



THE INFLUENCE OF SEED SIZE AND SOWING DEPTH ON THE INITIAL DEVELOPMENT OF PEANUTS

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Abstract

Seed size and sowing depth directly influence the initial development of peanut plants (*Arachis hypogaea* L.). This study aimed to evaluate the influence of seed size and sowing depth on the initial development of peanuts. The experimental design was in a 2x5 factorial scheme, with the first factor consisting of small seeds weighing between 170 and 485 mg and large seeds weighing between 486 and 800 mg, interacting with five depths: one, two, four, eight, and 12 cm, totaling 10 treatments and four replicates, totaling 40 plots or pots. The seed weighing between 486 and 800 mg showed the best initial development of the peanut crop. The peanut showed best development when sown at a depth of between 5.0 and 6.0 cm. Sowing above 12 cm negatively interferes with the initial development regardless of the seed size in the peanut crop. During crop establishment, the producer should consider seed size and planting depth to ensure the maximum number of plants per area.

Keywords: *Arachis hypogaea* L.; sowing; seedlings; early development.

A INFLUÊNCIA DO TAMANHO DA SEMENTE E A PROFUNDIDADE DE SEMEADURA NO DESENVOLVIMENTO INICIAL DO AMENDOIM

Resumo

O tamanho da semente e a profundidade de semeadura influenciam diretamente no desenvolvimento inicial das plantas de amendoim (*Arachis hypogaea* L.). Este estudo teve como objetivo avaliar a influência do tamanho da semente e da profundidade de semeadura no desenvolvimento inicial do amendoim. O delineamento experimental foi em esquema fatorial 2x5, sendo o primeiro fator constituído por sementes pequenas com peso entre 170 e 485 mg e sementes grandes com peso entre 486 e 800 mg, interagindo com cinco profundidades: um, dois, quatro, oito, e 12 cm, totalizando 10 tratamentos e quatro repetições, totalizando 40 parcelas ou vasos. As sementes com

peso entre 486 e 800 mg apresentaram o melhor desenvolvimento inicial da cultura do amendoim. O amendoim apresentou melhor desenvolvimento quando semeado na profundidade entre 5,0 e 6,0 cm. A semeadura acima de 12 cm interfere negativamente no desenvolvimento inicial independentemente do tamanho da semente na cultura do amendoim. Durante a implantação da cultura o produtor deverá considerar o tamanho da semente e a profundidade de semeadura para garantir o máximo número de plantas por área.

Palavras-chave: *Arachis hypogaea* L.; semeadura; plântulas; desenvolvimento inicial.

Introduction

The state of São Paulo is the largest producer, manufacturer and marketer of peanuts (*Arachis hypogaea* L.) and its derivatives (Singh *et al.*, 2024). The main causes that contribute to low productivity in its traditional areas include: the lack of good seed quality and improper cultural practices in management during the crop cycle (Syed *et al.*, 2020).

Costs have historically been high, as large quantities are required to overcome the problems associated with low physiological potential (germination and vigor) and achieve the initial stand expected for each cultivar (Martin *et al.*, 2021). These elements are essential to ensure maximum expression of the plant's genetic potential, directly influencing water absorption, seedling emergence, initial crop establishment and, ultimately, crop yield (Machado *et al.*, 2022).

Peanut development goes through several distinct phases, from seed germination to fruit maturation (Xu *et al.*, 2020). During this cycle, the plant faces a number of challenges, including competition for resources such as water, sunlight and soil nutrients, as well as exposure to diseases, pests and abiotic stresses such as drought and extreme temperatures (Santos *et al.*, 2022), which makes it necessary to have a greater quantity of nutrients from the reserve tissues present in the cotyledons of the seeds, which leads to an understanding of the influence of seed size at the time of sowing.

To ensure maximum productivity, care must be taken in crop management throughout its cycle. Among the agronomic factors that influence germination, initial growth and final peanut productivity, seed size and sowing depth are among the most critical (Silva *et al.*, 2020). The effects of seed size and sowing depth directly influence various stages of plant growth, development and establishment in the environment in which it is being cultivated, where they have been observed by many researchers. (Umeoka; Ogonnaya, 2016; Limede *et al.*, 2017).

To improve production during harvest, the effects of various agronomic characteristics have been sought, such as seed classification according to their size and sowing depth as the main factors that determine seed germination (Jarrar *et al.*, 2023).

It is clear that larger seeds tend to provide advantages in the initial establishment of seedlings, contributing to more robust development and better resistance to adverse conditions (Kimmelshue *et al.*, 2022a). Furthermore, determining the optimum seeding depth is crucial to ensure efficient seedling emergence, considering the potential effects of desiccation and damage by insect pests and diseases (Draves *et al.*, 2025; Thiyam *et al.*, 2017). Normally, the sowing depth for peanuts is between 4 and 8 cm, but due to errors in the seeder settings (Zheng *et al.*, 2020), sowing at a greater depth (above 8 cm) may occur, which requires greater energy consumption from the cotyledons for germination to occur uniformly and not compromise the number of plants per hectare.

In this sense, the application of management practices that take these factors into account, such as the careful selection of seeds and the appropriate sowing depth, play equally important roles in the success of production. It can result in significant gains in the productivity and sustainability of peanut cultivation (Kimmelshue *et al.*, 2022b).

This study aimed to evaluate the influence of seed size and sowing depth on the initial development of peanuts.

Material and Methods

Characterization of the location

The experiment was carried out at the Andradina Educational Foundation – FEA, located in the city of Andradina, state of São Paulo. With geographic coordinates 20°53'26.440"S and 51°22'24.632"W, with an altitude of 405 m above sea level. The local climate is classified as Cwa according to Koppen, characterized by hot summer and dry winter seasons, with the months from November to March having the highest rainfall index. The annual average temperature varies between 30.4°C maximum and 19.2°C minimum, average annual accumulated precipitation of 1311.6 mm and average relative humidity of 78%. Pots with a volumetric capacity of nine dm³ were used and were filled with soil originating from the 0-0.3 m layer classified as hypoferric Red Latoso (EMBRAPA, 2013) and presents the following chemical attributes, as shown in Table 1.

Table 1. Chemical attributes of the soil used in the experiment.

pH	OM	P	K	Ca	Mg	H+Al	Al	SB	CEC	V%	m%
CaCl ₂	g dm ⁻³	mg dm ⁻³	-----			mmol _c dm ⁻³	-----				
5,9	11	21	2,0	19	7,0	15	0	28	43	65	0

OM: Organic matter; **SB:** Sum of bases; **CEC:** Cation exchange capacity; **V%:** Base saturation; **m%:** Aluminum saturation.

Experimental design and treatments

The experimental design was in a 2x5 factorial scheme, with the first factor consisting of small seeds weighing between 170 – 485 mg and large seeds weighing between 486 – 800 mg, interacting with five depths, namely: one, two, four, eight and 12 cm, totaling 10 treatments and with four repetitions, totaling 40 plots or pots.

Installation and conduct of the experiment

The soil was fertilized according to the requirements of peanut cultivation, according to Raij *et al.* (1996), and then six viable seeds of peanut cultivar OL3 were sown with the respective treatments. During the experiment, the pots were irrigated until reaching field capacity and all cultural treatments were performed.

Development parameters

At 30 days after sowing, the following parameters were measured: plant height (PH) and root length (RL) determined through the use of a tape measure graduated in millimeters; total number of leaflets (NL) determined through direct counting on the plant; stem diameter (SD) determined two cm above soil level and a caliper graduated in millimeters was used. At the same time, the total dry masses of the shoot and root (SDM and DMR) were determined, which was obtained through drying in a circulation and air renewal oven at a constant temperature of 65°C until they reached constant weight.

Statistical analysis

The variables were subjected to normality tests where the Shapiro-Wilk test was used, after meeting the test precepts, the analysis of variance was performed using the F test ($p < 0.05$), for the qualitative factor, the seed sizes, their means compared by the Tukey test at 5% probability (Banzatto; Kronka, 2013) and for the quantitative factor, the depths, the polynomial regression analysis was performed where the linear, quadratic and cubic models were tested, where their significance and their coefficient of determination R^2 were considered (R Core Team, 2019).

Results and discussion

A significant interaction was observed between the seed size and sowing depth factors for PH as shown in Table 2.

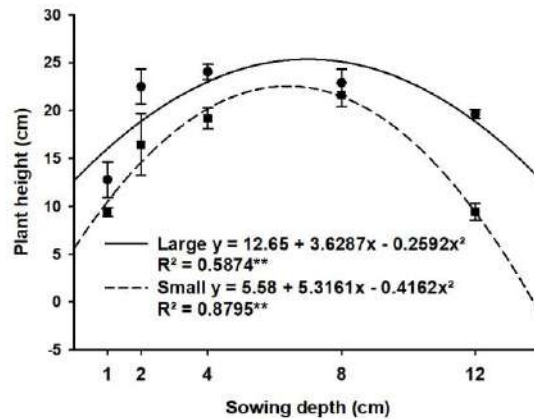
Table 2. Average values of plant height (PH), root length (RL), stem diameter (SD) and leaf number (NF) of peanuts cultivated with different seed sizes and peanut sowing depths.

Size (S)	PH (cm)	RL (cm)	SD (cm)	NL
Small	15.23b	24.25b	0.28b	77.65b
Large	20.37a	33.60a	0.31a	91.95a
MSD	0.99	4.15	0.01	5.33
p-value (S)	0.0001**	0.0001**	0.0072**	0.0001**
Depth (D)				
1.0 cm	11.10d	17.93c	0.30a	73.87c
2.0 cm	19.47b	29.25b	0.31a	83.12bc
4.0 cm	21.61ab	27.44b	0.31a	90.00b
8.0 cm	22.28a	41.07a	0.31a	105.50a
12 cm	14.52c	28.93b	0.31a	71.50c
MSD	2.23	9.32	0.03	11.98
p-value (P)	0.0001**	0.0001**	0.0602ns	0.0001**
p-value SxT	0.0001**	0.0308*	0.0514ns	0.0184*
OM	17.80	28.92	0.29	84.80
CV%	8.63	22.22	9.20	9.74

MSD = Minimum significant difference. ** = Significant at 1% probability level ($p < 0.01$); * = significant at 5% probability level ($0.01 = p < 0.05$); **Ns** = not significant ($p \geq 0.05$). Means followed by the same letter in the row do not differ statistically. Tukey's test was applied at 5% probability. **Overall Mean:** Overall mean. **CV:** Coefficient of variation.

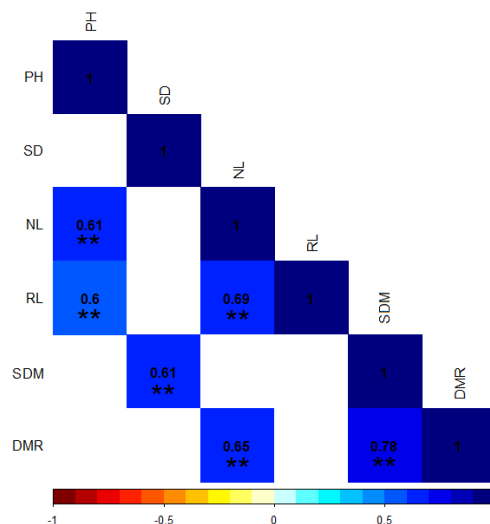
Peanut plants originating from larger seeds presented higher average values and had a maximum development point at a depth of 6.99 cm, which represented a difference of approximately 25.23% greater than plants originating from smaller seeds and cultivated at a depth of 6.38 cm, as demonstrated in Figure 1.

Figure 1. Regression analysis of peanut plant height (PH) as a function of small seeds (170 – 485 mg) and large seeds (486 – 800 mg) at different sowing depths.



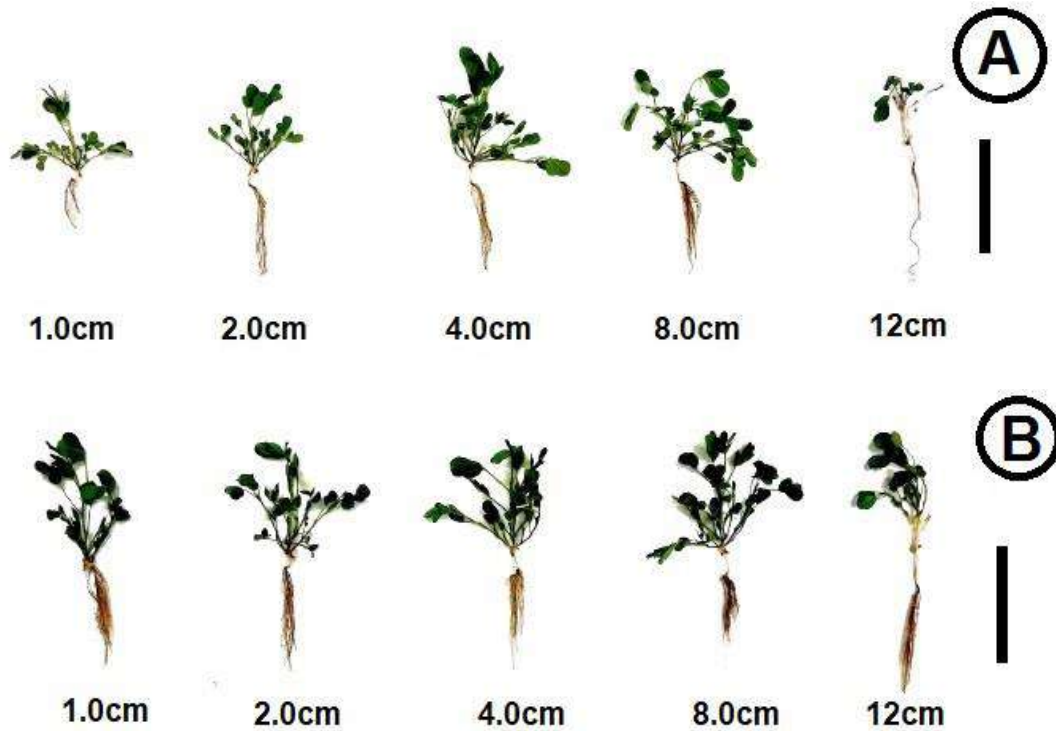
Plants require nutrients from the cotyledons in their initial phase. This availability made it possible for them to develop within the soil and thus overcome the soil layer until they reach the external environment (Kimmelshue *et al.*, 2022a; b), because they do not yet have the ability to carry out photosynthesis, in this way, the larger seeds enabled the development of larger plants. When the emergence of the plant on the surface of the soil occurs more quickly, it allows the expansion of the primary leaves to begin more quickly and thus ensuring a speedy start to photosynthesis, it begins to accumulate carbon in its dry mass of the roots and increase the number of leaves, thus showing that the height of seedlings (PH) correlated positively with the NL and RL as shown in Figure 2.

Figure 2. Significant Pearson correlations between the variables evaluated in peanut plants grown at different sowing depths and seed size. PH = plant height; SD = stem diameter (SD); NL = leaf number; RL = root length; SDM = shoot dry mass and DMR = root dry mass (DMR).



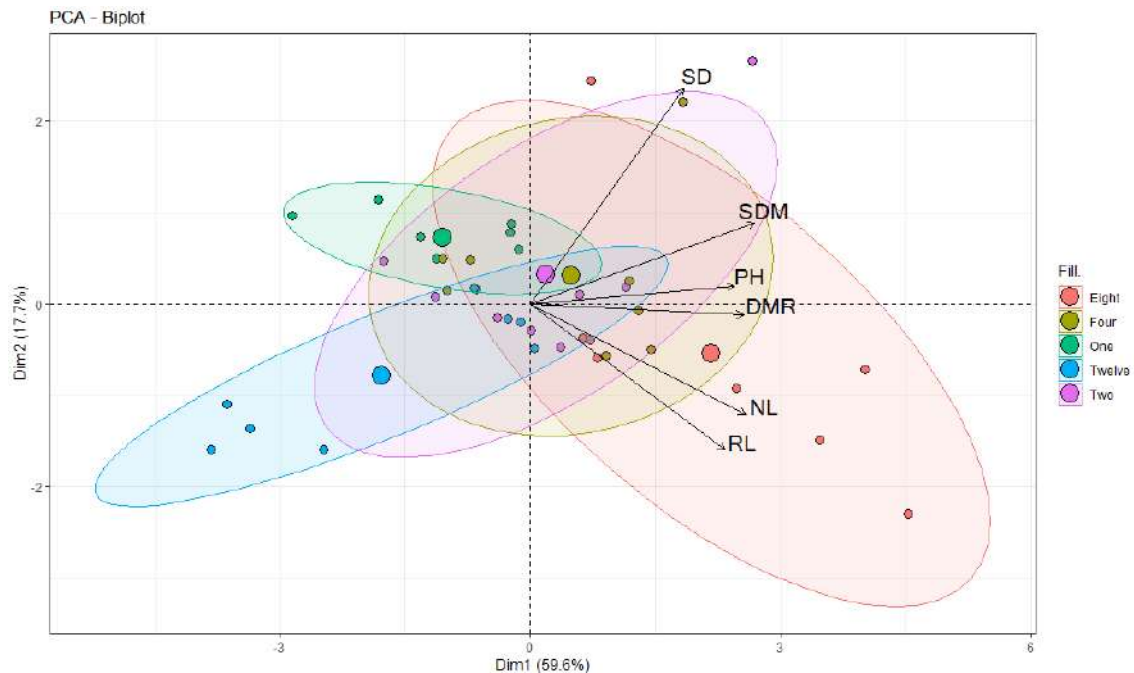
Greater seeding depths negatively influence the initial development of plants as demonstrated by Yang *et al.* (2021) and Alaamer *et al.* (2021). These differences can be seen in Figure 3, which shows peanut plants grown at different sowing depths and seed sizes.

Figure 3. Peanut plants grown at different sowing depths and seed sizes. A – Small seeds; B – Large seeds. Bar = 20 cm.



Sowing at a depth of eight centimeters contributed most to the average values of plant height (PH), root length (ERL), number of leaves (NL), and then to the dry mass of the aerial part and root (SDM and DMR), as observed in Figure 4.

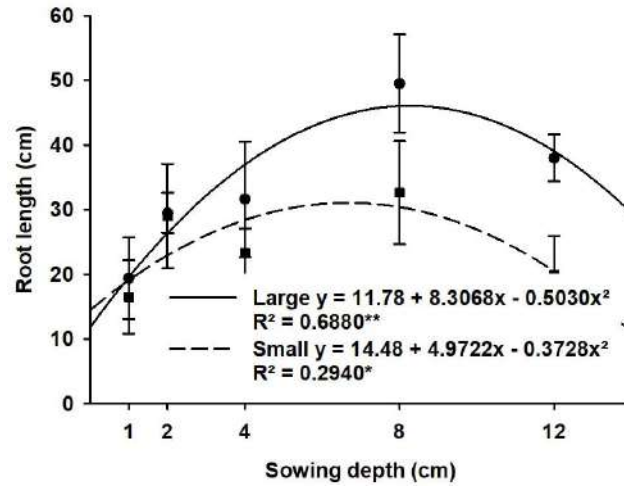
Figure 4. PCA and biplot analysis of the contribution of treatments to the means of the variables analyzed in peanut plants grown at different sowing depths and seed sizes. PH = plant height; SD = stem diameter (SD); NL = leaf number; RL = root length; SDM = shoot dry mass and DMR = root dry mass (DMR).



The size of the seedling can be compromised by the size or when mechanical damage occurs in the seed's cotyledon, as this reduces the availability of nutrients for the growth of the embryo, affecting the height of the aerial part in the initial stages (Lapaz *et al.*, 2017; Lapaz *et al.*, 2020). When the seedling emerges more quickly, it accelerates the emission of the first leaves, proving the correlation between the height of the plant and the number of leaves (Figure 2). As the new leaves develop, there is an increase in the photosynthetic rate, which demands greater assimilation of water and nutrients by the roots, stimulating their growth. It is worth noting that sowing at the appropriate depth allows for good root development (Figure 4), since sowing at depths greater than 7.0 cm causes the plant to allocate more energy to the emergence of the aerial part instead of maintaining the balance between the aerial part and the root.

An interaction was observed between the factors for the root length of the plants (RL) when cultivated at different depths and seed size (Table 2), where the plants originated from larger seeds sown at a maximum depth of approximately 8.25 cm, which represented a difference of 27.82% higher in relation to the plants originated from small seeds cultivated at a maximum depth of 6.66 cm as demonstrated in Figure 5.

Figure 5. Regression analysis of peanut root length (RL) as a function of small seeds (170 – 485 mg) and large seeds (486 – 800 mg) at different sowing depths.



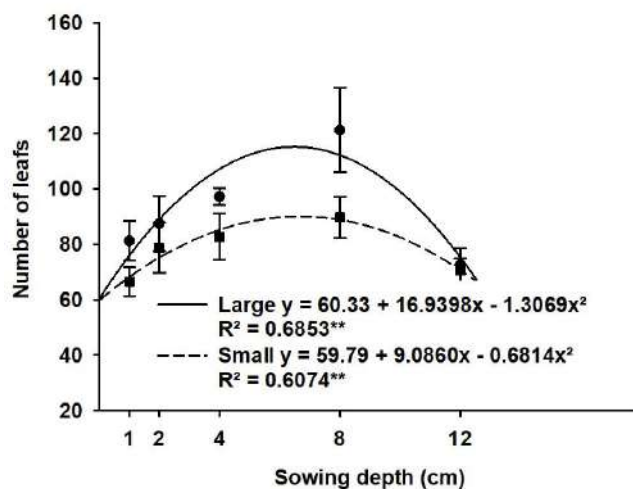
While the seedling received a greater amount of nutrients from the cotyledon of the larger seed, the initial development of the roots was also influenced (Figure 5), and showed a positive correlation with the PH (Figure 2). It is also worth noting that the sowing depth of 8.0 cm contributed to the greater root length (Figure 4), which allowed a balance in growth between the aerial part and the root. Similar responses were observed with the study of Draves *et al.* (2025); Limede *et al.* (2018) and Umeoka and Ogbonnaya, (2016). When sowing was done at a depth of 12 cm, the plant spent more energy on the emergence of the aerial part and less on the growth of the root, which is evident in Figure 3. The fact that choosing larger seeds may be a strategy to ensure greater development of the plant organs when they are under adverse sowing conditions (Table 2).

A statistical difference was observed only for seed size for SD, where plants originating from large seeds presented a higher average, which was 9.67% higher than plants originating from smaller seeds, as shown in Table 2. SD correlated positively with SDM as shown in Figure 2.

SD is a reflection of good development of the aerial part, thus showing a positive correlation between these characteristics (Figure 2), as plants that present etiolation growth characteristics have thinner stems and are likely to fall over (Armarego-Marriott *et al.*, 2019), a fact that the plant that emerged after sowing at the appropriate depth ensured good development of the stem diameter proportionally to the growth of the aerial part.

However, an interaction was observed between the factors for the number of leaves of the plants when grown at different depths and seed size (Table 2), where the plants originated from larger seeds sown at a maximum depth of approximately 6.48 cm, which represented a difference of 27.82% higher in relation to the plants originated from small seeds grown at a maximum depth of 6.66 cm as demonstrated in Figure 6. It also correlated positively with RL and DMR (Figure 2).

Figure 6. Regression analysis of number of leaves as a function of small seeds (170 – 485 mg) and large seeds (486 – 800 mg) at different sowing depths.



It is clear that the plant that emerged first had a greater NL, as it was exposed to sunlight before the seedlings that were still emerging at greater depth. The fact is that, when they are exposed to light, the synthesis of chlorophylls is stimulated, which then act in the photosynthetic process, and thus, the accumulation of dry mass is increased due to carbon fixation (Kimmelshue *et al.*, 2022a), and thus enabled greater root development, thus confirming a positive correlation between the NL (Figure 2). As the root develops, it explores the substrate, ensuring greater assimilation of nutrients and water that was destined for the leaves to carry out photosynthesis.

A statistical difference was observed in isolation between the factors for the dry mass of the aerial part as demonstrated in Table 3, where the plants originating from large seeds presented a higher average, which represented approximately 33.54% higher in relation to the plants originating from small seeds.

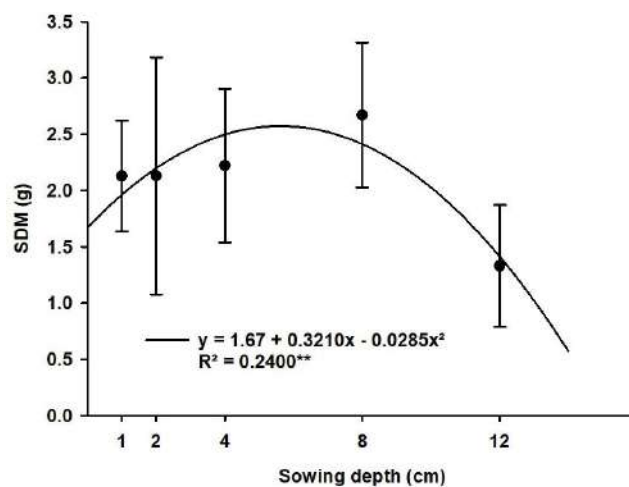
Table 3. Average values of shoot dry mass (SDM) and root dry mass (DMR) of peanuts cultivated with different seed sizes and peanut sowing depths.

Size (S)	SDM (g)	DMR (g)
Small	1.674b	0.189b
Large	2.519a	0.325a
MSD	0.369	0.051
p-value (S)	0.0001**	0.0001**
Depth (D)		
1.0 cm	2.129ab	0.289ab
2.0 cm	2.131ab	0.243bc
4.0 cm	2.223a	0.234bc
8.0 cm	2.671a	0.384a
12 cm	1.329b	0.133c
MSD	0.830	0.116
p-value (P)	0.0015**	0.0001**
p-value SxT	0.7155ns	0.0410*
OM	2.097	0.257
CV%	27.30	31.14

MSD = Minimum significant difference. ** = Significant at 1% probability level ($p < 0.01$); * = significant at 5% probability level ($0.01 \leq p < 0.05$); **Ns** = not significant ($p \geq 0.05$). Means followed by the same letter in the row do not differ statistically. Tukey's test was applied at 5% probability. **OM**: Overall mean. **CV**: Coefficient of variation.

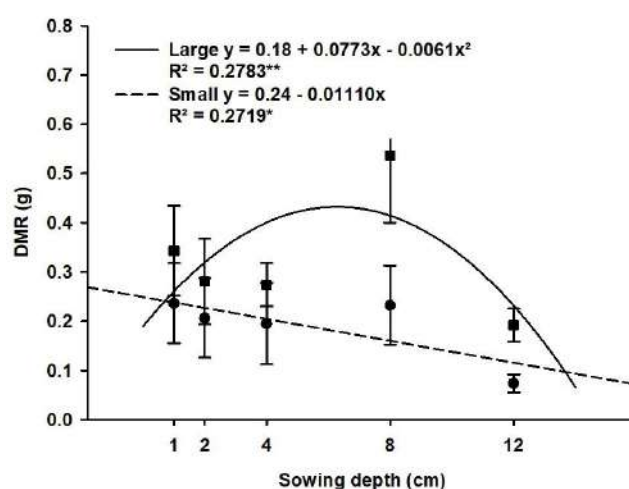
The dry DMAP of the plants cultivated at different depths showed a quadratic response, where the maximum sowing point was approximately 5.63 cm, as shown in Figure 8.

Figure 7. Regression analysis of shoot dry mass (SDM) as a function of small seeds (170 – 485 mg) and large seeds (486 – 800 mg) at different sowing depths.



An interaction was observed between the factors for root dry mass (RDM) when cultivated at different depths and seed size (Table 2), where plants originating from larger seeds showed a quadratic response, where the maximum depth was approximately 6.33 cm, which represented a difference of 41.84% higher in relation to plants originating from seeds that showed a linear response as demonstrated in Figure 8.

Figure 8. Regression analysis of peanut dry mass root (DMR) as a function of small seeds (170 – 485 mg) and large seeds (486 – 800 mg) at different sowing depths.



The seedlings developed from the larger seeds had an initial growth favored due to the greater availability of nutrients present in the seed cotyledons and also when sown at the

appropriate depth of 8.0 cm, which contributed to this result (Figure 4). Therefore, the seedlings started the photosynthesis process more quickly, which allowed for the largest SDM and DMR.

With the availability of nutrients for the embryo, it enabled the extrusion of the radicle more quickly, and thus accelerated the initial development of the seedling. When photosynthesis begins more quickly after the emergence of the aerial part, the photoassimilates are well used and redistributed inside the plant until they reach the root (Shakya *et al.*, 2018), showing this significant positive correlation between these dry masses of the aerial part and root (Figure 2). Further studies are needed to understand how seed size influences peanut crop in its initial phase, and whether it enables a better response when sown at non-recommended depths.

Conclusions

The seed weighing between 486 and 800 mg showed the best initial development of the peanut crop.

The peanut showed best development when sown at a depth of between 5.0 and 6.0 cm.

Sowing above 12 cm negatively interferes with the initial development regardless of the seed size in the peanut crop.

During crop establishment, the producer should consider seed size and planting depth to ensure the maximum number of plants per area.

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