigation (g.plants^{-1}); Rs= Yield under drought conditions (g.plants^{-1}); PR (%) =Yield loss; PMG= Mean geometrical productivity; PM= Mean productivity; IER= Relative efficiency index; ITS= Drought tolerance index; YI= Yield index; IEY= Yield stability index; ISS= Drought susceptibility index; MH= Harmonic mean; Tol= Tolerance
Means with equal letters do not significatively differ according to Tukey's multiple range test for p≤0,05

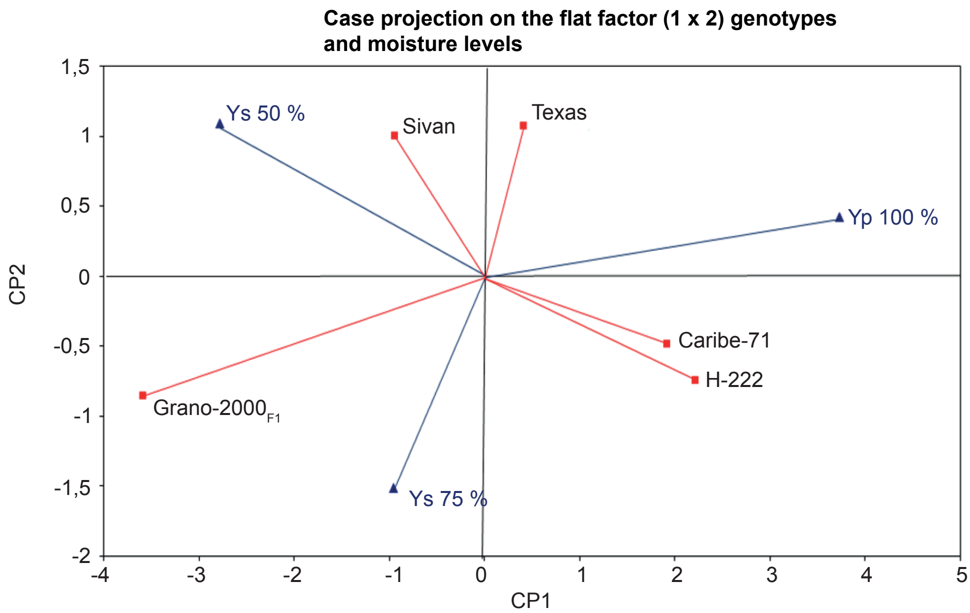

Figure 1. Biplot of the coordinates of the main components of the five varieties based on the yield of the five varieties and three level of moisture

A "biplot" graphic (Figure 1) was used to complete the study; it shows a medium yield according to the coordinates CP1 of varieties and moisture levels. The varieties with the highest contribution in the interaction variety/moisture levels was the treatment at 100 % of moisture in varieties like Grano-2000 $_{F1}$, Sivan and Texas, with a yield compared to the general mean of (143.94 g/plant^{-1}) respectively, while the varieties with the lowest contribution were Caribe-71 and H-222 with a treatment slightly lower than the general mean, respectively. As to moisture levels, the ones with the highest contribution were 100 % and 75 % of soil moisture, respectively.

The "biplot" graphic shows information on the main genotypic effects, moisture levels and their interaction simultaneously. The variety Grano-2000 $_{F1}$ showed the best values, reaching the first place in all moisture levels evaluated, while variety H-222 occupied the last place in all studied levels. Consequently, varieties and moisture levels CP1 of the same sign interact positively and their grouping in the same quadrant indicates a positive association.

As to moisture levels, varieties Grano-2000 $_{F1}$, Sivan and Texas positively interact and associate with 100 and 75 % of soil moisture; varieties Caribe-71 and H-222 did not show a positive association and interaction pattern with the above-mentioned levels since closer varieties to the origin are the most stable and as they get farther of it, their response is more variable (9).

These results show similarity with experiments done by several authors who confirm not to base selection in only criterion, being recommendable to group varieties of similar potential yield and select those whose yields show better reduction under rain-fed conditions using the yield geometrical mean as support (9).

Among the tolerance indexes to water deficit, PM, PMG and TOL, are known as the most convenient and the best indexes. Because these indexes always choose varieties whose average yield is always high. In this study, according to PM, PMG and the index of TOL, Grano- 2000 $_{F1}$ was the most tolerant variety to water deficit 75 % and 50 %, while the variety H-222 was the most sensitive under both conditions. According to the "biplot" analysis (Figures 2 and 3) this distribution means that the comparison of this analysis and the indexes distribution with the varieties Caribe-71 and H-222 characterized for having a positive and strong relation with yield loss, they were more sensitive to water deficit and therefore less tolerant. On the other hand, Grano-2000 $_{F1}$,Sivan and Texas characterized for having higher yields under water deficit conditions, with strong and positive values of PMG, PM, IER, ITS, IY and IEY, above the mean of all varieties and therefore the most tolerant to water deficit, so it is confirmed that such indexes are based on the production per variety under two moisture conditions (14).

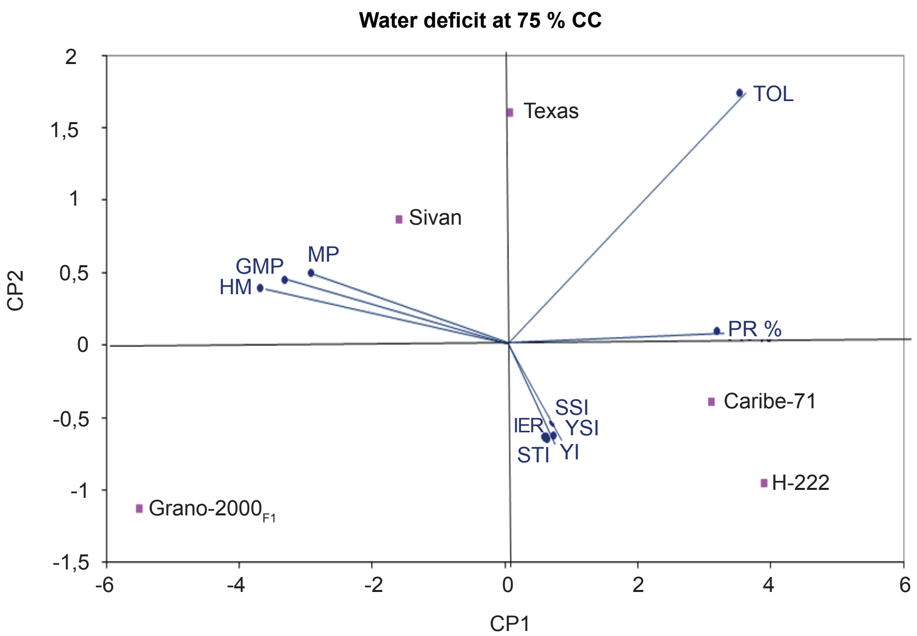

Figure 2. Biplot of the coordinates of the main components of the five varieties and the tolerance indexes

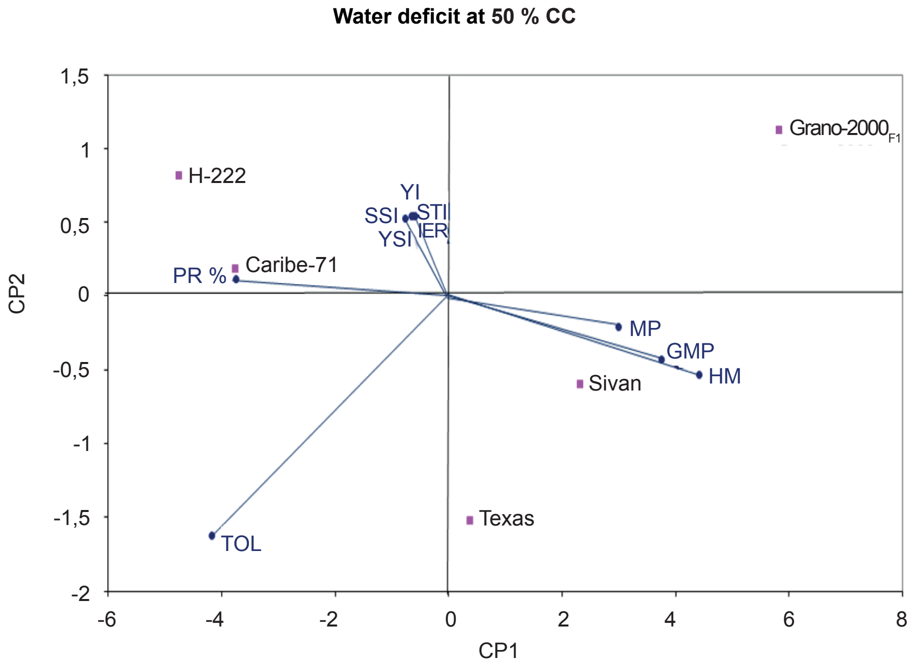

Figure 3. Biplot of the coordinates of the main components of the five varieties and the tolerance indexes.

Selection based on a combination of indices is a useful criterion for plant breeders regarding drought tolerance, but the study of correlation coefficients is also useful to find the linear overall degree of association between any attribute (14).

The effectiveness of selection indexes by differentiating tolerant crops with the severity of the stress was calculated. The convenience of indicators seems to depend on the election at the right time and the severity of the stress (14, 15).

CONCLUSIONS

- Yield received a marked influence by the soil moisture level and the variety Grano-2000 F1 showed the best response under such conditions, with yields of 153,2; 119,3 and 107,7 g.plant-1 respectively.
- The variety Grano-2000 F1 showed a higher tolerance to water deficit while the H-222 was the most susceptible.
- The selection indexes used allow to characterize the behavior of these varieties under different soil moisture conditions, though the combined use of at least one index of each group is recommended to thus combine the high yield potential with the drought tolerance.

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