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# Performance of bean (*Phaseolus vulgaris* L.) genotypes in the second-season under high and low technology management in Parana, Brazil

## Desempeño de genotipos de frijol (*Phaseolus vulgaris* L.) en la segunda zafra bajo alto y bajo manejo tecnológico en Paraná, Brasil

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## Abstract

In the face of bean (*Phaseolus vulgaris* L.) crops with low grain yield in Brazil, specifically in the state of Parana-Brazil, this research aimed to evaluate the agronomical performance of different genotypes grown in the second-season under high and low technology management. The experimental design was a randomized block design with three replications in a 3x13x2 triple factorial arrangement, where Factor A was composed of three years of cultivation (second-season 12/13, 13/14 and 14/15), Factor B consisted of 13 bean cultivars (BRS Campeiro; BRS Esplendor; IPR Gralha; IPR Tuiuiú; IPR Uirapuru; BRS Ametista; BRS Estilo; BRS Notável; BRS Pérola; IPR 81; IPR Campos Gerais; IPR Curió and IPR Tangará) and Factor C consisted of 2 levels of technological management (high and low technology). The use of high-technology management resulted in higher grain yield, statistically different from the low-technology management in the second-season 12/13, 13/14 and 14/15 and from the overall mean of the three years of cultivation. Thus, greater investment in technology increases the probability of increasing in economic profitability of the producer due to the growth in bean crop productivity. The cultivar BRS Pérola exhibited grain yield values statistically higher than cultivars IPR Tuiuiú, IPR Gralha, IPR Campos Gerais, IPR Tangará, IPR Uirapuru, IPR 81 and IPR Curió, proving to be a good choice to achieve high productivity.

**Key words:** Cultivars, environment, genetics, technology, yield.

## Resumen

Con miras de afrontar la baja productividad en cultivos de fríjol (*Phaseolus vulgaris* L.) en el estado de Paraná, Brasil, esta investigación buscó evaluar el desempeño agronómico de diferentes genotipos de frijol cultivados en la segunda época de siembra empleando alto y bajo manejo tecnológico. El diseño experimental fue de bloques completamente al azar con tres repeticiones en esquema factorial triple del tipo 3x13x2, el Factor A estuvo constituido por tres años de cultivo (segunda época de siembra: 12/13; 13/14 y 14/15), el Factor B estuvo compuesto por 13 cultivares de frijol (BRS Campeiro; BRS Esplendor; IPR Gralha; IPR Tuiuiú; IPR Uirapuru; BRS Ametista; BRS Estilo; BRS Notável; BRS Pérola; IPR 81; IPR Campos Gerais; IPR Curió e IPR Tangará) y el Factor C, constituido por dos niveles de manejo tecnológico (alta y baja tecnología). El manejo de alta tecnologia, resultó en productividad de granos superior y estadísticamente distinta del manejo de baja tecnología en la segunda época de siembra: 12/13, 13/14 y 14/15, y en el promedio general de los tres años del cultivo de frijol. Por lo tanto, una mayor inversión en tecnología aumenta la probabilidad de aumento de la rentabilidad económica del produtor, debido al aumento en la productividad del cultivo de frijol. El cultivar BRS Pérola, presentó productividad de granos superior estadísticamente a los cultivares IPR Tuiuiú, IPR Gralha, IPR Campos Gerais, IPR Tangará, IPR Uirapuru, IPR 81 y IPR Curió, demostrando ser una buena opción para lograr una alta productividad.

**Palabras clave:** Ambiente, cultivares, genética, productividad, tecnología.

## Introduction

Bean (*Phaseolus vulgaris* L.) is the species of this genus most produced and consumed in the world (Stähelin *et al.*, 2010). This legume is an important source of plant protein, with considerable content of carbohydrates and iron (Ferreira *et al.*, 2009). Even today, bean is the main source of protein for the population with low purchasing power.

Bean cultivation is widespread throughout the Brazilian territory (Yokoyama, Carneiro & Villar, 2001), and its wide adaptation to soil and climatic conditions, allows the cultivation during the first-season or *rainy season* (sowing from August to November), second-season or *dry season* (sowing from December to March) and three-season or irrigated season (sowing from April to July) (Barbosa & Gonzaga, 2012).

In Brazil, the bean crop stands out, with about 3 million hectares planted is surpassed only by soybean crop [*Glycine max* (L.) Merrill] and corn (*Zea mays* L.) (CONAB, 2015). The average bean yield obtained during three growing seasons of the agricultural year 2014/2015 in the state of Parana-Brazil, was 1775 kg.ha$^{-1}$, higher than average of Brazil of 1050 kg.ha$^{-1}$, which is considered low (CONAB, 2015).

The state of Parana-Brazil, with production of 720000 tons stands out in the Brazil as the leading producer in the agricultural year 2014/2015 (CONAB, 2015). In the same agricultural year, in the first-season, were grown 192.7 thousand hectares with yield of 1707 kg.ha$^{-1}$, with a total production of 328.9 thousand tons, in turn, during the second-season, were grown 208.1 thousand hectares with yield of 1858 kg.ha$^{-1}$, resulting in a total production of 386.6 thousand tons (CONAB, 2015). Thus, the second-season accounts for over 50% of the annual production of this legume in the state of Parana-Brazil, also responsible for raising the average yield of the common bean culture.

However, the average second-season yield in the state of Parana-Brazil, lies below the productive potential of most bean cultivars available on the market, which can achieve yields higher than 3000 kg.ha$^{-1}$ obtained by Andrade, Patroni, Clemente & Scapim (2004), Alvarez, Arf, Alvarez & Pereira (2005), and Junior, Lemos & Silva (2005). The main causes of the low bean yields include the low level of technology used by small and medium producers, due to the lack of financial resources that complicate the adoption of technologies. In addition, factors such as planting period, diseases, pests, unstable climatic conditions and price (high risk) discourage large farmers from planting beans. In concordance to Souza, Andrade, Muniz & Reis (2002), often small farmers, undercapitalized, cannot make major investments.

The bean crop lacks studies involving various types of farmers and current production systems, seeking high productivity and economic efficiency (Souza *et al.,* 2002). The few studies involving different management levels developed with the bean crop indicate increases in crop yield with increasing technological level employed, as reported by Souza *et al.* (2002), who registered an increase in grain yield of beans with increased levels of fertilization and liming, and Andrade *et al.* (2004), where found the increase in fertilization provided increment in the number of pods per plant, 100-seed weight and grain yield of bean crops.

Similarly to the aforementioned authors, Sangoi *et al.* (2006a), analyzed the corn crop under different levels of technological management and found increased grain yield, ears. m$^{-2}$ and grains. m$^{-2}$ with increasing management level used in the culture. Increase in corn grain yield was also reported by Sangoi *et al.* (2006b), with increased management level.

In concordance to Prochnow (1999), the potential producer profit result from attaining higher yields, improved product quality, more appropriate marketing strategies, reduction in production costs or a combination of these factors. Thus, the use of technology is essential for achieving high productivity and hence higher profitability in bean crop.

Therefore, the lack of information regarding the bean crop at different levels of technological management demonstrates the need assessing the performance of different bean genotypes for several years under low and high technology management and identify the most adapted to the soil and weather conditions, showing lower nutritional requirement variations, provides benefits to farmers, once it results in cost reduction, higher economic return, encouraging the production and regional socioeconomic development.

Given these concerns, this study aimed to evaluate the agronomic performance of different bean genotypes grown in the second-season under high and low technology management in Parana, Brazil.

## Materials and methods

This study was conducted in the experimental area of the Agronomy Course, of the Universidade Tecnológica Federal do Paraná. Câmpus Pato Branco, Parana- Brazil. The experimental area is located at 26º10'32" South latitude and 52º41'28" West longitude, with altitude of 760 m.a.s.l., Cfa climate, according to KÖPPEN classification and soil classified as Clayey Oxisol, following the soil classification system of EMBRAPA (2006). According to Lima, Lima & Melo (2012), Oxisol corresponds the main soil type found in Parana-Brazil, which is, distributed in 31% of the state territory, with characteristics such as good depth, almost flat relief, no rocks, large porosity, good drainage and permeability, which make this type of soil the most widely used in agricultural production. Oxisols are generally low fertility soils, but with fertilization and correcting practices they become very productive (Lima, *et al.*, 2012).

The soil chemical characteristics were determined in 2013, before setting the experiment. Analyses were conducted in the UTFPR Soil Analysis Laboratory, in partnership with the Instituto Agronômico do Paraná [IAPAR], Brazil with the following results: Organic matter (wet digestion): 36.19 (Medium); P (Mehlich l): 5.99 mg $dm^{-3}$ (average); K (Mehlich l): 109.48 mg $dm^{-3}$ (average); pH ($CaCl_2$): 4.40 (Low); Al: 0.34 $cmol_c$ $dm^{-3}$ (Low); H + Al: 5.76 $cmol_c$ $dm^{-3}$ (High); Ca: 4.10 $cmol_c$ $dm^{-3}$ (High); Mg: 1.60 $cmol_c$ $dm^{-3}$ (High); SB: 5.98 $cmol_c$ $dm^{-3}$ (High); V%: 50.94 (average); Al saturation: 5.38% (Low); Cation Exchange Capacity (CEC): 11.74. Weather data for the months of February to May, when the experiment was conducted in the years 2013, 2014 and 2015, were provided by the Sistema Meteorológico do Parana (SIMEPAR), Brazil.

**Table 1.** Common bean (*Phaseolus vulgaris* L.) genotypes traits used in the experiment

| Cultivar | Group | Cycle* | Growh habit | 100 grain weight (g) | Plant size |
|---|---|---|---|---|---|
| BRS Pérola | Carioca | Normal | Indeterminate (type III) | 27 | Semi-prostrate |
| BRS Notável | Carioca | Semi-early | Indeterminate (type II) | 25 | Semi-erect |
| BRS Esplendor | Black | Normal | Indeterminate (type II) | 22 | Erect |
| BRS Ametista | Carioca | Normal | Indeterminate (type III) | 30 | Semi-prostrate |
| BRS Campeiro | Black | Semi-early | Indeterminate (type II) | 25 | Erect |
| BRS Estilo | Carioca | Normal | Indeterminate (type II) | 26 | Erect |
| IPR Tuiuiú | Black | Normal | Indeterminate (type II) | 23 | Erect |
| IPR Gralha | Black | Normal | Indeterminate (type II) | 22 | Erect |
| IPR Campos Gerais | Carioca | Normal | Indeterminate (type II) | 24 | Erect |
| IPR Tangará | Carioca | Normal | Indeterminate (type II) | 29 | Erect |
| IPR Uirapuru | Black | Normal | Indeterminate (type II) | 25 | Erect |
| IPR 81 | Carioca | Normal | Indeterminate (type II) | 25 | Erect |
| IPR Curió | Carioca | Early | Determinate (type I) | 27 | Erect |

*Cycle: Early (< 75 days); Semi-early: (75-85 days); Normal (85-95 days); Late (> 95 days); Source: EMBRAPA (2006).

The experimental design was a randomized block design with three replicates in a 3x13x2 triple factorial arrangement, where Factor A, was composed of three years of cultivation (second-season 12/13, second-season 13/14 and second-season 14/15), Factor B, consisted of 13 bean cultivars (BRS Campeiro; BRS Esplendor; IPR Gralha; IPR Tuiuiú; IPR Uirapuru; BRS Ametista; BRS Estilo; BRS Notável; BRS Pérola; IPR 81; IPR Campos Gerais; IPR Curió and IPR Tangará), described in Table 1, and Factor C, consisted of 2 management levels (high and low technology), described in Table 2.

Bean sowing of the experiment in the second-seasons 12/13, 13/14 and 14/15 were carried out in 08/02/13, 12/02/14 and 19/02/15, respectively, with sowing rate of 18 seeds per linear meter. The basal fertilization consisted of 200 $kg.ha^{-1}$ and a commercial formulation of 04-14-08 for nitrogen, phosphorus and potassium (NPK), respectively.

**Table 2.** Detailed description of products and doses used in the high- and low technology management

| High Technology | | | | |
|---|---|---|---|---|
| **Products** | **Commercial name** | **Active ingredient** | **Rate g i.a. $ha^{-1}$** | **Application (DAS)** |
| Seed treatment | DEROSAL PLUS* | Carbendazim + Tiram | 45 + 105 | - |
| | BELURE* | Fipronil | 50 | - |
| Inoculant | TOTALNitro[1]** | *Rhizobium tropici* estirpe SEMIA 4080 | 100*** | - |
| 1st Herbicides | FUSILADE 250 EW | Fluazifope-P-Butílico | 187.5 | 12 |
| | FLEX® | Fomesafen | 250 | 12 |
| Fungicide | AUGE® | Hidróxido de cobre | 1612 | 20 |
| Insecticide | OBERON | Espiromesifeno | 120 | 20 |
| Nitrogen | Uréia | Nitrogen | 45 kg | 25 |
| 2nd Herbicides | FUSILADE 250 EW | Fluazifope-P-Butílico | 93.75 | 35 |
| | FLEX® | Fomesafen | 125 | 35 |
| Fungicide | Alterne® | Tebuconazol | 200 | 40 |
| Insecticide | CONNECT | Imidacloprido + Beta-Ciflutrina | 100 + 12.5 | 40 |
| Fungicide | MERTIN® 400 | Hidróxido de Fentina | 400 | 70 |
| Insecticide | CONNECT | Imidacloprido + Beta-Ciflutrina | 100 + 12.5 | 70 |
| Low Technology | | | | |
| **Products** | **Commercial name** | **Active ingredient** | **Rate g i.a. $ha^{-1}$** | **Application (DAS)** |
| Inoculant | TOTALNitro[1]** | *Rhizobium tropici* estirpe SEMIA 4080 | 100*** | - |
| Herbicides | FUSILADE 250 EW | Fluazifope-P-Butílico | 187.5 | 25 |
| | FLEX® | Fomesafen | 250 | 25 |
| Fungicide | Alterne® | Tebuconazol | 200 | 40 |
| Insecticide | CONNECT | Imidacloprido + Beta-Ciflutrina | 100 + 12.5 | 40 |

* Grams per treated 100 kg seed; ** Grams per 50 kg seed; DAS = days after sowing; *** Commercial product rate per hectare; [1] Product purchased from the company Total Biotecnologia (Curitiba, Brazil).

Plots consisted of 4 rows of 4 m long, spaced 0.45 m apart, with a total area of 7.2 $m^2$. For yield evaluation, we disregarded the two side rows and 0.5 m on either side of the plot, resulting in 2.7 $m^2$ of useful area. The grain yield was obtained by mechanical threshing of uprooted plants in the useful area of each plot when plants reached maturity for harvesting. Data were transformed into $kg.ha^{-1}$ and moisture adjusted to 13%.

Grain yield data were analyzed and subjected to Duncan's test ($P < 0.05$), using the software Genes ® (Cruz, 2013).

## Results and discussion

There was significant interaction only between management x year ($P < 0.05$). There was a significant effect for cultivars, management and year factors by F-test ($P < 0.05$).

The high-technology management propitiated higher grain yield, statistically different from the low-technology management in the three years of cultivation (Table 3). This result corroborates those observed by Andrade *et al.* (2004) and Souza *et al.* (2002), where increased levels of technology resulted in higher grain yield in beans. Also, the result corroborates yield results observed by Sangoi *et al.* (2006a; 2006b) in corn (*Zea mays* L.) crop.

**Table 3.** Mean values of grain yield ($kg.ha^{-1}$) for high- and low technology managements in the three years of cultivation of common bean (*Phaseolus vulgaris* L.)

| Management | Second-season | | |
|---|---|---|---|
| | 12/13 | 13/14 | 14/15 |
| High Technology | 2.487 aB* | 2.397 aB | 3.671 aA |
| Low Technology | 1.874 bC | 1.991 bB | 3.329 bA |

* Mean values followed by different letters in the same row and in the same column, are statistically different by Duncan's test ($P < 0.05$). Least significant difference (LSD) for year = 109.21 and for management = 103.71.

The highest grain yield verified in the management using high technology can be attributed to increased investment in seed treatment that ensured adequate development of seedlings without loss of stand by pests or diseases, two additional applications of fungicide and insecticide, which provided better plant health, and nitrogen fertilization, which supplied the high demand for nitrogen to the plant.

Numerous studies (Alvarez *et al.*, 2005; Silva, Arf, Sá, Rodrigues & Buzetti, 2004 and Stone & Moreira, 2001), found considerable increase in grain yield in bean crop provided by nitrogen fertilization. Therefore, the adoption of greater investment in inputs and technology is critical to achieve high yields.

The grain yield in the second-season 14/15 was statistically superior to the other years for both managements (Table 3). This is due to the excellent weather conditions occurred during the period in which the experiment remained in the field in this year, where the lowest temperatures were higher compared to the same period of 2013 (second-season 12/13) and 2014 (second-season 13-14). In addition, the values of total rainfall recorded between the months from February to May 2013, 2014 and 2015 during the experiment were of 970.2, 808.2 and 679.6 mm, respectively. Therefore, the rainfall in 2015 was more suitable for the development of beans compared to the same period of years 2013 and 2014, when the rainfall was excessive for the crop, causing extreme conditions of humidity. These conditions, according to Pereira *et al.* (2014), results in the deficiency of oxygen available in the soil to the plant, affecting the development and establishment of the root system and favoring the incidence of leaf and root diseases, thereby reducing the productivity of the culture. According to Coimbra *et al.* (2009), variations in grain yield are the result of the sensitivity of genotypes to environmental changes. Thus, when environmental factors favor the good development of the culture, it is possible to achieve high grain yield.

Analyzing separately each factor of the significant interaction, as for the years of cultivation for the average grain yield, in the second-season 14/15, there was higher yield, statistically different from the second-seasons 12/13 and 13/14 (Table 4). Again, the optimal weather conditions during the second-season 14/15 contributed to obtain high grain yield.

The average grain yield of the three years of cultivation in the high-tech management was statistically superior to low-tech management (Table 4). This result is related to the best conditions provided to the culture by the use of higher technological level, which enabled the achievement of high productivity, much higher than the average of the Brazil 1050 $kg.ha^{-1}$ and Paraná 1775 $kg.ha^{-1}$.

**Table 4.** Mean values of grain yield for high- and low technology managements and for the second-seasons 12/13, 13/14 and 14/15

| Second-season | Yield ($kg.ha^{-1}$) | Management | Yield ($kg.ha^{-1}$) |
|---|---|---|---|
| 12/13 | 2.180 b | High Technology | 2.852 a |
| 13/14 | 2.194 b | Low Technology | 2.398 b |
| 14/15 | 3.500 a | - | - |

* Mean values followed by different letters in the same column are statistically different by Duncan's test ($P < 0.05$). Least significant difference (LSD) for year = 110.04 and for management = 85.31.

In addition, a greater investment in technology by farmers results in increased grain productivity, and consequently, also increases the probability of increased profitability with bean crop. Although, in agreement with Alvarez *et al.* (2005), many producers grow this legume just for their livelihood.

For the cultivar factor, the BRS Pérola was superior and statistically different from cultivars IPR Tuiuiú, IPR Gralha, IPR Campos Gerais, IPR Tangará, IPR Uirapuru, IPR 81 and IPR Curió, producing as much as the others (Table 5).

**Table 5.** Mean values of grain yield ($kg.ha^{-1}$) of different common bean (*Phaseolus vulgaris* L.) cultivars evaluated in this study

| Cultivar | Yield |
|---|---|
| BRS Pérola | 2.920 a* |
| BRS Notável | 2.909 ab |
| BRS Esplendor | 2.849 abc |
| BRS Ametista | 2.786 abc |
| BRS Campeiro | 2.738 abcd |
| BRS Estilo | 2.711 abcd |
| IPR Tuiuiú | 2.670 bcd |
| IPR Gralha | 2.657 cd |
| IPR Campos Gerais | 2.618 cde |
| IPR Tangará | 2.499 de |
| IPR Uirapuru | 2.414 e |
| IPR 81 | 2.386 e |
| IPR Curió | 1.964 f |

* Mean values followed by different letters in the same column are statistically different by Duncan's test ($P < 0.05$). Least significant difference (LSD) = 260.39.

The cultivar IPR Curió, exhibited the lowest grain yield compared to other cultivars (Table 5). This low yield can be attributed to the earliness traits of this cultivar, which has an average cycle of 70 days (MAPA, 2016), (Table 1).

It should be noted that all the bean cultivars evaluated in this research have the genetic potential to provide a grain yield higher than the average of Brazil and Paraná, allowing the farmers to obtain greater profitability with the harvest and to assure their permanence in the agricultural activity.

## Conclusion

The high-technology management of when compared to low-technology management, enables the achievement of greater yield of bean grown during the second-season period, increasing the probability of farmer get increased profitability economic with culture. The BRS Pérola cultivar stood out among evaluated cultivars, showing to be a good choice for get high grain yield.

It is noteworthy that this study, does not indicate the high-technology management with higher productivity also provided greater profitability, since the economic analysis of the costs involved in bean production using high and low technology was not conducted, which encourages further studies in this same line of research, also considering the economic analysis in order to obtain more detailed information.

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