Genotype x environment interaction effects on the iron content of common bean grains

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ABSTRACT

Iron deficiency in the human organism is a serious public health problem throughout the world. In the human food, one of the main sources of this mineral element is legumes, among which the common beans are important. The objective of this experiment was to study the genotype x environment interaction effects on the grain bean iron content to estimate the adaptation and stability of common bean genotypes in three environments. The experiments were carried out in Londrina, Marechal Cândido Rondon and Iguatemi, in Paraná state, Brazil, from September to December 1998. Twenty-five common bean genotypes were assessed in randomized complete block designs with four replications. Nitroperchloric digestion was performed and the iron was quantified in ground bean grains, using an atomic absorption spectrophotometer. The genotypes Iapar-57 and Pérola are recommended for cropping based on the adaptation and stability results. They showed superior grain iron content, had wide adaptation (Bli = 1) and good predictability (σ^2di = 0).

KEY WORDS: Adaptability, iron, nutrition, plant breeding, seedling, stability.

INTRODUCTION

Iron deficiency in the human organism is a serious public health problem throughout the world, affecting approximately two billion people (Della Penna, 1999). Due to their substantial iron content, common bean grains play an important role among foods (Pennington and Young, 1990). Highly consumed by populations in Latin American and African countries, this type of bean is one of the main sources of protein, calorie and iron for these populations. It is also the main supplier of all the iron the human organism requires for its metabolism (Krista et al., 1991; CIAT, 1981) in African countries, such as Rwanda and Burundi. Thus, issues related to improving the nutritional quality of foods, such as the common bean, should be addressed by genetic plant breeding programs (Koehler and Burke, 1981).

The genotype x environment interaction for certain bean characteristics, such as yield, may hinder cultivar recommendation for large geographical areas. This experiment was carried out to study the genotype x environment interaction effect on the iron content of 25 common bean genotypes cultivated in three localities in order to estimate their adaptability and stability.

MATERIAL AND METHODS

The experiments were performed in the localities of Londrina, Marechal Cândido Rondon and Iguatemi, in the state of Paraná, Brazil, from September to December 1998. Twenty-five common bean plant genotypes, 11 commercial cultivars and 14 elite lines, cultivated in randomized complete block designs with four replications, were assessed. The experimental plot consisted of a single 1.50m row for each genotype, with 1.00 meter spacing between rows, and with 12 seeds sown per meter. For the area to be evaluated, the center meter was considered by subtracting 0.25m from each end. Sowing took place in the periods recommended for each locality. Weeds were controlled by hoeing, pests and diseases were controlled by chemical products recommended for the crop. Supplementary sprinkler irrigation was applied to the experimental area, increasing water availability by 12.5 mm per week, resulting from the sum of rain + irrigation by spraying.

After being harvested, the pods were hulled to obtain the grains which were placed separately (by plot) in a stove with forced air circulation (at 50º- 55ºC) and dried until constant weight was reached. The material was then ground in a rotating mill and sieved through a 1 mm mesh. Three 400 mg samples were weighed from each experimental plot, and nitroperchloric digestion was performed until the samples were lightened. Each sample was then diluted in distilled and deionized water up to a 100 mL. A representative aliquot was taken from this sample, and the iron present in the ground bean grains was quantified by an atomic absorption spectrophotometer (Malavolta et al., 1989)

The iron content data were submitted to a combined analysis of variance to study the effect of genotypes, localities and the genotype x locality interaction. Localities and year were considered random variables, while the genotypes were treated as a fixed varible. Genotype adaptability and stability were studied according to the Eberhart and Russel method (1966). This method uses the linear regression of individual means with the environment index defined by the mean of all the genotypes cultivated in these localities.

RESULTS AND DISCUSSION

The iron content mean for the grains collected in Londrina was lower than those collected in Marechal Cândido Rondon and Iguatemi which were higher and similar (Table 1). The bean with the highest iron content was the Iapar-65 cultivar, collected in Londrina, which can be considered the least favorable locality, while the Iapar-72 and the Rudá cultivar showed the greatest iron content in the studies carried out in the localities of Marechal Cândido Rondon and Iguatemi, respectively. The Iapar-72 and the Rudá cultivars also showed the greatest iron content in bean grains when the mean of the three localities was

Table 1. Iron concentration means in grains (mg/100g dry matter) from 25 common bean genotypes, cultivated in Marechal Cândido Rondon-PR, Londrina-PR e Iguatemi-PR, 1998.

Genotype	Marechal C. Rondon Mean[1]		Londrina Mean		Iguatemi Mean		Genotype mean
Akitã	7.03	ABC	2.74	AB	6.38	CDEFGHI	5.38
Aruã	6.24	ABC	2.57	AB	6.73	BCDEFGH	5.18
FT-Bonito	7.90	AB	3.25	AB	6.53	CDEFGHI	5.89
Iapar-14	5.77	BC	2.56	AB	6.33	DEFGHI	4.89
Iapar-31	6.42	ABC	2.80	AB	6.22	EFGHI	5.15
Iapar-57	7.25	ABC	2.94	AB	7.53	ABC	5.91
Iapar-65	6.99	ABC	3.59	A	6.45	CDEFGHI	5.68
Iapar-72	8.73	A	2.79	AB	7.27	BCDE	6.26
LP-93-2	7.05	ABC	2.56	AB	7.38	BCD	5.66
LP-9019	6.85	ABC	2.58	AB	6.90	BCDEFG	5.44
LP-9082	6.65	ABC	2.34	B	6.02	FGHI	5.00
LP-9122	6.89	ABC	2.98	AB	6.13	FGHI	5.33
LP-9123	6.17	BC	2.91	AB	5.82	GHI	4.97
LP-9315	5.49	C	2.58	AB	5.68	HI	4.58
LP(SPI)-9317	7.10	ABC	2.84	AB	5.56	I	5.17
LP-9329	6.55	ABC	3.08	AB	5.50	I	5.04
LP-9333	7.96	AB	2.75	AB	5.85	GHI	5.52
LP-9338	6.01	BC	2.84	AB	6.26	DEFGHI	5.04
LP-9381	6.43	ABC	2.63	AB	6.31	DEFGHI	5.12
LP-9382	5.61	BC	2.73	AB	6.12	FGHI	4.82
LP-9429	6.07	BC	2.67	AB	6.98	BCDEF	5.24
Pérola	6.58	ABC	3.18	AB	7.31	BCDE	5.69
PF9029984	6.86	ABC	2.45	B	7.50	AB	5.60
Pvatã	6.37	ABC	2.98	AB	7.72	AB	5.69
Rudá	6.16	BC	3.17	AB	8.75	A	6.03
Locality Mean	6.86		2.82		6.61		
CV%	13.33		11.24		6.34		
δg^2 (Means)	0.363		0.055		0.580		
H%	64.60		68.70		93.00		

In the columns, values followed by the same letter are considered equal by the Tukey Test, at the 5% level of probability.

considered. These iron content differences found in each cultivar, locality and among localities suggest the existence of a representative genotype x locality interaction.

The locality effect and the genotype x environment interaction were significant ($p < 0.05$). Thus, a careful analysis of the data and characterization of the cultivar response to the locality fluctuations is required (Table 2).

The genotype x locality interaction (linear) was significant, suggesting that variation in the environments is explained by the linear regression. The superiority of a genotype is clearly conditioned to the environment and to the genotype x environment interaction (G x E), which influences the selection of elite cultivars adapted to wider regions. The significant genotype x locality interaction (linear) revealed the existence of genetic differences among the 25 genotypes assessed in their linear behaviors in the localities studied. In other words, the linear regression coefficients (Bli) were not similar. Thus the linear regression coefficients were useful parameters for differentiating the adaptation of these genotypes to diverse environments (Table 3).

The linear regression coefficients varied from 0.78 to 1.25 , which shows little variation in the mean response of the cultivars to environment variations. Eberhart and Russel (1966) considered a cultivar stable when it showed a linear regression coefficient equal to the unit (Bli =1) and a deviation variance from the nil regression associated to a high phenotypic mean. According to this concept, a stable variable presents increasing responses as the same genotype. Therefore, the more favorable localities were Iguatemi and Marechal Cândido Rondon and the least favorable was Londrina, where the soil had been limed to correct soil acidity (Table 4).

Based on the linear regression coefficient of the iron content stability analysis, the diverse genotypes were grouped in:

a) with specific adaptability to favorable environments Bli>1: Iapar-72, LP93-2, LP90-19 and PF90-29984;

b) with wide adaptability Bli=1: cultivars which have average adaptability to diverse environment such as the Akitã, Aruã, FT Bonito, Iapar-14, Iapar-31, Iapar-57, LP90-82, LP91-22, LP91-23, LP93-15,

Table 2. Analysis of variance of genotypes, localities and genotype x localities, interactions, 1998. Data transformed to log N (x).

Source of variation	df[1/]	MS[2/]
Block/location	9	-
Genotypes	24	0.054169[ns]
Location	2	27.89312[3/]
Genotype/location	48	0.037545[3/]
Linear environment	1	55.786209[3/]
Genotype/ linear environment	24	0.034812[3/]
Pooled deviations	25	0.038669[3/]
Error	216	0.011503

[ns] indicates non-significance; [1/]Degrees of Freedom; [2/] Mean Squares; [3/] indicates significance at 1% level.

Table 3. Stability and adaptability parameters according to Eberhart and Russel (1966) method of iron content in 25 genotypes assessed in three environments in 1998.

Genotypes	B_{0i}	B_{1i}	σ^2di	σdi
Akitã	1.57	1.01	0.0001	0.01
Aruã	1.53	1.08	0.0002	-
FT Bonito	1.68	0.91	0.0114	0.11
Iapar-14	1.48	1.02	0.0007	0.03
Iapar-31	1.55	0.93	-0.0025	-
Iapar-57	1.66	1.08	-0.0018	-
Iapar-65	1.65	0.78	-0.0001	-
Iapar-72	1.69	1.21	0.0112	0.11
LP93-2	1.60	1.17	-0.0009	-
LP90-19	1.57	1.15	-0.0028	-
LP90-82	1.49	1.12	0.0005	0.02
LP91-22	1.58	0.90	0.0015	0.04
LP91-23	1.51	0.87	-0.0018	-
LP93-15	1.45	0.88	-0.0022	-
LP(SPI)92-17	1.54	0.90	0.0222	0.15
LP93-29	1.56	0.78	0.0055	0.07
LP93-33	1.58	1.05	0.0369	0.19
LP93-38	1.53	0.91	-0.0021	-
LP93-81	1.53	1.03	-0.0028	-
LP93-82	1.49	0.92	0.0004	0.02
LP94-29	1.55	1.02	0.0098	0.10
Pérola	1.64	0.94	0.0039	0.06
PF90-29984	1.57	1.25	0.0043	0.06
Pyatã	1.63	1.04	0.0158	0.13
Rudá	1.67	1.03	0.0629	0.25

B_{0i}: regression constant; B_{1i}: regression coefficient; s^2di: variance of the linear regression deviations; sdi: standard deviation of the deviation from the regression

LP(SPI)93-17, LP93-33, LP93-38, LP93-81, LP93-82, LP-9429, Pérola, Pyatã and Rudá.

c) with specific adaptability to unfavorable environments and with the linear regression coefficient statistically different from 1 and very close to 0. The Iapar-65 and LP93-29.

The regression analysis reflects the response or adaptation of a cultivar to various environments as well as its stability. Stability is the ability of cultivars to show highly predictable behavior due to environment stimuli. This stability is assessed by the variance attributed to the deviation of the regression (s^2d) (Cruz and Regazzi, 1997). The genotypes are typified with high stability or predictability when their variance from the deviations are equal to zero; while the genotypes with low parameters are those with variance from deviations lower than zero. Genotype stability was on the whole high, with variance from the deviations statistically equal to zero. The genotypes with low stability ($s^2di=0$) were: FT Bonito, Iapar-72, LP(SPI)93-17, LP93-33, LP94-29, Pyatã and Rudá.

The stability and adaptability results (Table 3) show that the Iapar-57 and the Pérola genotypes are recommendable due to their greatest iron content, wide adaptability (Bli=1) and high predictability ($s^2di=0$). Other promising cultivars are the FT Bonito, Rudá and Pyatã beans because they presented superior means (Bli=1), however, they had the disadvantage of showing low behavior predictability. Nevertheless, these cultivars should not be considered totally undesirable, once their determination coefficients (R^2) reached levels over 90%, indicating that the linear regression may explain the variation in the responses found in the studied environment.

CONCLUSIONS

The Iapar-57 and the Pérola genotypes are recommendable due to their greatest iron content, wide adaptability (Bli=1) and high predictability ($s^2di=0$).

Other promising cultivars are the FT Bonito, Rudá and Pyatã beans which presented superior means (Bli=1); however, they had the disadvantage of showing low behavior predictability.

Results from this study indicate the possibility of obtaining more adaptable, stable and iron rich cultivars through genetic improvement methods.

ACKOWLEDGEMENT

We are grateful to Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and Conselho Nacional de Desenvolvimento Cientifico e Tecnológico (CNPq) for financial support.

RESUMO

Efeitos da interação genótipo-ambiente sobre o teor de ferro em grãos de feijão

A deficiência de ferro no organismo humano constitui-se num sério problema de saúde pública mundial, atingindo aproximadamente dois bilhões de pessoas. Na alimentação humana entre as principais fontes desse mineral estão os legumes, especialmente os feijões. O objetivo deste experimento foi o estudar a interação genótipo x ambiente, visando-se estimar a adaptabilidade e estabilidade de 25 genótipos de feijoeiro em relação ao teor de ferro em grãos de feijão. Os experimentos foram conduzidos em Londrina, Marechal Cândido Rondon e Iguatemi, no estado do Paraná, Brasil. O delineamento experimental foi o de blocos ao acaso com quatro repetições. Procedeu-se a digestão nitro-perclórica e para a quantificação de ferro foi empregada a espectrofotometria de absorção atômica. Os genótipos Iapar-57 e Pérola foram recomendados para o melhoramento baseado nos

Table 4. Soil analysis in Londrina (PR), Marechal Cândido Rondon(MCR) (PR) and Iguatemi (PR), 1998.

Localities	pH $CaCl_2$	Al^{+3}	M.O g/dm^3	Ca^{+2} cmol/dm^3	Mg^{+2} cmol/dm^3	K^+ cmol/dm^3	P^+ mg/dm^3	Mn mg/dm^3	Fe mg/dm^3
Londrina	6.3	0.00	25.55	7.65	2.50	0.64	19.24	282.1	83.5
MCR	5.7	0.00	21.62	6.32	2.24	0.49	17.62	370.6	157.7
Iguatemi	5.0	0.30	22.86	3.92	1.19	0.82	5.68	311.3	104.9

Extractors: Mn, Fe (Mehlich); Ca^{+2}, Mg^{+2}, Al^{+3} (KCl 1N) and P, K, SO^2_4

resultados de adaptabilidade e estabilidade. Estes apresentaram teor es superior de ferro em seus grãos boa adaptabilidade (Bli = 1) e boa estabilidade (s^2di = 0), pelo método de Eberhart e Russel.

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Received: December 17, 2002;

Accepted: January 27, 2003.