EFFECTIVENESS OF FIELD EXPERIMENTATION ON BEAN VARIETAL MICROLOCATION AND EVALUATION OF GENOTYPE-ENVIRONMENT INTERACTION

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ABSTRACT. Among breeding programs, the latest selective stages generally deal with several environments with experimental evidence, in which genotype-environment (GE) interaction is an important component of phenotypical variation. Participatory plant breeding (PPB) enables to achieve a significant integration: diversity fair and field experimentation to create an extensive and efficient experimental network; if varieties are evaluated on the farms previous to its extension, then GE interaction effects are positively observed when selecting the most adapted individuals to a specific ecosystem. Putting PPB into practice will enable to establish highly adaptable material to present low energy input conditions, by increasing yield and harvest quality; therefore, either economic, ecologic or social profits will be feasibly attained in peasant communities. Credit and service cooperative peasants from La Palma, Pinar del Río, developed spontaneity and creativity after attending bean biodiversity fair celebrated at INCA, so proving peasants' selection of the best genotypes for sustainability conditions. Some results show experimental evidence on GE environment, as an important phenotypical variation component and an effective use for field experimentation. It was also demonstrated on each farm that diversity improves after getting involved with PPB; besides, seeds become enough as a result of varietal introduction in the location.

Key words: plant breeding, field exprimentation, peasantry, genotype environment interaction, rapid rural appraisal, social participation

RESUMEN. Entre los programas de mejora, en las últimas etapas selectivas se trabaja generalmente dentro de varios ambientes, con evidencias experimentales donde la interacción genotipo-ambiente (GA) es un importante componente de la variación fenotípica. Con el fitomejoramiento participativo (FP) se podría lograr una importante integración: feria de diversidad y experimentación campesina, creando una red experimental extensiva y eficiente; si las variedades se evalúan en la fincas previo a su extensión, los efectos de la interacción GA se manifiestan positivamente al escoger los individuos que más se adaptan a un ecosistema específico. La implementación del FP permitirá el establecimiento de materiales con mayor adaptación a las actuales condiciones de bajos insumos energéticos, lo que redundará en un incremento en el rendimiento y la calidad de las cosechas; por lo tanto, las ganancias económicas, ecológicas y sociales serán factibles de alcanzar en las comunidades campesinas. La espontaneidad y creatividad desarrollada por campesinos de varias cooperativas de crédito y servicio de La Palma, Pinar del Río, posterior a su participación en la feria de biodiversidad desarrollada en el INCA en el cultivo del frijol, demostró la acertada selección por los campesinos de los mejores genotipos para las condiciones de sostenibilidad. Se presentan resultados de algunos casos de estudio, donde hay evidencias experimentales de la interacción GA, como un importante componente de la variación fenotípica y efectividad del uso de la experimentación campesina. Se demuestra en cada finca, el aumento de la diversidad posterior a la intervención del mejoramiento participativo y, además, la suficiente semilla creada debido a la introducción de variedades en la localidad.

Palabras clave: fitomejoramiento, experimentación en campo, campesinado, interacción genotipo ambiente, diagnóstico rural rápido, participación social

INTRODUCTION

Different production programs of improved seeds in Cuba has not satisfied quality or quantity of grower's demands, mainly due to a poor availability of resources

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and little genotypic adaptation to the specific conditions of agroecosystems, since input deficit itself consequently brought a greater agroecological and socioeconomic differentiation of environments, which encouraged different crop varieties to get adapted to several environments.

On one hand, conventional plant breeding has not been able to respond to the new situation, which requires a wider varietal diversification for the adaptation to heterogenous agroecological conditions, due to a restrained availability of energetic resources. Varieties coming from a formal system do not have enough levels of production, storage and distribution of improved seeds for diverse environments. Sometimes varieties derived from conventional plant breeding programs are vulnerable to pest and disease attacks from specific agroecosystems. Moreover, the conventional plant breeding system structure is centralized and has a few opportunities to implement a system enabling to develop materials for the most diverse circumstances. This phenomenon has provoked a production deficit of improved seeds and poor profits to farmers.

Over the last selective stages of the breeding program, the work is generally performed under various environments and experimental evidences are recorded whenever G x E interaction is an important component of phenotypic variability (1) and determines a differentiated genotypic performance. In Cuba, the significance of such interaction has been discussed (1, 2, 3), thus, it is now a common practice at the selective process and has been replicated in its two main senses: spatial and temporary; however, it is always limited to costs and operational capacity when centrally performed by research centers.

Participatory plant breeding (PPB) allows to construct an extensive and efficient experimental network by means of interactions between diversity fairs and farm experimentation, varieties are seeded under the existing low-input conditions, in such a way that the farmer can select the most adaptable varieties to a specific ecosystem as well as to include experimentation in his own farm, considering sowing dates, technologies, polyculture, etc.

PPB approach provides a promising alternative by combining knowledge and farmer's capacity with plant breeders' specialties and their access to materials (4).

The ideal method to let the farmer get exploiting diversity of food crops, such as bean and maize, is diversity fairs (5), which not only invite farmers to participate but give them the possibility of choosing the materials they consider to adapt to their lands and take other materials to be chosen in their own lands.

This paper was aimed at proving the effectiveness of farmer experimentation to select bean varieties that will be seeded on their farms. Besides, results from study cases are presented, providing evidence of such experimentation effectiveness. Diversity increases on each farm after applying PPB and there is enough seed as a result of introducing varieties to this location.

MATERIALS AND METHODS

In order to evaluate the possible differentiated varietal response according to season and locality, a wide collection of bean was firstly evaluated in a same locality at the early and late sowing dates; the latter was also evaluated in two different locations.

Such evaluation included 50 genotypes: 24 black, 19 red and 7 white grain genotypes. These materials were collected in farms from La Palma, Pinar del Río, as well as *ex sito* germplasm, commercial and precommercial varieties. A randomized block design with two replicates was employed in a useful 14-m^2 area per plot, managing an approximate density of 250 000 plants/ha^{-1}. Early seeding was carried out at the National Institute of Agricultural Sciences on October 2, 2000 whereas the late one on January 28, 2001; one replicate was seeded in La Palma on January 27, 2001 (late season). The three seedings were conducted under low-input conditions without chemical fertilizers, or irrigation and phytosanitary control, in such a way that the crop could show its capacity to tolerate biotic and abiotic stresses of each environment.

The following variables were evaluated: days to flowering and to harvest, resistance to rust and bacteriosis by an inverse scale ranking from 0 to 5 (6) and grain yield/area. Data were processed through a bifactorial analysis, in order to evaluate the effect of varieties and seasons as well as varieties and localities, including its interaction. With the purpose of estimating GxE interaction, an AMMI analysis was performed.

Evaluation of bean varieties selected by farmers in their land. Regarding bean diversity fair celebrated at INCA (7), farmers received seed samples from materials previously selected in August, 2001 (presented in numeric keys). Eight farm investigators were selected in La Palma, Pinar del Río, who seeded the previously selected bean varieties in their lands at two seasons (Table I): early (August-October) and late (December-February). Seedings followed the traditional way per row, including those varieties farmers used to sow.

For evaluating the effect of seeding season on varieties, performance of grain yields of different varieties was graphically represented in late and early sowings as well as the mean value of each farm in each season. For estimating G x E interaction, an AMMI analysis was performed (8, 9). Besides, the existing bean varietal diversity was evaluated before and after the fair and farm experimentation. The sufficient amount of seeds from this species was also evaluated, as a result of introducing varieties in the location and the effort for its extension.

RESULTS AND DISCUSSION

Evaluation of a wide bean collection at two different seasons in San José de las Lajas, Havana. Table II shows results from a mean square estimate of each factor analyzed and its interaction for the studied varieties. In general, values recorded in every variable were mostly determined by the influence of sowing seasons, with highly significant differences, which are closely related with rainfall and temperature in both seasons. Higher temperatures and rainfall characterize early seedings; the opposite occurs in late seedings.

Table I. Farm investigators, seeding dates and genotypes evaluated

No	Farmer	Seeding date	Keys for selected varieties in the fair									Varieties previously used by farmers		
			41*	48*	(50)	(54)	55*	(56)	60	63		T~N	T~R	T~B
1	Sergio y	21/10/01	X	X	X	X	X	X	X	X		X	~	X
	Vestina	15/1/02	X	X	X	X	X	X	X	X		X	~	X
		Keys	9*	(11)	(13)	(15)	25	43*	(50)	72*	77	T~N	T~R	T~B
2	Silvia	28/8/01	X	X	X	X	X	X	X	~	~	X	X	~
	Hernández	29/12/01	X	X	X	X	X	~	X	X	X	~	~	~
		Keys	6*	8*	45*	55*	(74)					T~N	T~R	T~B
3	Berto	18/10/01	X	X	X	X	X					X	X	~
	Ireno	2/2/02	X	X	~	~	~					~	~	~
		Keys	44*	(50)	58	62						T~N	T~R	T~B
4	Pucho Prieto	21/9/01	X	X	X	X						X	X	~
		Keys	(11)	18	44*	(50)	(54)	(73)				T~N	T~R	T~B
5	Reino Medero	21/10/01	X	X	X	X	X	X				X	X	~
		17/1/02	X	~	~	X	~	X				~	~	~
		Keys	1*	(17)	21	41*	44*	77	79			T~N	T~R	T~B
6	Andrés Aldaz	1/9/01	X	X	X	X	X	X	X			X	~	~
		2/1/02	~	X	X	X	X	X	X			~	~	~
		Keys	5*	9*	42*	47*	72*					T~N	T~R	T~B
7	Gervacio Pérez	13/10/01	X	X	X	X	X					X	X	~
		10/1/02	X	X	X	X	X					~	~	~
		Keys	1*	2*	3*	(12)	21	41*	44*	77	79	T~L	T~R	T~B
8	Pedro F.	26/8/01	X	X	X	X	X	X	X	X	X	X	~	~
	(Coco)	14/1/02	X	X	X	X	X	X	X	X	X	X	~	~

T~L mixed bean named «ligatrucho» by the farmer
T~N black bean, T~R red bean, T~B white bean traditionally used by farmers
Key number of the variety: * commercial variety; ( ) precomercial variety and __ collected variety
Black (1 to 25), red (41 to 63), white (72 to 79) varieties

Table II. Mean square estimate of evaluated variables

Sources of variation	DF	Mean square: Grain yield ($t.ha^{-1}$)	Rust resistance	Resistance to bacteria	Days to flowering	Days to harvest
Treatments	99	0.0360**	1.2675***	1.7949***	26.6193***	6.7917***
Variety	49	0.0394**	1.3715***	2.4581***	42.1033***	7.5025 ns
Season	1	0.1469***	41.4050***	29.6449***	43.2500**	36.1250***
V*S	49	0.0303*	0.3438 ns	0.5634*	10.7559***	5.4821***
Error	99	0.0221	0.2367	0.3414	5.0594	1.4901
VC (%)		38.96	31.03	22.98	0.56	0.79

* significant to P<0.05, ** significant to P<0.01, *** significant to P<0.001 DF- degrees of freedom

With regard to four from those five variables analyzed, varieties x season interaction was significant, which proved the existence of an unlike response of varieties per season for yield, flowering inititation and total crop cycle; thus, it is important to select materials/season; in other crops, this interaction has also been very important (10, 11). Just in case of bacteriosis, varieties have to be selected according to sowing time.

As it is observed in Figure 1, concerning AMMI analysis, an important group of varieties presented interaction with sowing season; by the way, others are more stable: among the first varieties having values different from cero are no. 30 (collected in La Palma); a prospection with low yields and no. 42 (CC25-9-R) with high yields. Among the most stable varieties with values close to cero are no. 24 (selected by Mongo Medero) with adequate yield and no. 25 (selected by Tony Pedroso) with a bad performance in both seasons.

In general, there was an important effect of genotype x season interaction; therefore, these arguments influenced farmers to have in mind both sowing seasons (late and early) for evaluating the varieties selected at bean diversity fair, as part of farmer experimentation promoted at farm level.

Evaluation of bean work collection in San José de la Lajas and La Palma. With the objective of evaluating the effect of location and its interaction with varieties, a factorial analysis was performed (Table III). According to results from mean square of yield, location had a remarkable importance among all sources of variation, L x V interaction being significant; therefore, it encourages genotype evaluation in those localities where they could be exploited. Besides, it would be satisfactory to celebrate fairs in target localities to evaluate diverse genotypes on each farm, in order to find which is the most adaptable one to such specific conditions.

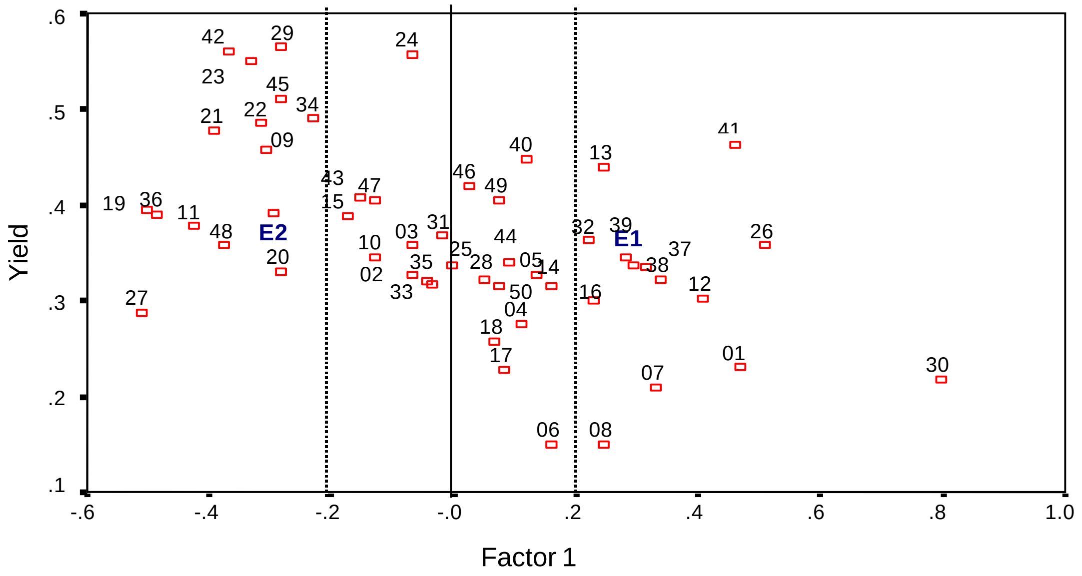

Figure 1. Mean yield and scoring of the first axis from the main components of 50 varieties and two different environmental seasons

Table III. Factorial variance analysis for yield in two locations

Sources of variation	DF	Grain yield (t.ha^{-1}) Sum of squares	Mean square	F
Treatments	97	53.4628	0.5512	5.975***
Location (L)	1	37.210	37.210	258.66***
Variety (V)	48	9.3477	0.1947	1.354 n.s
LxV	48	6.9051	0.1439	1.560*
Error	98	9.0398	0.0922	

* significant to P<0.05, ** significant to P<0.01,
***ssignificant to P<0.001 DF-degrees of freedom

Figure 2 shows the varieties existing very close to central axis "0"; however, lots of them get away and are grouped in a given environment, then, they are unstable or have a great interaction with environment. As an example between varieties close to cero and thereby stable are no. 5 (BAT-304) and 42, which have good yields; when analyzing season (Figure 1) they are stable. Varieties no. 25 and 30 presented low yields and they are unstable because they are from the central axis: the former one was stable in the previous analysis. Everything strengthens the criteria for evaluating the future exploitable varietal place. Results proved how useful experimentation at land level is.

Evaluation of bean varieties by farmers in their lands from La Palma, Pinar del Río. There is a differentiated response of varieties according to season: there is a group of bean varieties with a stable performance but others have a highly differentiated response according to sowing season (Figure 3). White and red varieties interacted a lot according to season. Regarding selection in diverse farms, the objective was to exploit GE interaction, improving the specific adaptation among target environments; this can only be completely achieved by selecting under target environments (13).

Figure 4 presents the mean potential of different farms: eight experimenting farmers seeded the varieties they have selected at both seasons; in each farm, yields ranged from 0.49 to 3.28 t.ha^{-1}. Moreover a differential response is recorded per seeding season; thus, season-farm is a very important interaction which repeats what is accepted by farmer experimentation in their lands: there are three farmers increasing mean yield at the second seeding, but there are four farmers, whose yield was depressed at the 2nd seeding; consequently, it proves the significance of doing experiments at farm and season levels. After applying PPB, biodiversity of this species has risen in the community (11, 12) and by means of farmer experimentation, an essential plant breeding program was solved: «relationship between selection environment and target environment» (13), that is the same in this case. The main objective of farmer experimentation is varietal selection for specific adaptations of farms.

According to AMMI analysis (Figure 5), some genotypes were more adapted to one seeding season whereas others are grouped to the second season; one group gets aways from groupings and denotes a poor adaptability to this locality. Results of this technique have been informed (14, 15), which are very similar to those obtained in previous analyses (Figures 1, 2).

On one hand, these results indicate it is necessary to perform trials on farmers' lands of a given location under these circumstances; on the other hand, it can only be possible by farmer experimentation within PPB program. The use of replicates in time are needed to obtain less bias from variance and define the most adaptable genotypes to specific conditions.

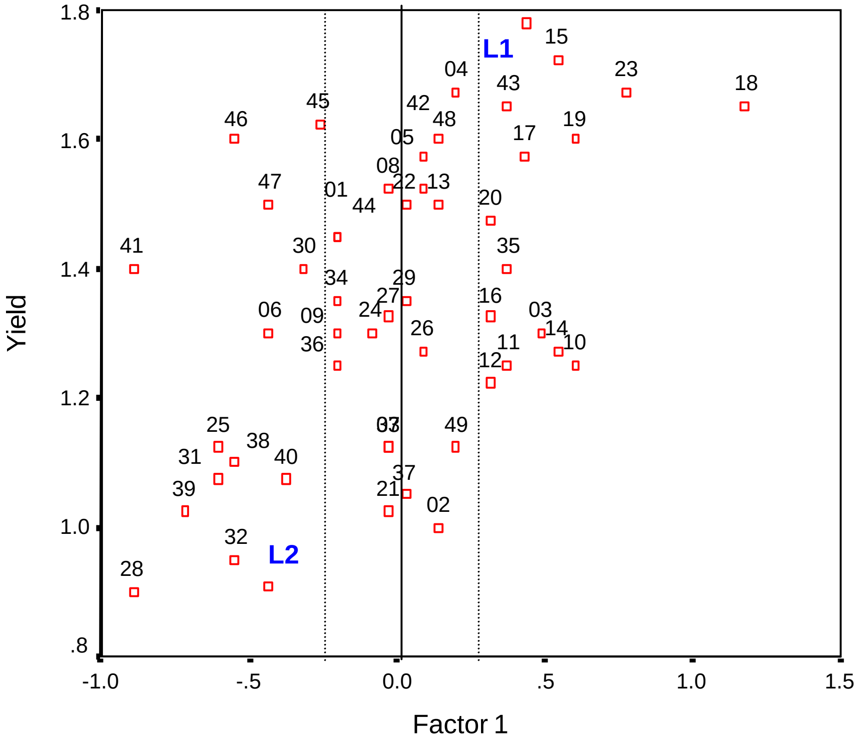

Figure 2. Mean yield and scoring of the first axis from the main components of 49 bean varieties and two different environmental places

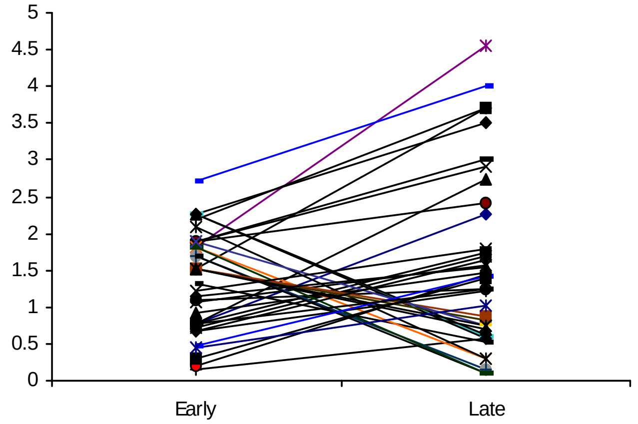

Figure 3. Performance of 35 new varieties evaluated by eight experimenting farmers at two sowing seasons

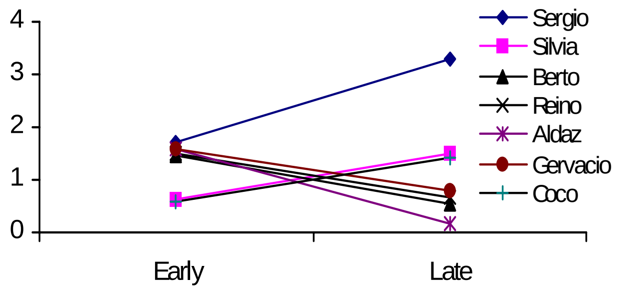

Figure 4. Mean values obtained in different farms at both seasons

Through this approach to include diversity of a species by means of fairs and evaluate varieties on farms, diversity is actually risen; also, GE interaction is positively managed in specific ecosystems, which are mainly determined by the kind of soil, farm environment, cultural technology and specific sowing season, which determines a differentiated response of diverse genotypes. A wide varietal diversity increment was recorded in the farms and community.

Widening of varietal diversity and enough seed. Farmers from La Palma involved to study 80 g bean seeds delivered in August, 2001, have attained an average of more than 50 kg with the best genotypes; this amount supplies enough seeds to produce bean on their farms within the next season. Mean yield and bean area have increased; therefore, prospects are fulfilled by applying PPB to fair-farmer experimentation.

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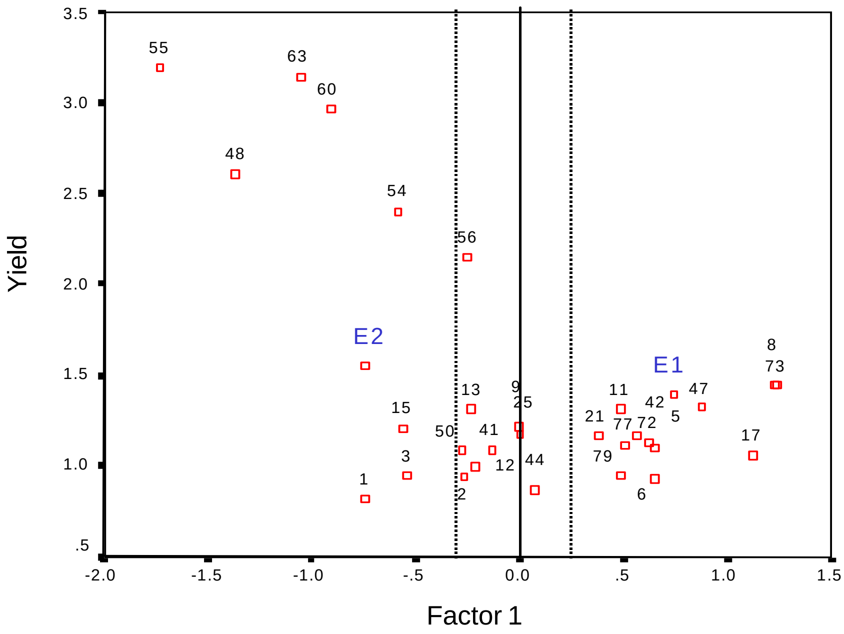

Figure 5. Mean yield of varieties and scoring of the first axis from the main component of 35 bean varieties and two different environmental seasons

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