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Breeding for culinary and nutritional quality of common bean (*Phaseolus vulgaris* L.) in intercropping systems with maize (*Zea mays* L.)

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Common bean (*Phaseolus vulgaris* L.) is widely intercropped with maize (*Zea mays* L.) in the North of Spain. Breeding beans for multiple cropping systems is important for the development of a productive and sustainable agriculture, and is mainly oriented to minimize intercrop competition and to stabilize complementarity with maize. Most agricultural research on intercropping to date has focused on the agronomic and overall yield effects of the different species, but characters related with socio-economic and food quality aspects are also important. The effect of intercropping beans with maize on food seed quality traits was studied for thirty-five bush bean varieties under different environments in Galicia (Northwestern Spain). Parameters determining Asturian (Northern Spain) white bean commercial and culinary quality have also been evaluated in fifteen accessions. There are significant differences between varieties in the selected cropping systems (sole crop, intercrop with field maize and intercrop with sweet maize) for dry and soaked seed weight, coat proportion, crude protein, crude fat and moisture. Different white bean accessions have been chosen according to their culinary quality. Under these environmental conditions it appears that intercropping systems with sweet maize give higher returns than sole cropping system. It is also suggested that the culinary and nutritional quality potential of some white bean accessions could be the base material in a breeding programme the objectives of which are to develop varieties giving seeds with high food quality.
Keywords. *Phaseolus vulgaris* L., *Zea mays* L., breeding, intercropping, nutritional quality, Spain.

Amélioration des qualités culinaire et nutritionnelle du haricot commun (*Phaseolus vulgaris* L.) cultivé en association avec le maïs (*Zea mays* L.). Le haricot commun (*Phaseolus vulgaris* L.) est habituellement cultivé en association avec le maïs (*Zea mays* L.) dans le nord de l'Espagne. L'amélioration des haricots en vue de leur utilisation dans différents systèmes culturaux est importante pour le développement d'une agriculture productive et durable, et est principalement orientée vers une diminution de la compétition entre cultures assurant une complémentarité plus stable avec le maïs. La plupart des recherches actuellement menées dans ce domaine se sont focalisées sur les effets agronomiques et le rendement global des différentes espèces, mais les caractères en relation avec les aspect socio-économiques et la qualité sont aussi importants. L'influence de l'association du haricot avec le maïs sur la qualité alimentaire des graines a été étudiée sur 35 variétés de haricot nain dans différents environnements en Galicie. Les paramètres déterminant la qualité commerciale et alimentaire d'une variété de haricot blanc ont également été évalués sur 15 introductions. Dans les systèmes culturaux choisis (culture pure, association avec le maïs grains, association avec le maïs doux), seules des différences significatives ont été mises en évidence pour les poids des grains secs et trempés, la proportion des téguments, les teneurs en eau, protéines et matières grasses. Différentes introductions de haricot blanc on été choisies pour la qualité alimentaire. Les résultats suggèrent que, sous les conditions culturales testées, l'association avec le maïs doux serait plus rentable économiquement que la culture pure, et que le potentiel des qualités culinaire et nutritionnelle de certaines introductions de haricot blanc pourrait servir de matériel dans un programme d'amélioration afin d'obtenir des variétés avec une bonne qualité alimentaire des grains.
Mots-clés. *Phaseolus vulgaris* L., *Zea mays* L., amélioration, culture en association, qualité nutritionnelle, Espagne.

1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is a species widely cultivated due to its good nutritional composition (high protein content in dry seed and a good source of fibre in snap bean) and its high market value, and is consumed either as a dry bean (pulse) or as a snap bean (fresh vegetable). Consumers have progressively shown specific preferences for various combinations of size and shape of bean seeds and pods, and the market reflects this trend by giving preference to types of good quality rather than high yield. Common bean is widely grown in the North of Spain (Galicia and Asturias) in small farms and principally in association with maize (*Zea mays* L.) (Moreno *et al.*, 1985; Santalla *et al.*, 1994). Some dry bean varieties such as Alubia de riñón, Faba Granja Asturiana, Pinta de León and Tolosana have acquired considerable importance due to their good seed quality and these varieties are protected by law. The socio-economical peculiarities of this region and the use of traditional varieties, grown in smallholdings which are self-sufficient in seeds, have made possible the maintenance of these traditional cultural systems. However as a consequence of new technology and market opportunities the intercropping system is being replaced by sole crop mainly in the case of varieties with high added values such as Faba Granja Asturiana.

The increasing concern on agricultural sustainability favours the maintenance of intercropping systems which give an efficient soil conservation due to the increased ground cover that it provides, and a more stable agricultural production than sole crop, for small farms, where capital is limited and labour is available (Willey, 1979). Selection of bean varieties for intercropping with maize has received low priority in breeding programmes, although the differential response of crops to the cultural associations justifies the introduction of varieties specifically adapted to these cropping systems (Zimmermann *et al*, 1996). Improved intercropping systems would provide an alternative to sole cropping, particularly for small scale agriculture.

Germplasm collection of common bean varieties is maintained at the Mision Biologica de Galicia (MBG-CSIC, Pontevedra–Galicia, Spain) and Agricultural Research Service (SERIDA, Villaviciosa–Asturias, Spain) in the north of Spain, with two main goals. The first one, at short-term level, concerns the evaluation of the genetic diversity and the identification of varieties with promising values in agronomic and quality traits, and the second goal, at a long-term level, is focused on the diversity conservation and the exchange of germplasm with other institutions, both for breeding purposes and for medium- and long term seed storage. In relation with the first goal, evaluation of Spanish varieties from various origins have been carried out in different years, locations and cropping systems to obtain reliable information on their agronomic and quality values, and with the purpose to select elite bean varieties which complement efficiently in the different cropping systems. Concerning the second goal, MBG-CSIC and SERIDAparticipate in the Spanish network for bean genetic resources with the aim to maintain and to characterize landraces from Spain.

The objectives of this work are to study the influence of cropping systems (sole crop, intercrop with field maize and intercrop with sweet maize) on food quality traits and to determine the attributes which affect the commercial and culinary quality of Asturian white bean (cultivar Faba Granja Asturiana).

2. MATERIAL AND METHODS

2.1. Plant material

Thirty-five common bean varieties (types I and II according to CIAT, 1983), which differed in seed quality attributes, were used in intercropping studies at the MBG-CSIC, and fifteen Asturian white bean genotypes from the variety Faba Granja Asturiana included in the collection of the SERIDA, were evaluated to determine the commercial (seed shape and size) and culinary quality. The evaluation of the culinary quality was only carried out in five varieties, previously chosen on the basis of their commercial quality. All these accessions are well adapted to the bean production areas in the north of Spain (de Ron *et al.*, 1997; Escribano *et al.*, 1998). The maize cultivars used in intercropping were two field maize hybrids named Dea and Eva, both with a FAO 200 maturity rating, and a sweet maize hybrid named RODEO. These maize cultivars are currently recommended for this area.

2.2. Experimental design

The field experiments on intercropping were carried out in the northwest of Spain, Pontevedra (42º N 8º W latitude, 20 m asl, 14 ºC mean temperature, average rainfall 1608 mm) during the warm season of four consecutive years: from 1992 to 1995. Plots were fertilized with 160 kg of N/ha, 120 kg of P/ha and 200 kg of K/ha just prior to sowing and 50 kg of N/ha was top dressed 30 days after planting. Diseases and pests were controlled in all trials, and irrigation was supplied when necessary. A split plot design with two replications was used where the main plots were 25 bean varieties in the first experiment carried out in 1992 and 1993, and three cropping systems (bean sole crop, intercrop of bean with field maize, and intercrop of bean with sweet maize) in the second experiment carried out in 1994 and 1995, while the subplots were two cropping systems (bean sole crop and intercrop of bean with field maize) in the first experiment and 10-bean varieties in the second experiment. The crops were manually harvested 100 and 150 days after planting, respectively for beans and field maize.

The experimental design used to determine the commercial and culinary quality of the white bean accessions was a randomised complete block design with three replications.

2.3. Data analysis

Food quality data were measured on dried, soaked and cooked bean seeds from each plot. These include dry seed weight (determined on 100 seeds per plot), seed hardness (determined with a penetrometer on 10 cooked seeds per plot), seed texture (determined with a tenderometer on 10 cooked seeds per plot), proportion of seed coat (defined as the ratio in weight between seed coat and cotyledon plus seed coat, after removing the seed coat from the cotyledon and keeping them for 24 h at 105 ºC), and water absorption (measured as the amount of water dried seeds absorb during soaking), all of them related to seed culinary quality, and crude protein (%), crude fat (%), starch content (%), total sugars (%) and moisture (%), all of them related to seed nutritional quality. The methodology to calculate each of these traits is detailed elsewhere (Fueyo *et al.*, 1990; Santalla *et al.*, 1995; Escribano *et al.*, 1997).

The least significant difference (LSD) and DUNCAN methods ($p < .05$) were used to evaluate differences between variety and cropping system means. Standard errors and coefficients of variation were determined for the traits under study.

3. RESULTS AND DISCUSSION

Table 1 indicates means, standard errors and coefficients of variation for each trait and cropping system in both experiments. For all the studied traits, the standard errors were lower than 10% of the varietal mean, demonstrating the accuracy of the means. Significant differences among cropping systems were observed for dry and soaked seed weight, crude protein and moisture content in the field experiment carried out during 1992 and 1993, and also for seed coat proportion and crude fat in the field experiment carried out during 1994 and 1995. Seed weight (dry and soaked) was significatively higher in intercrop with field maize compared to the other cropping systems, while seed coat proportion was slightly less in this cropping system. Crude protein was reduced by intercropping (both with field and sweet maize) compared to sole crop, which was observed in previous studies (Santalla *et al.*, 1995).

Significant variation was detected among white bean genotypes for water absorption (**Table 2**). The bean white genotype with the highest percentage of water absorption was V-105 while the lowest was the control genotype.

Bush bean varieties showed relatively little differences for food quality in sole crop compared to their ability to compete with maize. It appears that the risk of rejecting a bean variety which is outstanding in intercropping would be minimal if early plant evaluation is done mainly in sole crop. Hence, promising bean varieties, which present quality attributes acceptable by consumers, could be selected firstly in the sole crop system and subsequently tested in the intercropping system.

Intercropping systems remain important in the future, as they represent alternative systems likely to be more sustainable than the current mechanized and labour efficient systems that prevail in developed countries. Moreover, bean varieties selected with a particular sweet maize genotype should be also suitable under sole cropping, at least within reasonable limits, compared to intercropping with a more aggressive field maize hybrid. The modification of one component crop in the intercropping system will not disturb markedly the traditional cropping system, and it can open a new direction for research and development in agriculture with two objectives: food security and preservation of a liveable environment. Small farmers have not benefited from improved technology because of the unavailability of appropriate recommendations and varieties, and the lack of financial resources required to incorporate new practices. Economic return is the most important criteria for farmers participating in the market. Intercropping of traditional bush bean landraces and sweet maize could be an interesting alternative cropping system for small farmers in south of Europe under the pressure of an extensive agriculture.

The present work provides useful information on the diversity for food quality characteristics in common bean varieties from north of Spain under different environments and cropping systems. Such results have an impact, on the farming system of the region based upon diversified productions and could contribute to the improvement of the welfare in the rural environment.

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Table 1. Food quality traits in common bean varieties from Northwest of Spain, in sole crop and in association with field and sweet maize — *Caractères estimant la qualité alimentaire de variétés de haricot commun provenant du nord-ouest de l'Espagne, en culture pure et en association avec du mais-grain ou du maïs doux*.

	Field experiments during 1992 and 1993				Field experiments during 1994 and 1995					
	Mean ± SE (1)		CV		Mean ± SE			CV		
	S	IF	S	IF	S	IF	IS	S	IF	IS
Seed culinary quality traits										
Dry weight (g)	44.4b ± 1.50	47.1a ± 1.55	6.78	6.60	41.4b ± 1.73	44.9a ± 1.56	41.3b ± 1.89	8.36	6.94	9.14
Soak weight (g)	92.6b ± 3.28	97.0a ± 4.27	7.08	8.81	75.9b ± 4.78	83.7a ± 3.91	76.1b ± 5.29	12.59	9.34	13.91
Coat proportion (%)	8.6a ± 1.70	7.95a ± 0.267	39.53	6.71	7.91a ± 0.267	7.41b ± 0.32	7.8ab ± 0.80	6.76	8.64	20.47
Water absorption (%)	108.7a ± 2.35	107a ± 7.70	4.33	14.37	108.2a ± 2.09	103.6a ± 2.08	106.8a ± 3.16	3.87	4.02	5.91
Hardness (1/10 mm)	21.0a ± 1.40	20.7a ± 1.76	13.34	17.04	34.8a ± 3.15	33.8a ± 2.36	33.4a ± 1.41	18.06	13.96	8.45
Seed nutritional quality traits										
Crude protein (%)	23.3a ± 0.67	22.6b ± 0.58	5.75	5.18	26.88a ± 0.285	26.45b ± 0.198	26.75ab ± 0.342	2.12	1.50	2.55
Crude fat (%)	1.42a ± 0.054	1.43a ± 0.055	7.61	7.68	1.546ab ± 0.027	1.580a ± 0.021	1.508b ± 0.026	3.61	2.67	3.48
Starch content (%)	38.4a ± 0.93	38.4a ± 1.43	4.82	7.47	43.83a ± 0.0287	43.94a ± 0.302	43.85a ± 0.315	1.31	1.38	1.44
Total sugars (%)	3.74a ± 0.100	3.77a ± 0.138	5.36	7.33	4.47a ± 0.079	4.43a ± 0.065	4.49a ± 0.051	3.54	2.95	2.28
Moisture (%)	12.82a ± 0.150	12.66b ± 0.127	2.34	2.01	12.41a ± 0.061	12.33a ± 0.077	12.350a ± 0.0316	0.99	1.25	0.51
Ash (%)	3.77a ± 0.098	3.77a ± 0.098	5.23	5.19	-	-	-	-	-	-

(**1**) Mean ± SE: Means comparisons among columns by LSD at p = 0.05 and standard error; CV = Coefficient of variation (%).
S = Sole crop. IF = Intercrop with field maize. IS = Intercrop with sweet maize.

Table 2. Means of water absorption (%) in white bean genotypes (cultivar Faba Granja Asturiana) from northwest of Spain — *Moyennes des valeurs en % de l'absorption d'eau chez des génotypes de haricot commun à grains blancs (cultivar Faba Granja Asturiana) du Nord-Ouest de l'Espagne*.

Variety	Water absorption (%)
V-105	117.60 a
V-95	109.30 b
V-100	109.22 b
V-136	109.68 b
V-143	106.18 b
Control (**1**)	98.35 c

(**1**) White bean accession (cultivar Faba granja asturiana) obtained from the local market. Means comparisons within column by DUNCAN at p = .05.

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