THE IRANIAN SUGARCANE SELECTION PROGRAM: AN OVERVIEW OF METHODOLOGIES

By

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Abstract

The main sources of genetic variation, G × E interaction, response to selection and heritability values were studied in order to establish methodological bases for the selection in initial stages of the Iranian sugarcane breeding program. A representative sample of 10 bi-parental combinations was evaluated in six environments. The component of variance attributable to environment was prevailing and the genotype-environment interaction was significant. Three types of environment were defined and differences between them contributed to selection efficiency. The greatest genetic variability was obtained in the northern region of Khuzestan, and the best results for selection were registered in Imam Khomeini sugar factory's locality.

Introduction

It is estimated that the consumption of sugar in the Islamic Republic of Iran is around 30 kg *per capita* with a total demand of 2 million tonnes of refined sugar annually for direct and indirect use. Iran produces 1 300 000 tonnes of sugar, and imports the remainder.

Sugarcane cultivation has increased in the south of Iran and in Khuzestan province, and Iran aims to be self-sufficient in sugar and develop various by-products. In fact, the Sugarcane and By-Products Development Corporation has been created to produce sugar, animal food, paper, particle boards, pulp paper and other by-products.

This has motivated special interest in the adoption of modern technologies and improved cultivars. Therefore, the National Breeding Program is working under special climatic conditions in Khuzestan to grow sugarcane, with different environmental stress conditions (drought, salinity and freeze). The main commercial varieties are CP48-103, CP57-614, CP69-1062 and NCo310.

The particular growing conditions enabled a study of genotype-environment interaction, its sources of variation and genetic parameters that allow breeders to establish methodologies and bases for the Breeding and Selection of sugarcane in Iran and here we present a summary of the results.

Materials and methods

The experiments were planted between September 2003 and March 2007, in three locations of the Sugarcane Research Center, belonging to *Sugarcane and By-Products Development Corporation* in Khuzestan province.

Progenies of 10 bi-parental combinations of representative commercial varieties of different geographical origin were evaluated in a randomised block design. Each combination had a

population of 60 seedlings and the evaluations were carried out in plant cane and first ratoon at 10 and 12 months respectively. Data were taken for plant height, stem diameter, number of stems and brix, following procedures described by Jorge *et al*. (2002) and Hamdi *et al.* (2003).

Analysis of variance of double classification (clones × locality) was performed to identify the sources of genotype × environment interaction (G × E) using a factorial model (Cochran and Cox, 1965).

The model of simple classification of randomised effect balanced proposed by Kempthorne (1952) was used to estimate the statistical genetic parameters for each of the localities. Heritability estimates in narrow sense (h^2_e) were calculated from the components of variance (Hogarth, 1968; Milligan *et al.,* 1990).

The approximate standard error was obtained according to Anderson and Bancroft (1952) and Becker (1984) and the genetic coefficient of variation (CGV) according to Falconer (1970). To compare the selection efficiency between localities and characters, the response to selection (R) was utilised and a selection index (ΔG) of 40% of the population selected was utilised (Falconer, 1970; Cesnik and Vencovsky, 1974).

Results and discussion

The analysis of variance shows significant differences (p = 0.05) in the G × E interaction in most of the evaluated characters, but not for brix in plant cane and number of stems in first ratoon. This can affect selection efficiency, reaffirming the importance of replication in time and space (Table 1).

Drought stress under these cultivation conditions, with water deficiency combined with high temperatures, might be the reason for the high values presented here. The heritability values estimated in first ratoon confirm the previous results for stem height and field brix as major trends. The genetic coefficient of variation (CVG) had very similar behaviour.

Localities presented the most important source of variation in plant cane and first ratoon for stem height. On the other hand, stem diameter was the character with no location effects. For the remaining characters, experimental error proved to be the main source of variation.

The heritability values and their consistency calculated for each locality were very low for the different environments for cane yield, and the rest of the components of cane yield (Table 2). These results do not agree with Garcia (2004) for conditions of drought stress in Cuba, who found genetic variability for diameter.

Other statistical genetic parameters evaluated were genetic variance (σ^2_g), genetic coefficient of variation (GCV), response to selection and selection gain, but heritability values might be the best criteria for selection for cane yield in seedling stage in Iran, using stem height and stem diameter. Sugar content might be useful for selection in first ratoon.

Selection efficiency is evaluated using the balance between genetic components and phenotypic expression. The best results of selection were expected at Imam Khomeini in plant cane for three of the four characters (stem diameter, stem height and number of stems).

In terms of the G × E interactions and the main statistical genetic parameters, three types of environments in Khuzestan were confirmed to contribute to selection efficiency, relating to the types of soil and environmental conditions. Environments in the northern Province show great variability where selection in seedling stage will provide better results. A climatic zones classification confirmed differences between Imam Khomeini and Mian Abb localities. The first one shows better efficiency. The southern environment (Amir Kabir) did not show major differences in genetic statistical parameters.

These results show the importance of adopting strategies for selection in the seedling stage, but not assign major importance to evaluation in ratoon, applying low to moderate selection intensity to allow selection of a high proportion of individuals from the population.

Table 1—Variance components and genetic parameters**.**

Variance components	Plant cane					First ratoon				
	σ^2		SE		PTV	σ^2		SE		PTV
	Stem height									
σ^2g	73.19	±	49.45		2.2	230.87	±	113.52	**	6.3
σ^2l	4923.08	±	3489.96		75.2	2873.78	±	2039.57		50.7
σ^2gxl	96.57	±	37.39	**	1.5	79.54	±	33.55	**	1.7
σ^2e	936.61	±	23.45	**	21.0	1592.85	±	37.84	**	41.3
EV	5859.70				96.23	4466.63				92.00
Average	160.03					185.77				
he^2	0.33	±	0.22			0.44	±	0.21	**	
GCV (%)	5.35					8.18				
	Stem diameter									
σ^2g	0.01	±	0.05		2.9	0.03	±	0.07		8.7
σ^2l	0.00	±	0.02		0.0	0.02	±	0.04		2.6
σ^2gxl	0.01	±	0.01		2.1	0.38	±	0.13	**	14.6
σ^2e	0.57	±	0.01	**	95.0	1.22	±	0.03	**	74.1
EV	0.57				95.0	1.25				76.6
Average	2.20					2.39				
he^2	0.02	±	0.08			0.08	±	0.21		
GCV (%)	5.03					6.73				
	Number of stems									
σ^2g	1.45	±	0.83		3.1	4.53	±	2.23	**	3.7
σ^2l	19.61	±	13.97		24.4	17.99	±	12.88		9.5
σ^2gxl	0.58	±	0.41		1.3	0.27	±	0.68		1.0
σ^2e	39.01	±	0.98	**	71.2	112.56	±	2.68	**	85.9
EV	58.63				95.6	130.55				95.3
Average	15.33					17.90				
he^2	0.39	±	0.22			0.43	±	0.21	**	
GCV (%)	7.85					11.89				
	Field brix									
σ2g	1.88	±	1.08		2.8	1.85	±	0.83	**	12.3
σ2l	18.40	±	13.13		16.0	5.07	±	3.61		23.9
σ2gxl	0.53	±	0.53		1.2	0.12	±	0.09		1.2
σ2e	62.80	±	1.57	**	80.0	9.10	±	0.22	**	62.7
EV	81.20				96.0	14.17				86.5
Average	14.94				1.2	15.91				
he^2	0.38	±	0.21			0.47	±	0.20	**	
GCV (%)	9.17					8.55				

σ^2. Component of variance g. genotype l. locality gxl. genotype x locality interaction e. experimental error EV. Environments variance SE. Standard error PTV. Percent of total variance **. Precise Estimate ($\leq 2\sigma^2$) he^2 heritability GCV. Genetic Coefficient of Variation

Table 2—Variance components and genetic parameter for locality.

Locality		Stem height				Stem diameter			
Amir Kabir	σ^2_G	337.27	±	14.95	(28,8)	0.02	±	0.00	(12.7)
	σ^2_E	835.28	±	34.33	(71,2)	0.14	±	0.01	(87.3)
	CVG	10.14				6.37			
	h_e^2	0.58	±	0.03		0.25	±	0.01	
	R	19.37				0.10			
	ΔG	0.57				0.24			
Imam Khomeini	σ^2_G	445.96	±	19.70	(30,7)	0.02	±	0.00	(11.3)
	σ^2_E	1007.19	±	41.40	(69,3)	0.19	±	0.01	(88.7)
	CVG	15.70				6.92			
	h_e^2	0.61	±	0.03		0.23	±	0.01	
	R	45.85				0.09			
	ΔG	1.22				0.20			
Mian Abb	σ^2_G	147.95	±	8.39	(4.8)	1.16	±	0.05	(25,8)
	σ^2_E	2936.08	±	120.67	(95.2)	3.34	±	0.14	(74,2)
	CVG	5.03				40.22			
	h_e^2	0.10	±	0.01		0.52	±	0.02	
	R	1.98				0.18			
	ΔG	0.04				0.42			
		Number of ítems				Refractometric brix			
Amir Kabir	σ^2_G	5.47	±	0.29	(5.9)	2.28	±	0.10	(21,8)
	σ^2_E	86.91	±	3.57	(94.1)	8.20	±	0.34	(78,2)
	CVG	12.15				9.20			
	h_e^2	0.12	±	0.01		0.44	±	0.02	
	R	0.47				1.21			
	ΔG	0.05				0.38			
Imam Khomeini	σ^2_G	4.42	±	0.23	(7.3)	1.81	±	0.08	(19,3)
	σ^2_E	55.90	±	2.31	(92.7)	7.55	±	0.31	(80,7)
	CVG	16.05				7.53			
	h_e^2	0.15	±	0.01		0.39	±	0.02	
	R	2.46				0.67			
	ΔG	0.32				0.22			
Mian Abb	σ^2_G	4.60	±	0.34	(2.3)	1.82	±	0.09	(13,6)
	σ^2_E	194.47	±	8.01	(97.7)	11.57	±	0.48	(86,4)
	CVG	10.06				10.05			
	h_e^2	0.05	±	0.00		0.27	±	0.01	
	R	0.51				1.37			
	ΔG	0.04				0.38			

σ^2_G. Genetic variance σ^2_E. Error variance CVG. Genetic coefficient of variation. h_e^2. heritability R. Response to the selection ΔG. Profit for selection

Conclusion

1. A suitable strategy for the selection will be to conduct it in ratoon with low to moderate intensity and using the length of stalk and refractometric brix as the principal criteria.
2. The environmental effect proved to be the most important source of variation (76-96% of the total phenotypic variation) with a reduction in ratoon.
3. Three types of environments were identified, according to the soil classification, and these contribute to the differences in the efficiency of the selection. Imam Khomeini is the most effective locality for selection.
4. The need to enlarge the genetic base used was ratified for breeding purposes.

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LE PROGRAMME DE SÉLECTION DE CANNE À SUCRE IRANIEN: UNE VUE DE L'ENSEMBLE DES MÉTHODOLOGIES

Par

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MOTS-CLÉS: Programme de Sélection,
Interaction Génotype-Environnement.

Résumé

LES SOURCES principales de la variation génétique, l'interaction G × E, la réponse à la sélection et les valeurs d'héritabilité ont été étudiées afin d'établir la méthodologie de base pour la sélection au stade préliminaire du programme d'amélioration génétique de la canne à sucre iranien. Un échantillon représentatif de 10 combinaisons bi-parentales ont été évaluées dans six environnements. La composante de variance imputable à l'environnement était prévalente et l'interaction génotype-environnement était significative. Trois types d'environnements ont été définis et les différences parmi eux relèvent de l'efficience de la sélection. La plus importante variabilité génétique a été observée dans les régions septentrionales du Khuzestan, et les meilleurs résultats pour la sélection ont été enregistrés dans la localité de la sucrerie de l'Imam Khomeini.

EL PROGRAMA DE SELECCIÓN IRANÍ DE CAÑA DE AZÚCAR: UNA VISIÓN GENERAL DE LAS METODOLOGÍAS

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PALABRAS CLAVES: Programa de Selección de Caña,
Interacción Genotipo-Ambiente.

Resumen

LAS PRINCIPALES fuentes de variación genética, la interacción G × A, la respuesta a selección y los valores de heredabiliad se estudiaron con miras a establecer las bases metodológicas para seleccionar en estados iniciales de selección dentro del Programa de Selección de Caña de Azúcar de Irán. Una muestra representativa de 10 combinaciones biparentales fue evaluada en seis ambientes diferentes. Los componentes de variación atribuidos al ambiente fueron los más notorios y la interacción G × A fue significativa. Tres tipos de ambientes fueron definidos y las diferencias entre ellos contribuyeron a la eficiencia de la selección. La mayor variabilidad genética se obtuvo en la región norte de Khuzestan y los mejores resultados de selección se registrados en la localidad de la empresa Imam Khomeini.