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Determination of substrate proportion, sowing depth and temperature for tomato seedling emergence

Determinação de proporção de substrato, profundidade de semeadura e temperatura para emergência de plântulas de tomate

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ABSTRACT

The tomato crop figure among the vegetables with the largest cultivated areas and profitability in the world. Characteristics of temperature, potting media and sowing depth act directly on the speed and uniformity of tomato seedling emergence. The object of the study was using soil and sand to determine the best proportion of substrates, sowing depth and temperature for tomato seedling emergence. A germination test was assessed in three temperatures (20-30, 25 and 30 ºC) to verify seed physiological quality, then, an seedling emergence test was carried out using different substrate proportions of sand:soil (1:0, 1:1, 1:2, 2:1 and 0:1), temperatures (20-30, 25 and 30 ºC) and sowing depths (1, 2, 3 and 4 cm), also the speed of seedling emergence was evaluated in the same test. The experimental design was completely randomized with 5 x 3 x 4 factorial (substrates x temperatures x sowing depths), with four replicates. The best germination results were obtained at the temperature of 25 °C. The proportion of substrate that allows the best performance of tomato seedlings is 2:1, using a temperature of 25 °C and a sowing depth of 2 cm.

Keywords: *Lycopersicon esculentum* Mill.; seeds; vigor; development.

RESUMO

O tomate está entre as culturas hortaliças de maior área cultivada e rentabilidade no mundo. Características de temperatura, substrato e profundidade de semeadura agem diretamente na velocidade e uniformidade da emergência de plântulas de tomate. Objetivou-se utilizar solo e areia para determinar a melhor proporção na composição do substrato, profundidade de semeadura e temperatura para emergência de plântulas de tomate. Foi realizado teste de germinação em três temperaturas (20-30, 25 e 30 ºC) para verificar a qualidade fisiológica das sementes, então, foram analisados os fatores substrato (proporção areia:solo de 1:0, 1:1, 1:2, 2:1 e 0:1) , temperatura (20-30, 25 e 30 ºC), e profundidade de semeadura (1, 2, 3 e 4 cm) por meio do teste de emergência de plântulas e velocidade de emergência de plântulas. Os melhores resultados no teste de germinação foram obtidos na temperatura de 25 °C. A proporção de substrato que possibilita o melhor desempenho das plântulas de tomate é o 2:1, utilizando temperatura de 25 °C e a profundidade de semeadura de 2 cm.

Palavras-chave: *Lycopersicon esculentum* Mill.; sementes; vigor; desenvolvimento.

INTRODUCTION

The tomato (*Lycopersicon esculentum* Mill.) crop has among the vegetables the largest cultivated areas and profitability in the world (Nangare *et al*., 2016). Due to frequent fluctuations in fruit prices, small producers are vulnerable to loss of profitability (Carvalho *et al*., 2014). One of the bottlenecks that raises costs in tomato farming is the production of seedlings, in which there is great diversity of substrates used, but without a best economical composition (Costa *et al*., 2013).

Normally, proportions of two or more products are used to compose the potting media used in the production of tomato seedlings, this is due to the difficulty of finding a single material that satisfies all characteristics of adequate porosity, presence of essential nutrients, good sanitary standard and affordable cost (Medeiros *et al*., 2013). Among the most used subtracts there are coconut fiber (Krause *et al*., 2017), sand (Costa *et al*., 2013), soil (Souza *et al*., 2013), and commercial mixes that are ready to be used (Braun *et al*., 2010).

It is possible to find commercial mixtures with good characteristics for the production of tomato seedlings (Braun *et al*., 2010), however, its high cost limits the acquisition by small farmers, making it necessary to choose substrates that are easily accessible and have low cost (Medeiros *et al*., 2013), such as soil and sand that suit these prerequisites. When the ideal environment for tomato seedling growth is set, choosing the substrate becomes one of the main decisions (Silveira *et al*., 2002).

Tomato seeds germinate at temperatures of 10 to 35 °C, but the ideal condition may vary (Nafees *et al*., 2019). The Brazilian Rules of Seed Analysis defines an alternation of temperatures between 20 to 30 °C (12/12 hours) for a germination; however, evidences have shown that other temperatures can provide better conditions for the germination in this species (Campos and Tillmann, 1997). The substrates modify the temperature conducted to the seed and depending on which one is being used the ideal temperature could be changed and affect the performance of germination and, consequently, seedling emergence (Olson *et al*., 2012). Associated with the microclimate around the seed is also the sowing depths, which can be significant in the retention of moisture due to level of exposure to the external environment.

The sowing depth must be sufficient for the seed not be exposed to predators and atypical weather, such as high variations in temperature and moisture; also, it should not be too deep that it has difficulties in breaking through the soil above the seedling (Tillmann *et al*., 1994; Abebaw *et al*., 2016). For tomato and some Solanaceae crops, the best performance is at shallower depths (Tillmann *et al*., 1994; Olatunji and Afolayan, 2019), however, the relationship between the best depth and substrate still lacks recent research for the production of tomato seedlings.

According to the aforementioned literature, there is a need for a research that relates substrates, sowing depths and ideal temperatures for the production of tomato seedlings at low cost, therefore, the objective of this study was to evaluate the relation between substrate proportions, sowing depths and temperatures in the emergence of tomato seedlings.

MATERIALS AND METHODS

The tomato seeds, cultivar Santa Cruz, were produced in 2018/19 at Federal University of Lavras (UFLA), Minas Gerais, Brazil. The experiment was carried out at The Central Seed Analysis Laboratory, also located at UFLA, in 2019.

To determine the initial quality of the seed lot and check which temperature provides better performance in germination compared to the alternation of 20-30 °C recommended by the Brazilian Rules of Seed Analysis (Brazil, 2009), 25 and 30 °C were tested. The design was completely randomized, with four replicates of 50 seeds. The evaluations performed were described below.

Germination

In a gerbox the seeds were distributed homogeneously on blotting paper, with a volume of distilled water for imbibition in the amount of 2.5 times the weight of the dry paper. Then, they were placed in a BOD incubator, with 12/12 hour photoperiod regulation at temperatures of 25, 30 and 20-30 ° C. Germination was evaluated 14 days after sowing and the results are expressed in percentage (Brazil, 2009).

First count of germination

It was carried out in conjunction with the germination test, counting the number of normal seedlings five days after sowing, the results were expressed in percentage (Brazil, 2009).

Germination speed

It was carried out in conjunction with the germination test. After root protrusion (0.2 mm) started daily evaluations were performed, until the 14th day after sowing, the results were expressed as an index according to Maguire (1962).

To verify the conditions that provide better performance in the emergence of tomato seedlings, sowing was carried out at depths of 1, 2, 3, and 4 cm, using substrates composed of sand and soil in the proportions of 1:0, 1:1, 1:2, 2:1 and 0:1, respectively, then, submitted to temperatures of 25, 30 and 20-30 °C at a BOD incubator. Thus, composing a completely randomized design in a factorial scheme 4 x 5 x 3 (depth x substrate x temperature), with four replicates of 50 seeds. The evaluations performed were described below.

Seedling emergence

Soil and sand were sieved and homogenized in the proportions of 1:0, 1:1, 1:2, 2:1 and 0:1 of sand:soil, respectively, then they were placed in 500 mL plastic cups (10 cm in diameter) in quantities that would allow sowing on the substrate surface referring to the desired depths (1, 2, 3 and 4 cm), the seeds were then covered with the same substrate and leveled. This method was applied to provide homogeneity in the sowing depth.

After sowing, each container was moistened at 70% of the field capacity and conditioned randomly in a BOD incubator (25, 30, and 20-30 °C) with photoperiod regulation of 12/12 hours, when necessary the humidity of the cups was restored. The count of emerged seedlings was performed at 14 days after sowing with results expressed in percentage.

Seedling emergence speed

It was carried out together with the seedling emergence test. When the seedling cotyledons were above the substrate, daily counts were made up to the 14th day after sowing, with the results expressed as an index according to the calculation proposed by Maguire (1962).

The results were submitted to analysis of variance by the F test, and comparison of means by Tukey test at 95% of probability. A polynomial regression analysis with a coefficient of determination and significance at 5% probability was performed for the quantitative data. The Sisvar software was used as a computational aid for data analysis (Ferreira, 2014).

RESULTS AND DISCUSSION

At temperatures 20-30 °C and 25 °C the seeds reached 89% and 92% germination respectively (Table 1), both above 30 °C, which presented 75%. The decrease in germination was probably caused by high temperature and its deleterious effects on the germination metabolism, as observed by Zhou *et al*. (2016). Chaudhary *et al*. (2017) analyzing different temperatures and their effect on the germination of different tomato cultivars also obtained lower results at 30 °C, relating mild temperatures to the greater ease of mobilization of the reserves present in the seeds, favoring germination.

Table 1 - Mean results of germination (GERM, %), first count of germination (FC, %) and germination speed (GS, index) of tomato seeds submitted to different temperatures (TEMP, °C)

TEMP	GERM	FC	GS
20-30	89 a*	85 b*	8.80 b*
25	92 a	91 a	11.44 a
30	75 b	52 c	6.36 c
Mean	85	76	8.87
CV**	2.86	4.28	4.82

*Means followed by distinct lowercase letters differ by Tukey's test at 95% probability. ** Coefficient of variation.

Regarding the performance in the first count of germination, 25 °C was higher than the others with 91%. This demonstrates that the temperature of 25 °C allows the best metabolic condition for the seeds, minimizing the deleterious effects of the thermos inhibition (Zhou *et al.*, 2016). Campos and Tillmann (1997) analyzing the first count of germination in tomato seeds found that the temperature of 25 °C was better compared to 30 and 20-30 °C. With that, it is possible to observe that the temperature of 25 °C favors an optimized germination environment when compared to the alternation of temperature 20-30 °C, recommended by the Rules for Seed Analysis (Brazil, 2009).

Similar to the performance in the first count of germination, the temperature of 30 °C provided inferior results to the others in the germination speed, presenting an index of 6.36, being the best result in 25 °C, with 11.44. It was also possible to observe a significant loss of quality at a temperature of 20-30 °C, with an index of 8.80, probably due to exposure to a high temperature of 30 °C, with damage to the metabolic apparatus of the seeds, as well as exposure to a temperature below ideal at 20 °C, causing a decrease in the rate of hydration of the seed tissues in the second phase of germination (growth induction), impairing performance in the germination speed and first count of germination (Ferreira *et al.*, 2013).

Considering the best results that the temperature of 25 °C provides for the germination of tomato seeds, it is possible to establish this temperature as the one that provides an environment closer to the ideal in relation to the others tested temperatures, and recommending an update of the temperatures 20-30 °C defined in the Brazilian Rules of Seed Analysis (Brazil, 2009), in order to accurately estimate the real physiological quality of the seeds.

After verifying the initial quality of the tomato seeds, it was possible to evaluate the effect of different factors on seedling emergence, in order to clarify which are the best environmental and management conditions in the production of seedlings.

Based on the analysis of the data, significant interactions were identified between substrate, temperature and sowing depth in the seedling emergence and seedling emergence speed, both variables were separated between the temperatures tested, for best visualization of the results. Observing the seedling emergence (Figure 1), the proportion of substrate 2:1 (sand:soil) showed results superior to the others in the sowing depth of 2 cm, in all the tested temperatures, however it stands out 25 °C (Figure 1B) as being the temperature that presented the best result (94%).

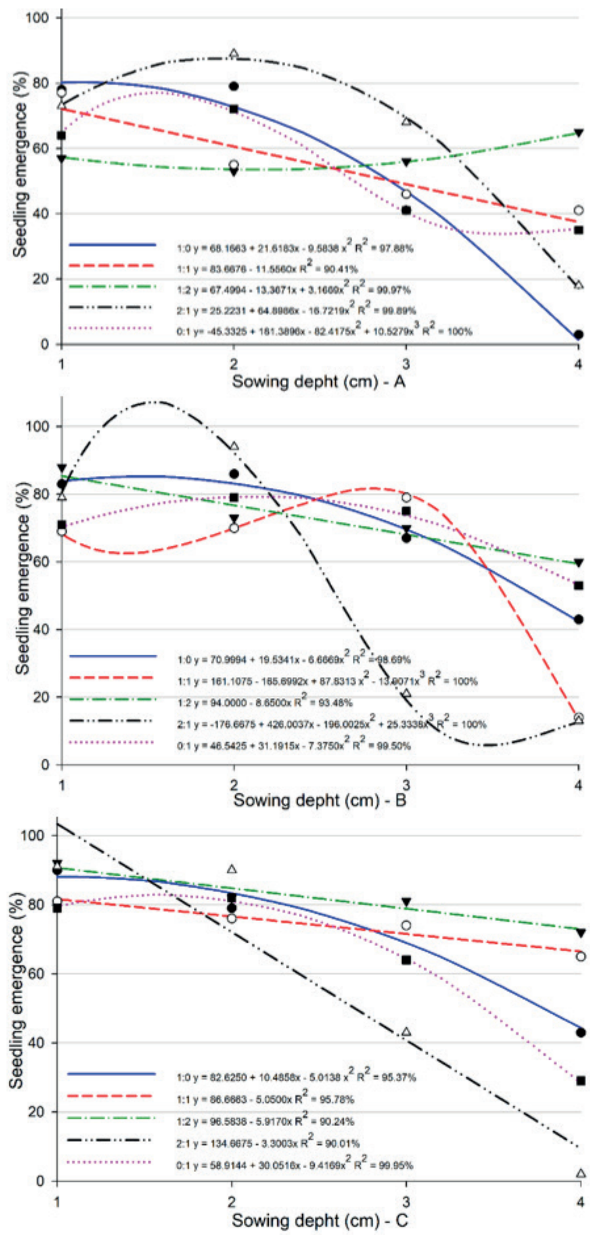

Figure 1 - Regression of tomato seedling emergence, submitted to the sand:soil proportions of 1:0 (●), 1:1 (○), 1:2 (▼), 2:1 (△) and 0:1 (■), temperatures of 20-30 (A), 25 (B) and 30 °C (C) and sowing depths of 1, 2, 3 and 4 cm.

This satisfactory result contrasts with the substrates with a higher proportion of soil, such as 1:2, which obtained only 73% seedling emergence in 2 cm at 25 °C. The good aeration provided by the sand, balanced by the reduction in the density of the substrate and greater water retention with the addition of the clay soil, probably explain the good performance of this potting media (Mentges *et al.*, 2016; Macedo *et al.*, 2017).

However, the 2:1 ratio did not show a satisfactory result at 3 and 4 cm in depth, with 21% and 13% emergence respectively at 25 °C; possibly due to the greater weight of the sand particles in relation to the soil, which becomes a considerable physical barrier due to the greater layer of substrate above the seeds/seedlings (Macedo *et al.*, 2017), which imposes a decline in the regression curves of the 2:1 and 1:0 substrates.

A higher proportion of soil has great importance in the performance of seedling emergence at greater sowing depths, as well as higher temperatures, favoring metabolic activity (Nafees *et al.*, 2019) and percentage of seedlings emerged, as can be seen in substrate 1:2 at 30 °C (Figure 1C), showing 81% and 72% of seedling emergence at 3 and 4 cm deep, respectively, higher than all other proportions in this environment.

However, the need for balancing the proportion with sand persists, exemplified in the substrate with only soil that obtained 29% emergence in 4 cm at 30 °C, compared to 1:2 and 1:1, which obtained 72% and 65% respectively, at that same depth and temperature. The excessive density provided by the clay particles can eventually prevent the seedling, making it difficult to emerge at all temperatures tested (Rogers *et al.*, 2016; Shamshiri *et al.*, 2018).

In Figure 1, it is possible to see the decreasing trend in seedling emergence as the sowing depth is increased, especially from 2 cm. As could be seen in the means 78%, 77%, 60% and 37%, referring respectively to 1, 2, 3 and 4 cm of sowing depth, obtained from all depths.

A similar trend was found by Tillmann *et al.* (1994) using substrate in a 3:1 ratio (sand: soil), when testing the performance of tomato seedlings at different sowing depths, despite highlighting that sowing close to the surface could expose the seeds to predators and weather variations, damaging the stand establishment. The different sowing depths affect the final formation of the stand, with greater depths being a physical impediment to seedling development (Tracy *et al.*, 2012).

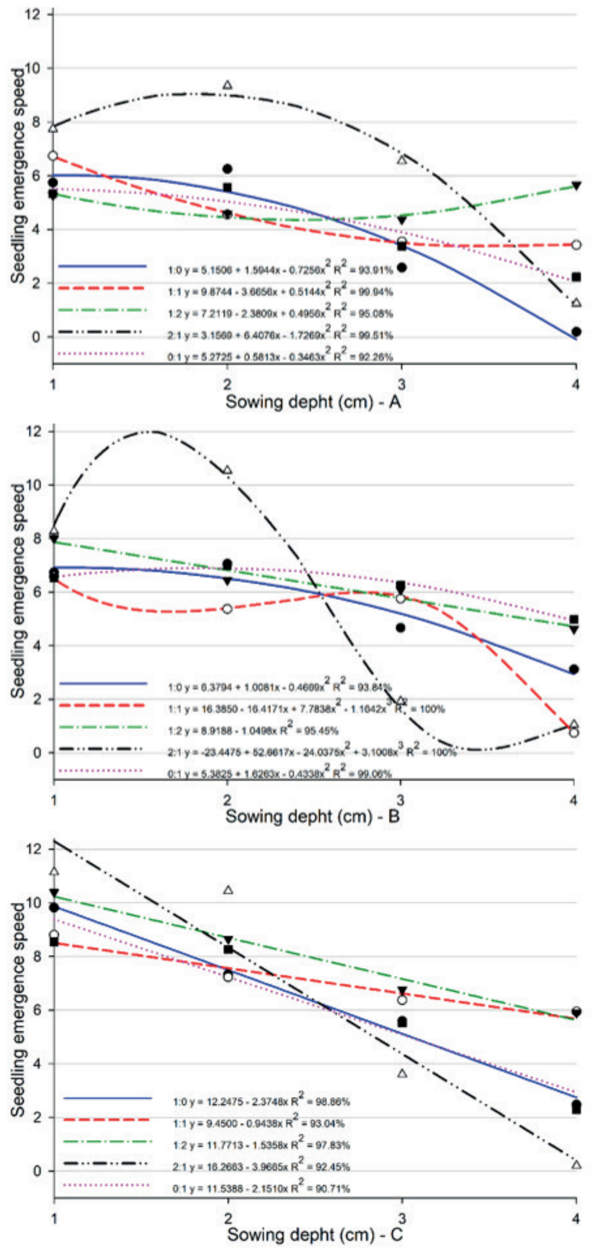

Figure 2 - Regression of tomato seedling emergence speed, submitted to the sand:soil proportions of 1:0 (●), 1:1 (○), 1:2 (▼), 2:1 (△) and 0:1 (■), temperatures of 20-30 (A), 25 (B) and 30 °C (C) and sowing depths of 1, 2, 3 and 4 cm.

Regarding the seedling emergence speed (Figure 2), it was possible to verify the superior performance in all the tested temperatures of the substrate 2:1 in the sowing depth of 2 cm, presenting the 3 best results respectively, with indexes of 10.53 at 25 °C (Figure 2B), 10.45 at 30 °C (Figure 2C) and 9.35 at 20-30 °C (Figure 2A).

In contrast, the 1:2 substrate obtained its best result at 30 °C and 2 cm, where it reached an index of 8.65, showing that the higher proportion of sand in the mixture favors the speed of seedling emergence considerably. The good aeration provided by the sand, balanced by the reduction in the density of the media and greater water retention with the addition of the clay soil, probably explain the good performance of the substrate 2:1 (Mentges *et al*., 2016; Macedo *et al*., 2017).

In the sowing depths of 3 and 4 cm, the best results in the seedling emergence speed refer to the substrates 1:2 and 1:1 respectively, presenting indexes of 6.77 and 5.95, both at 30 °C. Considering the acceleration of seed metabolism at high temperatures and greater water retention due to higher proportion of soil in the substrate, it is possible to infer that to break the substrate layer to the surface in less time, water availability and higher temperatures are of great importance (Ferreira *et al*., 2013; Rogers *et al*., 2016).

In a similar situation of 4 cm at 30 °C, the substrate 2:1 presents an index of 0.20, the second worst performance, surpassing only the substrate composed of only sand, which presented an index of 0.19 in the same condition. Probably what hinders the good performance of substrates with a higher proportion of sand at greater depths is the fact that they have a higher average density, thus hindering the speed of seedling emergence (Macedo *et al*., 2017).

In the position of the regression curves, it was possible to see the increasing effect that the temperature has on the speed of seedling emergence, with averages in the indexes of 4.72, 5.59, and 6.77 respectively at 20-30, 25, and 30 °C, using averages of all temperatures, with the best result of 11.14 at 30 °C, 1 cm deep and 2:1 substrate. The temperature acts by increasing the seeds soaking speed, going through biochemical reactions and reorganizing cell membranes, thus having a direct influence on the speed of germination, and seedling emergence (Ferreira *et al*., 2013).

The increase in temperature from 10 to 30 °C in the seedling growth environment can accelerate the emergence of tomato seedlings from 43 to 6 days (Jones, 2013), due to the higher metabolic activity of seeds/seedlings.

Among the sowing depths tested, there was a gradual loss in seedling emergence speed as the depth increased, with a significant drop after 2 cm, as could be seen through all depths in the indexes 7.72, 7.24, 4.87, and 2.94 related to 1, 2, 3, and 4 cm respectively. The small layer of substrate necessary for the seedling to penetrate to the surface directly influences this result.

In small seed species, such as tomato, sowing depths greater than 1.5 cm could cause lower seedling emergence speed (Tillmann *et al*., 1994). Abebaw *et al*. (2016) when they tested several sowing depths and their response in the speed of the emergence of tomato seedlings, it was possible to verify that smaller depths favor the establishment of the stand, with the exception of the exposure of seeds to surface pests.

In the regression curves of seedling emergence and seedling emergence speed of the substrate 1:2 at a temperature of 20-30 °C, there was an upward trend as the sowing depth was increased. This could be explained by the greater presence of soil in this proportion of substrate, causing high cohesion between the particles, which provided elevation of soil after germination and seedlings positioned at depths 3 and 4 cm were attracted by phototropism (Taiz and Zeiger, 2017) to cracks formed in the substrate or to the sides of the containers up to the surface, thus giving the tendency to rise upward as the sowing depth increases.

In summary, considering the best results both in seedling emergence and seedling emergence speed, the substrate 2:1 has good physical characteristics for the production of tomato seedlings at a reduced cost, presenting a good proportion between micropores and macropores, with capacity for retain moisture satisfactorily and reduce the impediment in seedling emergence. Seedlings should be kept after sowing in a controlled environment at 25 °C, due to the maximum performance of seedling emergence at this temperature, without significant losses of seedling emergence speed in relation to the temperature of 30 °C and alternation of 20-30 °C. Sowing should be done at a depth of 2 cm, due to the balance between a smaller layer of substrate for seedling emergence when compared to 3 and 4 cm, and less interference from the external environment when related to 1 cm, which could be harmful to the seeds and seedlings for exposing to sudden changes in humidity and temperature, as well as surface pests.

CONCLUSIONS

The proportion of substrate that allows the best emergence of tomato seedlings is two parts of sand for one part of soil.

The temperature of 25 °C is the best alternative for the emergence of tomato seedlings.

The sowing depth of 2 cm is the most suitable for the emergence of tomato seedlings.

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