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FERTILIZER APPLICATION DEPTH AND SOIL WATER CONTENT: EFFECT ON SEED PLANTABILITY OF A SEEDER IN DIRECT PLANTING

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ABSTRACT

Mechanization is key to increasing efficiency and productivity in agriculture. Therefore, it is important to understand these machines and their operating conditions to assess whether the quality of equipment operation has been satisfactory. Furthermore, planting windows have become increasingly narrower; therefore, an efficient planting operation is essential to ensure uniform stands with high yields. The objective of this study was to evaluate the effects of three soil water contents (28.7; 36.4 and 47.6%) and three fertilizer application depths (6.3; 11.3 and 14.8 cm) on the seed plantability of a direct planting machine. The experiment was arranged in a split-plot randomized block design, with three replications. The water contents were assigned to the plots and the fertilizer depths to the subplots.

Palavras-chave:
Semeadura direta
Phaseolus vulgaris L.
Espaçamento entre plântulas

EFEITO DA PROFUNDIDADE DE DEPOSIÇÃO DO ADUBO E TEOR DE ÁGUA NO SOLO NA PLANTABILIDADE DE UMA SEMEADORA EM SISTEMA DE PLANTIO DIRETO

RESUMO

A mecanização é fundamental para a eficiência e produtividade na agricultura. Portanto, é importante conhecer estes equipamentos e as condições de trabalho as quais eles são submetidos para que se possa avaliar se a qualidade operação realizada por eles tem apresentado um resultado satisfatório. Além do mais, com as janelas de plantio cada vez mais curtas, é indispensável que se tenha uma operação de plantio com eficiência e qualidade, buscando garantir um estande uniforme com boa produtividade. Objetivou-se neste trabalho avaliar os efeitos de três teores de água no solo (28,7; 36,4 e 47,6%) e três profundidades de deposição do adubo (6,3; 11,3 e 14,8 cm). O experimento foi instalado em um esquema de parcelas subdivididas, no delineamento em blocos casualizados com três repetições. Nas parcelas foram dispostos os teores de água e nas subparcelas, as profundidades de deposição do adubo.

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INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is, among the genus *Phaseolus*, the most grown species worldwide. It has great nutritional and socioeconomic importance in Brazil and abroad.

Brazil has an area of around 2.78 million hectares cultivated with common beans per year, with production of approximately 3.7 million tons, and average yield of 1101 kg ha^{-1}. The state of Paraná has the highest production, 0.53 million tons, followed by Minas Gerais with 0.52 million tons and Mato Grosso with 0.36 million tons (COMPANHIA NACIONAL DE ABASTECIMENTO - CONAB, 2023).

The direct planting system (DPS) has expanded widely into new crop fields due to its outstanding results. In Brazil, more than 32.8 million hectares are cultivated in this system, which corresponds to more than 85% of the area cultivated with grains (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE, 2017).

Direct seeders have components to cut through residue cover and to deliver fertilizer and seeds. However, the direct seeding process may vary and affect its results. If the quality of this operation is low, the success of the crop will be compromised (Bernardes *et al*., 2023).

Besides balanced fertilization, the depth of fertilizers can damage germination and root development also affecting adequate plant growth, and consequently, crop yield.

The rational use of water, especially in agriculture, is highly important in the economic and environmental scenario. Lack or excess of water can affect plant growth and development because of its influence on mechanical resistance to soil penetration, aeration and plant nutrition.

rom the foregoing, therefore, the objective of this study was to evaluate the effect of the fertilizer application depth and the soil water content on the planting quality of a seeder-fertilizer machine.

MATERIAL AND METHODS

The experiment was conducted at the Teaching Research and Extension Unit (UEPE) of the Agronomy Department of the Federal University of Viçosa, in Coimbra, MG (Figure 1). The facility is located between the coordinates 20º 49' 50'' south latitude and 42º 45' 54'' west longitude, 715 m average altitude.

The combination of three soil water contents (28.7; 36.4 and 47.6%) and three fertilizer application depths (6.3; 11.3 and 14.8 cm) was used in the direct planting of common beans. The soil of the experimental area is classified as a Cambic Red-Yellow Argisol, according to the Brazilian Agricultural Research Corporation - Embrapa (2018). The relief is mountainous and the climate Köppen´s classification is humid mesothermal (Cwa), with hot summers and dry winters (Alvares *et al*., 2014).

The soil water contents were obtained under center pivot irrigation with application rate of 2 mm h^{-1} and flow rate of 12.5 m^{3} h^{-1}. A FieldScout TDR-300 soil moisture meter was used and a calibration curve was created to correct the data. A curve was created using the standard gravimetric method based on the mass of soil dried in an oven at average temperature of 105°C for 24 hours, according to Embrapa (2017).

The soil samples were taken on the day of the sowing operation and the water content was determined in the 0 - 10 cm and 10 - 20 cm depths. Nine samples were collected in each experimental plot, from both depths.

The mass of vegetation cover was estimated using a 0.50 x 0.50 m wooden square quadrat. Samples were collected before the sowing operation. The quadrat was randomly thrown four times within each plot. The samples were packed in paper bags and kept in an oven at 65 ºC to constant mass. After drying, the results were expressed as t ha^{-1}, totaling 1417 kg of vegetation cover.

Soil penetration resistance was determined using a Falker's digital penetrometer PenetroLOG-PLG 1020 equipped with a type II cone rod. Ten points were sampled per plot, ranging from 0 to 20 cm deep, with 10 mm interval readings.

A 5705 John Deere® tractor, with average speed of 1.86 m s^{-1} using the third reduced gear and the auxiliary front-wheel drive activated pulled a Jumil® POP JM2670PD SH EX seeder-fertilizer, 2 seeding lines spaced 0.5 m apart, adjusted to deliver 12 seeds m^{-1} at 3.5 cm deep.

The common bean cultivar Ouro Vermelho, type II plant, elliptical seed shape, 100% germination rate, was used in the trial. Fertilization was carried out with 350 kg ha^{-1} of NPK in the 8-28-16 formulation.

To assess the planting performance of the seeder, we evaluated the uniformity of longitudinal distribution and seedling emergence (emergence percentage and average emergence time). After emergence stabilization, the spacings (Xi) were measured in ten meters, sampled in the two seeding lines of each experimental unit. Subsequently, the spacings were classified into multiples, acceptable and flawed as shown in Table 1, were expressed as percentage and calculated based on the total number found.

The methodology used for the attribution was proposed by Kurachi *et al*. (1989). The limits adopted in this study were defined by the range of variation in relation to a reference value, which was obtained depending on the spacing and the population.

After the seeder passed, the furrows were reopened by hand, at random points, to investigate the seed ditching depth. The percentage and average time of seedling emergence were determined in the two lines of the experimental units, by counting the number of seedlings emerged in each seeding line in an area of 5 m^2. The seedling counting began on the first day of emergence (seven days after sowing) and ended when seedling emergence was stabilized. The percentage of plant emergence was calculated as the ratio between the number of plants emerged after stabilization and the number of seeds delivered during sowing.

The average emergence time (Nm) in days was calculated by equation 1, as described by Edmond and Drapala (1958).

$$N_m = \frac{E_1 \cdot T_1 + E_2 \cdot T_2 + \ldots + E_n \cdot T_n}{E_1 + E_2 + \ldots + E_n} \quad (1)$$

where,
Nm = Average emergence time (days);
E1...n = Number of seedlings emerged since the first count; and
T1...n = Number of days after sowing.

The experiment was arranged in split-plots, with water contents assigned to the plots (28.7; 36.4 and 47.6%) and the fertilizer depths (6.3; 11.3 and 14.8 cm) to the subplots, in a randomized block design with 3 replications, totaling 27 experimental units. The data were subjected to response surface and regression analyses. The models were chosen with basis on the significance of the regression coefficients, at 5% probability level, using T test, coefficient of determination and biological behavior of the phenomenon. All statistical analyses were performed using the computer program R (R CORE TEAM, 2017).

RESULTS AND DISCUSSION

Figure 1 shows the average values of soil penetration resistance, in MPa, as a function of the water content in the plots.

It was found that at greatest depths, as well as at lowest soil water contents, the soil penetration resistance increased. In the 0 – 20 cm layer,the soil penetration resistance ranged from 0 to 3.6 MPa.

In a study to model the spatial variability of soil penetration resistance (PR) at different depths, Silva *et al*. (2017) also found lower penetration resistance in locations with higher water contents. Soil water content is one of the most common

Table 1. Tolerance limits for the variation in the spacings (Xi) between seedlings and the type of spacing considered. Xi means spacing between seedlings obtained in the field and Xref means reference value obtained as a function of spacing and population

Spacing Type	Tolerance interval for variation of Xi
Multiples	Xi ≤ 0.5 * Xref
Acceptable	0.5 * Xref < Xi < 1.5 * Xref
flawed	Xi ≥ 1.5 * Xref

Source: Adapted from Kurachi *et al*. (1989)

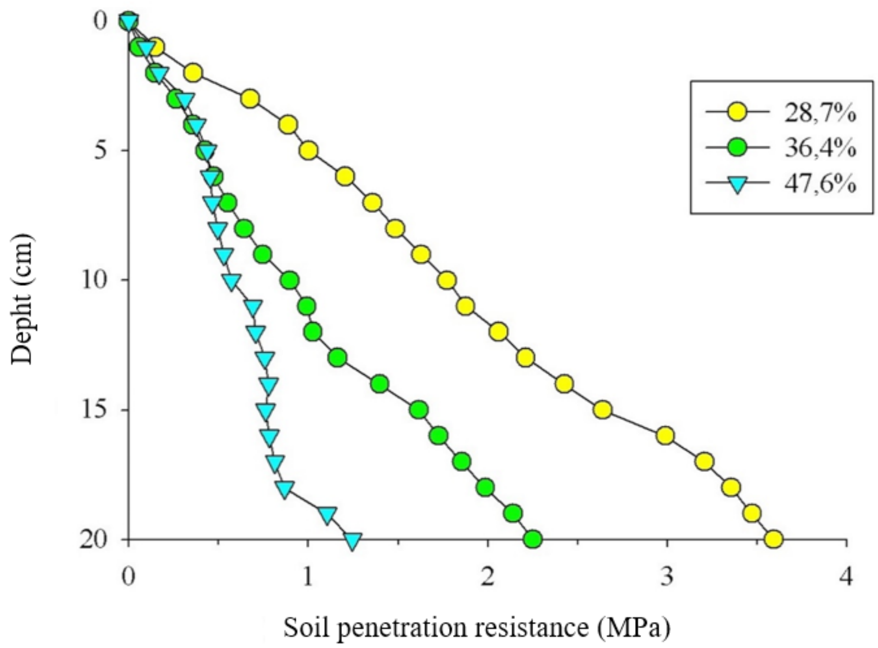

Figure 1. Soil penetration resistance (MPa) before seeding, as a function of depth in the experimental area

parameters used to evaluate the intensity of soil compaction and penetration resistance. High levels of compaction may hinder root growth as well as compromise the seeding operation, as the furrowing mechanism of the seeder needs to break the compacted layer for correct seed deposition (Valadão *et al*., 2015).

The seeder-fertilizer performance was evaluated by the average spacing between seedlings and classified as acceptable, failure or multiple deposition. According to the planter adjustments, the theoretical reference spacing was determined to be 8.33 cm. Using this value allowed the classification as multiple spacing when $Xi \leq 4.16$ cm, acceptable when 4.16 cm $< Xi <$ 12.49 cm, and failed when $Xi \geq 12.49$ cm.

The independent variables of soil water content and depth of fertilizer placement showed no significant effect, t test at 5% probability, on the percentage of multiple spacings (MS), acceptable spacings (AS), and flawed spacings (FS) between seedlings. Therefore, the linear equation is formed by the average of the observed variables (Table 2).

Regardless of the values of the variables soil water content and fertilizer application depth, the averages found would be 65.90% for acceptable spacings, 16.01% for failed spacings and 18.09% for multiple spacings.

Because the equipment has been operated with low density of seeds per meter and constant speed of 1.86 m s^{-1}, one can conclude that not much demand was put on the seeder.

The planter vibration and field surface roughness affect the seed trajectory inside the seed delivery tube. This friction in the seed guide tube may delay the seed from falling to the ground and lower the uniformity of seed spacing in the sowing furrow (Silva and Silveira, 2002).

The slipping of the drive wheel may also have contributed to the failure in spacing. The non-rotation of the wheel when the planter moves forward means that the metering mechanism is not set in motion and, consequently, seed discharge does not occur.

In some circumstances in which the seeds are placed in the reference spacing, when it occurs a multiple spacing with the next seed being dropped in the correct place, there is a failed spacing, which can also happen due to the non-emergence of the seedling in the field or when the seed metering disc is not completely filled.

Corroborating these results, Feitosa (2018), working with the onion crop, found that the soil water content had no influence on the longitudinal distribution of seedlings.

In this study, the seed deposition depth showed a linear, significant negative effect, while the variable fertilizer deposition depth showed a non-significant effect (Figure 2).

Table 2. Average values for seedling spacing

EM	$\hat{Y} = 18.09$	$R^2 = 0.7534$
EA	$\hat{Y} = 65.90$	$R^2 = 0.7627$
EF	$\hat{Y} = 16.01$	$R^2 = 0.5004$

$$\widehat{Pds} = 5.0659 - 0.04768 * U - 0.005645^{n.s} P \quad (R^2=0.8862)$$

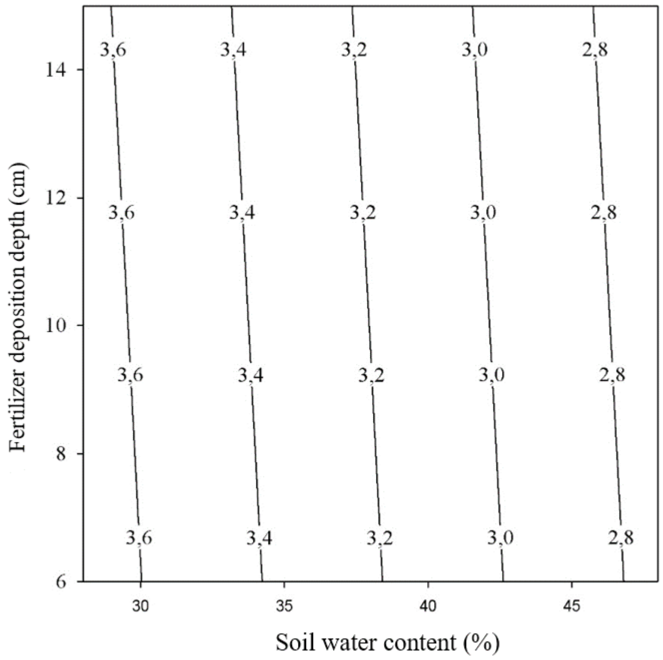

Figure 2. Seed deposition depth (cm) as a function of soil water content (U - %) and fertilizer deposition depth (P - cm). Adjusted equation and coefficient of determination (R^2) * – significant at the 5% probability level using the t test and n.s non-significant at the 5% probability level

For the same soil water content, an increase of one unit in the fertilizer deposition depth results in a decrease in the seed deposition depth by 0.005645 cm. An increase of one unit in soil water content resulted in a decrease in the seed deposition depth of 0.04768 cm. When the soil water content was 28.7% and the fertilizer deposition depth was 6.3 cm, the seed deposition depth was 3.7 cm; however, at the highest soil water content (47.6%) and the greatest depth (14.8 cm), the seed deposition depth was 2.7 cm.

Therefore, with the increase in soil water content, it is likely that this behavior was caused by the seed adhering to the more moist soil and not reaching the bottom of the planting furrow, remaining stuck to a shallower depth. Another possible cause would be the difficulty of the compacting wheel to operate and cover the seed properly, since the soil was stickier, it was molded, not broken.

The average seedling emergence time was 10.86 days for the soil water content of 28.7% and fertilizer deposition depth of 6.3 cm; for the same water content and the depth of 14.8 c, the SET was 11.3 days. For the soil water content of 46.7%, the SET was 9.36 and 9.80 days for the depths of 6.3 and 14.8 cm, respectively (Figure 3).

The lowest water contents, related to the greatest soil compaction, which result in the greatest mechanical resistance, may have made it difficult for the seedling to break through the subsurface soil layer, causing a delay in germination. On the other hand, higher water levels reduced the resistance, allowing an easier seedling emergence.

Regarding the fertilizer depth, Rinaldi at al. (2010) discussed that lower deposition depths facilitate fertilizer absorption by the seedling and make them less dependent on cotyledon reserves, thus seedlings become more vigorous and can

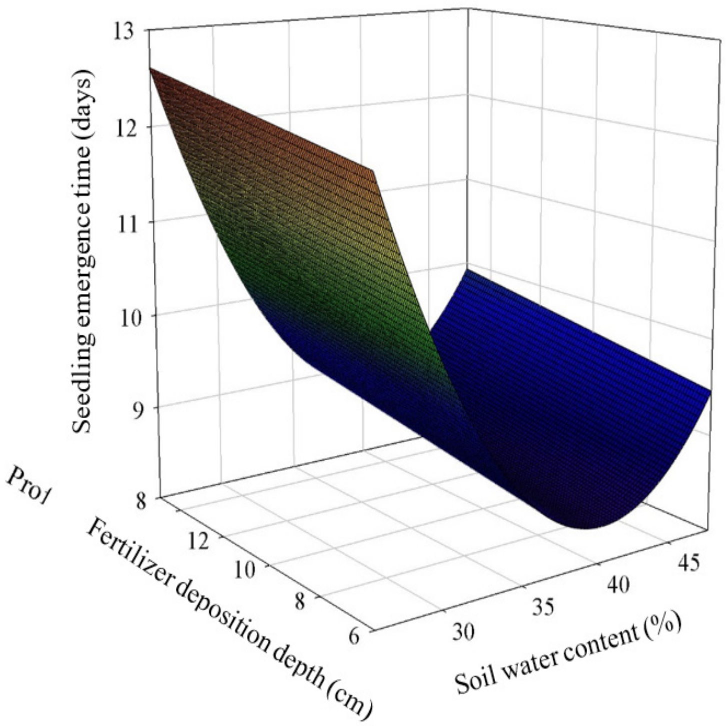

Figure 3. Average seedling emergence time (days) as a function of soil water content (U - %) and fertilizer deposition depth (P - cm). Adjusted equation and coefficient of determination (R^2) * – significant at a 5% probability level using the t test

break through the soil layer more easily and in less time.

CONCLUSION

- The soil water content and fertilizer deposition depth had no effect on the longitudinal distribution of seedlings.
- The shortest average emergence time was at the 6.3-cm depth and 46.7% soil water content.
- Making proper adjustments to the seeder equipment, including accurately determining seed density per linear meter and maintaining an appropriate operating speed, are key factors that directly influence seeding efficacy. Deviations from these configuration settings, referring to the manufacturer's recommendation and operating conditions, may undermine the plantability, resulting in suboptimal seed population.

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AUTHORSHIP CONTRIBUTION STATEMENT

ORLANDO JUNIOR, W. A.: Data curation, Formal Analysis, Methodology, Writing – original draft, Writing – review & editing: **CORREA, K. P.:** Data curation, Validation, Writing – original draft, Writing – review & editing: **PACHECO, A. F. C.:** Data curation, Writing – original draft, Writing – review & editing; **REZENDE, I. A.:** Data curation, Writing – original draft, Writing – review & editing; **TEIXEIRA, L. F.:** Data curation, Writing – original draft, Writing – review & editing; **FERNANDES, H. C.:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision.

DECLARATION OF INTEREST

The authors declare that they have no financial or personal interests that could influence the work reported in this article.

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