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Initial growth characterization of bean genotypes (*Phaseolus vulgaris* L.) cultivated in lowland soil

Caracterização do crescimento inicial de genótipos de feijão (Phaseolus vulgaris L.) cultivado em solo de várzea

Vinícius Jardel Szareski
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

Cristian Troyjack
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

João Roberto Pimentel
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

Ivan Ricardo Carvalho
Universidade Regional do Noroeste do Estado do Rio Grande do Sul, Brazil

Gustavo Henrique Demari
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

Márcio Peter
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

Francielen Lima da Silva
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

Liriana Lacerda Fonseca
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

Francine Lautenchleger
Universidade Estadual de Londrina, Londrina, Paraná, Brazil

Queiróz de Souza
Universidade Federal do Pampa, São Gabriel, Rio Grande do Sul, Brazil

Isabela da Rosa Bersch*
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

Francisco Amaral Villela
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

Tiago Zanatta Aumonde
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

Tiago Pedó
Universidade Federal de Pelotas, Capão do Leão, Rio Grande do Sul, Brazil

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***Autor de correspondencia:** isa1_rosa@yahoo.com.br

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Abstract

The objective was to evaluate the initial performance of the bean genotypes grown in lowland soil in the state of Rio Grande do Sul. The experiment was conducted in the 2015/2016 agricultural harvest, in a chapel greenhouse, arranged in the North-South direction, covered with polycarbonate and equipped with temperature controllers, located under the coordinates 31º 52'00 " South latitude and 52º 21'00 "west longitude with an altitude of 13 meters, this structure is located at the Federal University of Pelotas. The experiment was carried out in a randomized block design with five bean genotypes (IPR Tuiuiú, Carioca, Mouro, BRS Guabiju and BRS Embaixador) and four initial collection periods (9 DAS, 13 DAS, 17 DAS and 21 DAS), arranged in five replicates. The different bean genotypes reveal dissimilar initial growth rates in the face of the adversities imposed by lowland soils. The BRS Guabiju genotype is superior to the others for initial growth and is more acclimatized to the soils of the extreme south of Rio Grande do Sul.

Keywords: *Phaseolus vulgaris* L., seed production, crop, Brazil

Resumo

O objetivo foi avaliar o desempenho inicial de genótipos de feijão cultivados em solos de várzea no estado do Rio Grande do Sul. O experimento foi conduzido na safra agrícola 2015/2016, em uma capela-estufa, disposta no sentido Norte-Sul, recoberta com policarbonato e equipada com controladores de temperatura, localizada sob as coordenadas 31º 52'00 "latitude sul e 52º 21'00 “Longitude oeste com altitude de 13 metros, esta estrutura está localizada na Universidade Federal de Pelotas. O experimento foi conduzido em delineamento de blocos casualizados com cinco genótipos de feijão (IPR Tuiuiú, Carioca, Mouro, BRS Guabiju e BRS Embaixador) e quatro períodos iniciais de coleta (9 DAS, 13 DAS, 17 DAS e 21 DAS), dispostos em cinco. Os diferentes genótipos de feijão revelam taxas de crescimento inicial diferentes em face das adversidades impostas pelos solos de várzea. O genótipo BRS Guabiju é superior aos demais para crescimento inicial e está mais aclimatado aos solos do extremo sul gaúcho.

Palavras-chave: *Phaseolus vulgaris* L., produção de sementes, colheita, Brasil

INTRODUCTION

Bean (*Phaseolus vulgaris* L.) stands out in Brazil for being part of the basic human diet and because it is one of the main crops sown in the offseason period in irrigated systems, in the central and southeastern region of Brazil (Reifschneider et al., 2015; Pedó et al., 2016), with production of 3.4 million tons of grain in the 2017/2018 harvest, where Rio Grande do Sul contributed approximately 3% of this amount (Conab, 2018).

In Rio Grande do Sul, the lowland soils occupy an area that corresponds to 20% of the available agricultural areas. Soils are flat to mildly hilly, developed with varying conditions of drainage deficiency. In these sites, the extensive systems of beef cattle and irrigated rice by a water depth occur (Gomes et al., 2002).

The permanent or temporary flooding of the soil modifies the biotic relationships, causing oxygen deficiency, reducing aerobic respiration and promoting the unavailability of certain nutrients to the plants. During these stress conditions, the molecular oxygen is consumed by the aerobic microorganisms, being replaced by the anaerobic ones, causing an environment of reduction and accumulation of CO_2 (Meurer, 2017).

Therefore, the dry matter partition consists of the amount of biomass accumulated by the plant in the different organs during the life cycle, it is important in the study of the plant because it influences the carbon allocation in different plant structures (Guimarães et al., 2002; Carvalho et al., 2018). The assimilates that come from the leaves that reveal positive liquid productive rate, in general, are directed to the nearest drains. The leaves, according to their age or position, can export these through a preferential sense, thus, higher young leaves export to the apex, and lower mature leaves export to the roots, intermediates export to both directions (Lopes and Lima, 2015; Demari et al., 2018).

Several studies were carried out using the technique of partitioning the assimilates and the growth of cultivated plants under different management conditions or productive capacity. This analysis makes it possible to evaluate the contribution of different plant structures to the accumulation of dry matter, which allows an estimation of the development and contribution of morpho physiological processes to plant growth, development and productivity (Peixoto and Peixoto, 2009).

In order to increase the grain yield per unit area, breeding programs have been supplying the Brazilian market with new cultivars annually, in order to identify genotypes with better performance, being tolerant to edaphic climatic stress conditions, but which can maintain their productive performance and seed quality (Peske et al., 2012; Troyjack et al., 2017; Szareski et al., 2018). In this context, the objective was to evaluate the initial performance of the bean genotypes grown in lowland soil in the state of Rio Grande do Sul.

MATERIALS AND METHODS

CONDUCTION OF STUDY AND EXPERIMENTAL DESIGN

The experiment was conducted in the 2015/2016 agricultural harvest, in a chapel greenhouse, arranged in the North-South direction, covered with polycarbonate and equipped with temperature controllers, located under the coordinates 31º 52'00 " South latitude and 52º 21'00 "west longitude with an altitude of 13 meters, this structure is located at the Federal University of Pelotas, Capão do Leão municipality, state of Rio Grande do Sul, Brazil. The climate of the region, according to Köppen is characterized as subtropical Cfa.

The sowing was carried out in polyethylene trays with capacity of six liters, containing substrate from the Solodic Eutrophic Haplic Planosol soil of the A1 horizon belonging to the Pelotas mapping unit (Streck et al., 2008), previously corrected according to CQFS-RS/SC (2004) analysis and recommendation. Irrigation was performed periodically and soil was maintained at field capacity.

For the field establishment, seeds of the genotypes IPR Tuiuiú (Tu), Carioca (Ca), Mouro (Mo), BRS Guabiju (Pe) and BRS Embaixador (Ve), with germination higher than 95%, were used. They were produced in the municipality of Capão do Leão - RS.

TRAITS MEASURED

The initial growth characteristics were evaluated using four successive collections at regular intervals of four days after emergence of the seedlings (50% of the emerged seedlings), these being nine DAS, 13 DAS, 17 DAS and 21 DAS (days after sowing). For each genotype and collection 10 random and homogenous seedlings in each experimental unit were sampled. Afterwards, the following characters were measured:

Diameter of the hypocotyl (D_a): measured by means of a digital caliper, result expressed in millimeters (mm).
Total dry matter (W_t): the seedlings were stratified as to their organs, after cleaning the dirt, they were directed to a forced ventilation oven at 70 ± 2 ° C, until obtaining the constant mass, results expressed in milligrams (mg).
Leaf area (A_l): determined by a LI-COR LI-3100® model meter, where the leaf area index was obtained after the equation:

$$G = Umf / St$$

Being: Umf the leaf area and St the surface of the soil, which was covered by the plant.

The instantaneous values of the dry matter production rate were determined by adjusting the derived equations for the total dry matter related to the time of seedling collection (1967). The instantaneous values of *leaf area ratio* (F_a) (cm² mg $^{-1}$), *leaf mass ratio* (F_w) (mg mg $^{-1}$) and *specific leaf area* (S_a) (cm² mg^{-1}) were estimated using the Radford equations (Radford, 1967), as follows:

$$Fa = Al / Wt$$
$$Fw = Wf / Wt$$
$$S = Al / Wf$$

Being: Leaf area (Al), total accumulated dry matter (Wt), leaf dry matter (Wf),

The *dry matter partition* between the different plant structures (roots, stems and leaves) during the initial growth of the plants were determined separately, then the dry mass allocated to each plant structure was considered, followed by a percentage adjustment.
The experiment was carried out in a randomized block design, with five bean genotypes (IPR Tuiuiú, Carioca, Mouro, BRS Guabiju and BRS Embaixador) and four initial collection periods (nine DAS, 13 DAS, 17 DAS and 21 DAS), arranged and five replicates.

STATISTICAL ANALYSIS
The data were submitted to the assumptions of the statistical model, after that, the analysis of variance at 5% of probability was used to identify interaction between the genotypes x times of seedlings collection, where emphasis was given to the dismemberment of the quantitative effects and the best fit of the highest significant degree of the polynomial at 5% by the t test.

RESULTS

The analysis of variance showed that there was a significant effect ($p < 0.05$) for the primary growth data of hypocotyl diameter, total dry matter, leaf area. The hypocotyl diameter (Da) presented similar behavior for the five genotypes tested in relation to the increment of days after sowing (Figure 1a), but BRS Guabiju genotype revealed the highest magnitudes for this character, with a mean of 22.2 mg at 21 days after sowing (DAS), this being 26% higher than the IPR Tuiuiú (Tu) genotype, lower for this character in the same evaluation period.
The leaf area (Al) during the whole growth period showed an increase over the days after sowing of the genotypes (Figure 1b). Superiority for this character was evidenced at 21 DAS through genotype BRS Embaixador, under these conditions less leaf area was revealed by Carioca genotype being this 41% inferior to the best genotype relative to this character.
The total dry matter (Wt) of the seedlings was increased by increasing the initial growth collections for all the bean genotypes studied, however, the highest accumulation follows the trend of the previous traits being at 21 DAS higher for the BRS Embaixador genotype (1680 mg) followed by Mouro (1530 mg) and BRS Guabiju (1314 mg) (Figure 1c). Less emphasis is attributed to the Carioca genotype being this 50% lower than the genotype BRS Embaixador, and IPR Tuiuiú with 37% inferior.
The ratio of leaf area (Fa) of genotypes BRS Embaixador (Ve), IPR Tuiuiu (Tu) and Mouro (Mo) was reduced over the evaluation periods, but for the Carioca (Ca) genotype, an increase was observed in the ratio of leaf area on the 14th day after sowing, and progressive reduction after this

period. The behavior of the genotype BRS Guabiju (Pe) was maximized at seventeen days after sowing and was maintained throughout the study (Figure 1d).

The leaf mass ratio (Fw) was similar for the IPR Tuiuiú (Tu), Carioca (Ca), BRS Embaixador (Ve) and BRS Guabiju (Pe) genotypes, which increased throughout the measurement periods. The Mouro (Mo) genotype increased this ratio up to fifteen days after sowing with subsequent reduction (Figure 1e).

For the specific leaf area (Sa) the genotypes Mouro (Mo), BRS Embaixador (Ve) and IPU Tuiuiú (Tu) were similar throughout the evaluation periods. The genotype BRS Guabiju (Pe) showed a slight increment for the specific leaf area along the measurements, remaining constant throughout the time elapsed. The Carioca (Ca) genotype increased the specific leaf area up to fourteen days (Figure 1f).

There was similarity in dry matter partitioning in all seedling, stem, leaf and root structures of the five bean genotypes evaluated (Figure 2), and a slight increase in root dry matter partitioning is also observed (Figure 2A, B and C).

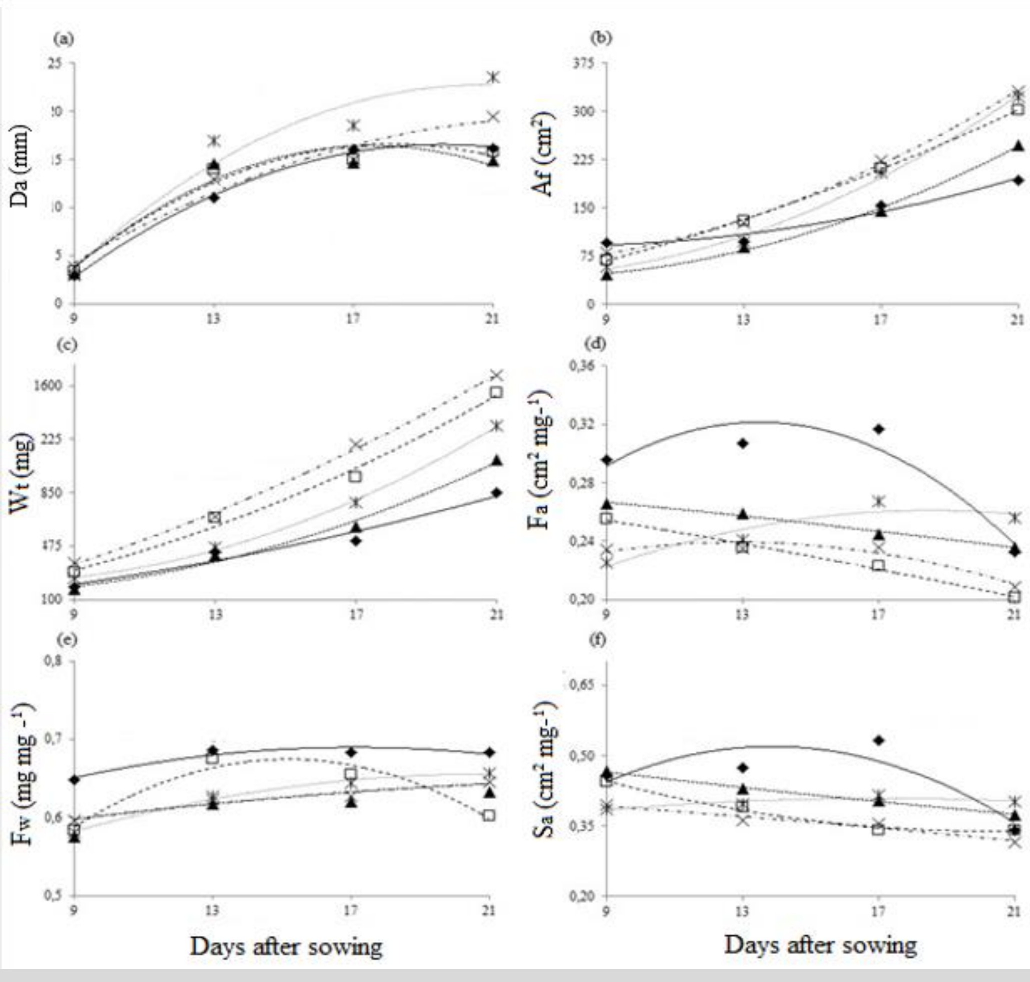

FIGURE 1

Diameter of hypocotyl (Da) (a), leaf area (Al) (b), total dry matter (Wt) (c); leaf area ratio (Fa) (d); leaf mass ratio (Fw) (e) and specific leaf area (Sa) (f) in bean plants (Phaseolus vulgaris L.) of genotypes Carioca (—♦—), Mouro (--□--), IPR Tuiuiú (⋯▲⋯), BRS Embaixador (-·✕·-) e BRS Guabiju (⋯✳⋯).

TABLE 1
Regression equation and coefficient of determination (R^2) of the hypocotyl diameter (Da), leaf area (Af), total dry matter (Wt); leaf area ratio (Fa); leaf mass ratio (Fw) and leaf area (Sa) in bean (Phaseolus vulgaris L.) genotypes of Carioca (Ca), Mouro (Mo), IPR Tuiuiú (Tu), BRS Embaixador (Ve) and BRS Guabiju (Pe).

Character	Genotype	Regression equation	R²	Character	Genotype	Regression equation	R²
Da	Ca	Y=-30,6+4,82x-0,12x²	0,99	Fa	Ca	Y=0,05+0,04x-0,002x²	0,89
	Mo	Y=-33,6+5,55x-0,15x²	0,95		Mo	Y=0,28-0,003x-5E-05x²	0,99
	Tu	Y=-37,1+6,11x-0,17x²	0,93		Tu	Y=0,28-0,002x-3E-0,5x²	0,98
	Ve	Y=-20,6+3,43x-0,07x²	0,96		Ve	Y=0,16+0,01x-0,0004x²	0,92
	Pe	Y=-36,6+5,74x-0,14x²	0,94		Pe	Y=0,12+0,02x-0,0004x²	0,88
Af	Ca	Y=120,2-8,22x+0,56x²	0,96	Fw	Ca	Y=0,51=0,02x-0,001x²	0,91
	Mo	Y=22,1+5,87x+0,45x²	0,99		Mo	Y=0,15+0,06x-0,002x²	0,94
	Tu	Y=77,0-11,77x+0,94x³	0,99		Tu	Y=0,53+0,008x-0,0001x²	0,94
	Ve	Y=70,4-7,94x+0,97x²	0,99		Ve	Y=0,53+0,008x-0,0001x²	0,94
	Pe	Y=83,0-14,12x+1,22x²	0,99		Pe	Y=0,43+0,02x-0,001x²	0,99
Wt	Ca	Y=-10,18+12,27x+1,31x²	0,95	Sa	Ca	Y=0,09+0,08x-0,003x²	0,77
	Mo	Y=-12,81+6,72x+3,18x²	0,98		Mo	Y=0,68-0,03x+0,001x²	0,98
	Tu	Y=238,27-338,42x+3,7x²	0,98		Tu	Y=0,55-0,01x+9E-05x²	0,99
	Ve	Y=-189,48+37,58x+2,45x²	0,99		Ve	Y=0,43-0,004x-8E05x²	0,95
	Pe	Y=415,81-63,47+5,06x²	0,99		Pe	Y=0,29+0,01x-0,0004x²	0,79

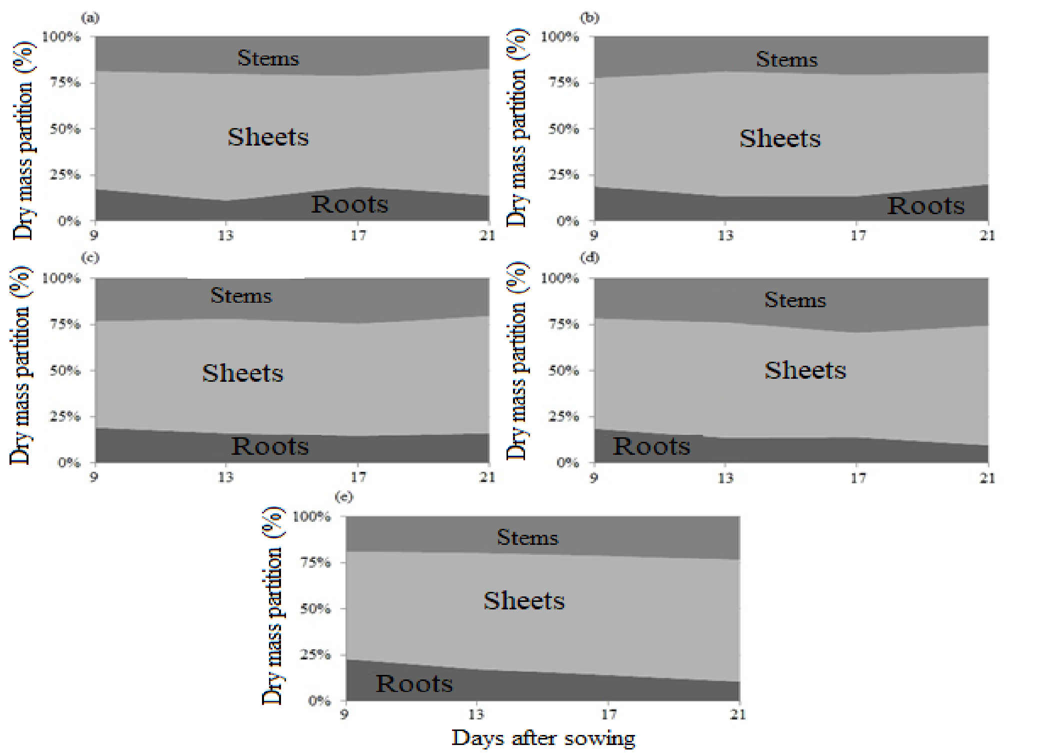

FIGURE 2
Partition of dry matter in different structures of bean (Phaseolus vulgaris L.) plants Carioca (a), Mouro (b), IPR Tuiuiú (c), BRS Embaixador (d) and BRS Guabiju (e), measured until 21 days after sowing.

DISCUSSION

The diameter of the hypocotyl is an effective indicator of the bean's architecture and can support evaluation by grades according to the bean crop (Silva et. al; 2009). Another study proved a correlation between plant architecture characters and the general adaptation index, therefore the fact that these characters are correlated increases the chances of success in the selection of plants with architecture that best adapt to the region and also facilitate mechanized harvesting and reduce the incidence of diseases by avoiding contact of the pods with the soil (Santos, 2020).

The magnitude of the leaf area is essential to supply the photosynthetic demand of the plants, to potentiate the light interception, use of water and nutrients, as well as to reflect these attributes in productive potential (De Souza Lima et al., 2008; Szareski et al., 2016; Aisenberg et al., 2016). Therefore, for this trait we observed an increasing and satisfactory evolution for the genotypes in general, and a considerable increase 21 days after sowing, contributing to light absorption and, consequently, to their establishment in the field.

The success in establishing the culture directly reflects on its performance, and the leaf area stands out when we mention light interception, because under restriction of light incidence, lateral redistribution of auxin occurs to the epidermis and cortical cells of the hypocotyl, causing the elongation of these tissues. Furthermore, plant species have the capacity to adapt to different biotic and abiotic stresses, causing changes in plant growth and development, such as stem length, dry matter, leaf area, among other characteristics (Martuscello et al., 2009).

The increase of the initial leaf area can result in the superior production of photoassimilates, being these destined to the growth and development of the plants and with that to improve the conditions of capture of the photosynthetically active energy (Aumonde et al., 2013). As leaves are the main photosynthetic organs of plants, the reduction of leaf area can compromise the interception of light energy and minimize the magnitude of carbon allocated in the morphological structures of plants (Pedó et al., 2013). The energy stored in the carbon compounds can be directed to the structural maintenance, growth and development of the plants (Taiz et al., 2017).

The increase in leaf area, added to the magnitude of synthesized assimilates that are directed to the growth and development of the bean plant corroborate the increase in the production of dry matter in the crop (Pedó et al., 2013).

The similarity of the leaf mass ratio for different genotypes, as well as the increase in the proportion after sowing with subsequent reduction are explained by the greater allocation of dry matter in the leaves at the beginning of growth, which can result in metabolic drainage at the beginning of the development of seedlings beans (Pedó et al., 2015; Koch et al., 2018).

As for the partition of dry matter in the different evaluated structures and the similarity observed in all seedling, stem, leaf and root structures of the evaluated genotypes, it is clearly observed that the plant directs its assimilates in the leaves during initial growth. And even so, it directs a large part of these to the development of the stem and root responsible for the fixation and absorption of water and nutrients. It can be said that the increase in the partition of dry matter from the roots culminated in the increase in adventitious roots, which is a mechanism of plant adaptation (Vieira et al., 2010).

CONCLUSION

The different bean genotypes reveal dissimilar initial growth rates in the face of the adversities imposed by lowland soils. The BRS Guabiju genotype is superior to the others for initial growth and is more acclimatized to the soils of the extreme south of Rio Grande do Sul.

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