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ANALYSIS OF THE LONGITUDINAL DISTRIBUTION OF TOMATO SEEDLINGS TRANSPLANTING AS A FUNCTION OF OPERATIONAL SPEED

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ABSTRACT

The semi-mechanized transplanting of industrial tomato seedlings has become a viable alternative for the farmers. The objective of this work was to evaluate the influence of operational speed in the transplanting process of tomato seedlings. The experiment was conducted in a commercial area with 58 ha irrigated by a center pivot. The operational speeds evaluated in the experiment were of 1.62; 3.15 and 4.00 km h^{-1}. The distribution and the number of transplanted seedlings were measured after the passage of the mechanized set. The values of the stand and distances between the transplanted seedlings were analyzed by the test of Tukey at 5% probability. The operational speed influenced the final stands. For lower operational speeds of transplanting, it was observed a greater distance between the seedlings.

ANÁLISE DA DISTRIBUIÇÃO LONGITUDINAL DE MUDAS DE TOMATE EM FUNÇÃO DA VELOCIDADE DE TRANSPLANTIO

RESUMO

O transplantio semi-mecanizado de mudas de tomate industrial tem se tornado uma alternativa viável para os produtores. Com o objetivo de se avaliar a influência da velocidade de operação no processo de transplantio de mudas, o trabalho foi conduzido em uma área comercial com 58 ha irrigada por meio de um pivô central. As velocidades operacionais avaliadas foram de 1,62; 3,15 e 4,00 km h^{-1}. A mensuração da distribuição e da quantidade de mudas transplantadas foi realizada após a passagem do conjunto mecanizado. Os valores de estande e distância entre as mudas transplantadas foram analisados pelo teste de Tukey a 5% de probabilidade. Houve influência da velocidade de operação nos estandes finais. Para menores velocidades de operação de transplantio houve uma maior distância entre as plantas.

INTRODUCTION

Currently, Brazil is the fifth largest producer of tomato for industrial processing in the world. Besides leading the production in South America, it is also the greatest consumer of its industrialized products. In 2018, the transplantation area reached a total of 64.57 thousand ha, whose production totaled 4.5 thousand tons, with an average productivity of 69.712 ton ha^{-1} (IBGE, 2018).

A whole set of machines that allows the performance of agricultural activities, which ranges from tillage to harvesting is what constitutes an agricultural mechanization (RIPOLI *et al.*, 2010). The evolution of mechanization improved the quality of nurseries, allowing them to be grown to a higher seedling industry (LIMA *et al.*, 2012).

Unlike Brazil, which is still in its early stages, mechanization of the transplantation process is common in Europe, North America and in some Asian countries, (MADEIRA *et al.*, 2016). For Zhang (2012), seedling transplants are widely used; however, the scarcity of labor requires techinfied farms, such as those already have in tractors and harvesters.

Madeira and Melo (2010) state that transplantation over straw, or direct transplant for tomato has been applied in approximately 50% of the total cropped area, and particularly in early crops, performed at late February until early April in the State of Goiás State. Also, according to Filgueira (2008), the process of seedling transplantation extends the crop cycle, providing an increment in the yield and in the product quality, besides reducing the quantity of seeds needed for implementation of the crop if they were introduced through seeding.

Regarding the manual seedling transplantation, it presents a high level of production costs, besides being laborious with low operational capacity. However, mechanized transplantation process only became viable with the introduction of the transplanters, and with it, the optimization of production processes has become a study case and a new technology development for this sector.

Particularly for the crop of industrial tomato, relevant studies in this area are still scarce, and the gathering of greater operational capacity by means of the increase in workforce speed might compromise the process, thus reducing the quality for seedling distribution. Hence, the use of Statistic Process Control (SPC) is an adequate tool used in the productive processes with the aim of providing information for a more efficient diagnosis for the prevention and detection of defects/problems in the evaluated processes.

For Toledo *et al*. (2008), the Statistic Process Control (SPC) allows reducing the variability of controlled variables, therefore granting the use of operational conditions which approach the variables of interest to its control limits.

Therefore, considering the little information and the few studies regarding semi-mechanized transplantation process for industrial tomato seedlings, the objective of this work was to evaluate the influence of the speed of transplantation operation on the stand and distribution of transplanted seedlings, considering afterwards, a passthrough performed by temporary workers to check casual flaws.

MATERIAL AND METHODS

This study was carried out on Santa Rosa Farm (17°44'31.0" S 49°03'12.9" W), in the municipality of Morrinhos, state of Goiás, on Hapludox Soil, under straw transplantation conditions, where soybean had been previously before. Soil moisture at the moment of operations was at 40%. The site is 770 m above sea level. It is a commercial property, with a total area of 290 ha, but the experiment area used 58 ha, irrigated be means of a center-pivot irrigation waterwheel.

A mechanized set made up by a tractor, New Holland model TM 7010, 4x2 MFWD (Mechanical Front Wheel Drive), with 141 cv (104 kW) and a Ferrari transplanter FX were used for transplantation over straw, with four transplantation units spaced by 0.6 m between the rows (two lines per block) and 1.2 m (3.93 ft) between the blocks,

with capacity for 36 trays and 630 kg of mass.

Three operational speeds were considered: 1.62; 3.15 and 4.0 km h^{-1}. The speeds were stablished by work velocity applied in the field, which was 3.15 km h^{-1}. The speeds of 1.62 and 4.0 km h^{-1} were chosen to determine the behavior of the machine when moving above and below the speed used in the field. The filling up of the deposition cell was performed by a crew specialized in this function, where 100% of cell filling was obtained in all speeds under evaluation. The transplanter was set for a stand of 26 thousand plants ha^{-1}. Under these conditions, the ideal spacing between the plants should be 32 cm.

The regulation of moving speeds for the mechanized set during the execution of the operations was executed by measuring the time spent to cover a distance of 100 m during the transplantation operation, with five samples. Afterwards, an arithmetic average was adopted to determine speed figures.

Seedling transplantation was evaluated by counting and measuring the distance between the transplanted seedlings in each line, for operational speeds of 1.62; 3.15 and 4.0 km h^{-1}, with five samples. The transplanter is set with four transplantation units; however, for this analysis, the distances between the plants were analyzed only in two transplantation lines. The transplantation units to be analyzed was randomly selected by picking up for each parcel. The experimental units were set by parcels measuring 20 m.

After counting and measuring, a manual passthrough was performed by temporary workers to correct the flaws in the transplantation performed only by the machines. A new seedling count was executed after the passthrough. After the count, the number of plants per hectare was calculated, aiming to determine the effect of operational speed regarding the stand.

Thus, the evaluation of the transplantation process considered the evaluation on transplanter performance and later, the evaluation on the process taking into account the passthrough operation (manually performed), which adequately characterized the operations performed on the field.

The experiment was conducted in a random block design, with the effect from the influence of operational speed for the variables under observation, before and after passthrough operation, evaluated through the comparison of the means test or regression analysis at 5% significance, considering data characteristics.

The retrieved data was also submitted to descriptive statistics, where it was determined the arithmetic average, value of the median, maximum and minimum values, standard deviation (σ) and coefficient of variation, asymmetry and kurtosis. The verification of data normality was performed using the test of Shapiro-Wilk, and control charts were used as statistical method for each variable. For the variables whose data had not reached a normal distribution, the weighted exponential moving average (WEMA) was used to evaluate the variability among the tested means.

The control charts were elaborated from statistical parameters into transplantation process, considering as a central line, the overall mean and the average amplitude, composed by the upper control limit (UCL) and by the bottom control limit (BCL). The control limits UCL and BCL were calculated based on standard pattern from variables corresponding to 3σ and -3σ respectively.

Analysis regarding control charts were also performed with fixed UCL and BCL, where the upper control limit was determined from 10% of the standard stand determined by the technical recommendation for culture transplantation (26 thousand plants ha^{-1}), and the bottom control limit was considered as a standard stand value from 26 mil plants ha^{-1}. All the statistical analyses were performed using Minitab® computer program, version 15.

RESULTS AND DISCUSSION

It was observed from the data retrieved from the previous variable analysis that all final stands, with or without a passthrough, were influenced by the operational speed. Table 1 shows the means in the stands for the different operational speeds that were evaluated. When a passthrough was not performed, greater stands were found for higher operational speeds. The speeds of 4.00 and 3.15 km h^{-1} were not significantly different from each other.

Table 1. Averages of stands before and after the passthrough operation in the different evaluated operating speeds

Without passthrough		With passthrough	
Speed (km h^{-1})	Stand (plants ha^{-1})	Speed (km h^{-1})	Stand (plants ha^{-1})
1.62	19.112 b	1.62	27.056 b
3.15	26.222 a	3.15	27.223 b
4.00	25.445 a	4.00	29.222 a

Means followed by the same letter in the column do not differ by the test of Tukey at 5% probability.

At the speed of 1.62 km h^{-1}, the lowest stand was computed amongst the analyzed speeds. Also, a qualitative analysis in seedling transplantation showed that most seedlings were overturned or buried. At the speed 4.00 km h^{-1}, the majority of the seedlings did not have their substratum covered so they were overturned and found on the soil surface.

Genaidy (2008) evaluated the transplantation of cotton seedlings and observed that the raise in the speed for the mechanized set resulted in an increase in the number of non-viable or damaged seedlings. Another point observed by the authors is the greater difficulty in covering the seedling with soil as the speed is raised, which corroborates with the results found in this study.

Machado *et al.* (2015) evaluated three different operational speeds for industrial tomato seedlings and concluded that the different operational speeds followed by a passthrough modified the final stands in the evaluated processes, in which the highest speed was more favorable regarding the stand of transplanted seedlings and the lowest speed showed smaller final stands.

After the passthrough operation, at the speed of 4.00 km h^{-1} the highest final stand was retrieved, with 29.222 plants h^{-1}. However, the speeds of 3.15 and 1.62 km h^{-1} were even more different than the speed at 4.00 km h^{-1}. After the passthrough, for all analyzed speeds, the stands surpassed the standard stand stablished for the area (26.000 plants ha^{-1}).

Figure 1 shows the stands gathered before and after the passthrough performed by temporary workers. The speeds of 1.62 and 4.00 km h^{-1} were most the influenced by the passthrough for a final stand. In these speeds, the stand increases from the passthrough operation, was of 41.56% and 12.89% respectively. Thus, it is possible to observe that operational speed of 3.15 km h^{-1} was less influenced by the passthrough because the increase in the stand under this condition was only 3.81%, therefore, showing the speed that obtained the best transplantation efficiency among the studied speeds.

The tendency of the stand to increase at the different speeds can be explained by the fact that the decrease in speeds resulted in a less uniform distribution, therefore, causing a larger space between seedlings. Thus, during passthrough operation, this visual aspect presented flaws to the eyes of the temporary workers who performed the operation.

This context was the most viable and less dependent on the influence from the temporary workers. Even with an efficient transplanter regarding the number of seedlings deposited in the soil, an inspection was needed to verify overturned seedlings and possible flaws in transplantation or buried seedlings in the ground.

Cunha *et al.* (2012) compared manual tomato transplantation systems with the semi-mechanized and observed that in the semi-mechanized process occurs a greater efficiency in seedling transplant, greater stand and plant viability, in addition to allowing for a better system adequacy for mechanized harvest, due to fewer problems caused by inadequate spacing.

According to Chioderolli *et al.* (2012), the process can vary because of some particular causes. The particular causes in agricultural operations might be related to several factors such as the experience of the operator, soil conditions, and mainly to the transplanter settings, which corroborates with some retrieved results. However, a common cause is the passthrough operation that contributed in modifying the final expected stands.

The analysis of the distance between transplanted seedlings regarding the operational speed shown in the Figure 2 showed that the speed of 3.15 km h^{-1} resulted in the shortest distances between seedlings, which is the value closest to the ideal stand, *i.e.* 32.00 cm. However, the speed of 1.62 km ha^{-1} presented a greater variability in the values of the distance between the seedlings. It also presented the greatest amplitude between
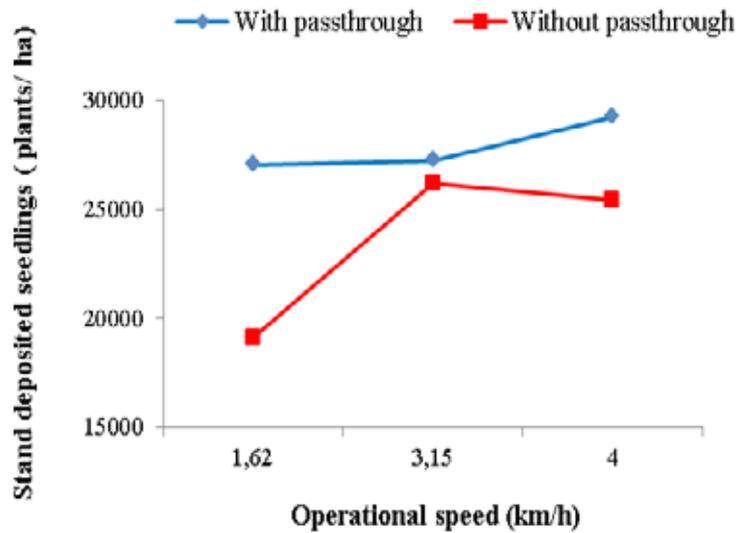
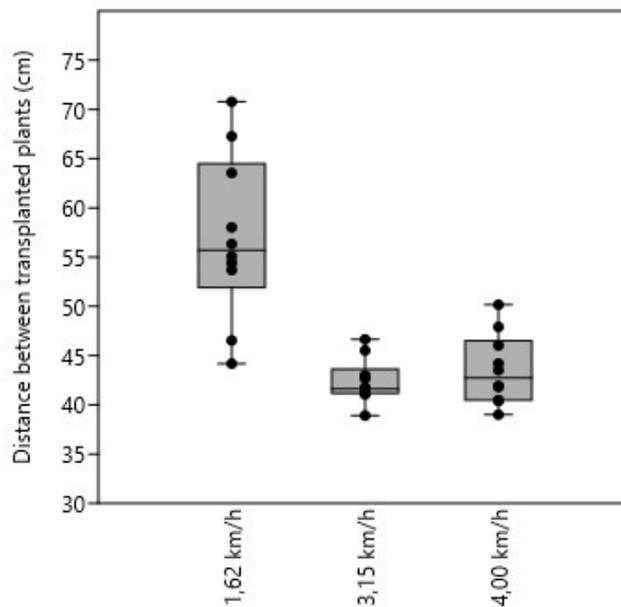**Figure 1.** Graph comparing the stands before and after the passthrough at different operating speeds

Figure 2. Boxplot for the effect of operational speed at the distance of transplanted seedlings

maximum and minimum values between the evaluated speeds.

According to Rocha *et al.* (1991), the viability of a mechanized transplantation system will always depend upon three factors: the set operational capacity, equipment cost and planting precision offered by the machinery. In the experimental conditions of this research, the speed of 3.15 km ha^{-1} presented the least variability in the space between the seedlings.

As shown in Table 2, the results related to

the descriptive statistics performed to evaluate the effect of operational speed on the distance in between transplanted seedlings (distance between plants) allowed to observe that the lowest operational speed of the machinery (1.62 km h^{-1}) resulted in an asymmetric data distribution, presenting negative kurtosis values and positive asymmetry, which explains the reason the average value was higher than the median value, in addition to presenting a high amplitude.

Table 2. Descriptive statistical analysis for the distances between plants according to the three analyzed speeds

Variable	Average	Median	Value		Standard deviation	Coefficients			Test
			Max.	Min.		CV (%)	Ck	Cs	
1.62 km h⁻¹	55.54	55.35	70.80	44.20	8.51	15.32	-0.51	0.21	A
3.15 km h⁻¹	42.67	42.15	46.65	38.90	2.38	5.59	0.61	0.28	A
4.00 km h⁻¹	43.55	42.73	50.18	39.00	3.58	8.23	-0.41	0.68	A

Ck: coefficient of kurtosis; Cs: skewness coefficient; * N: distribution of normal frequency by the Shapiro-Wilk test ($p<0,05$); A: asymmetric distribution.

The average distance between plants was 55.54 cm (21.86 in), resulted in a final stand smaller to the expected in relation to desired commercial stand. The variation found between the distances was also higher due to the value of the variation coefficient, 5.32%, therefore showing the lack of uniformity among the values found in the study.

The operational speed of 3.15 km h⁻¹ resulted in an asymmetric distribution, with positive kurtosis and asymmetric values, which explains the majority of values above average. The average distance value between plants was 42.67 cm (16.79 in), presenting a result similar to the desired commercial one. The positive kurtosis coefficient allows to demonstrate that the values of the distance between plants tended to concentrate around the average. Under this condition, the variation coefficient showed itself with a lower value (5.59%), indicating that the results found in the experiment had a tendency for higher uniformity among each other when compared to the results from the speed of 1.62 km h⁻¹.

For the highest operation speed in the study (4.00 km h⁻¹), the data presented asymmetric distribution with negative kurtosis values and positive asymmetry, whose behavior is similar to the ones retrieved from the lowest evaluated speed, with average value of 43.55 cm (17.14 in) for the distance between transplanted seedlings. The positive kurtosis coefficient also allows showing that the loss values had a tendency to concentrate themselves around the average. The analysis of the variation coefficient showed that the results presented a tendency of higher uniformity in relation to the results associated with the lowest studied speed (1.62% km ⁻¹).

The control chart for the studied data is shown in Figure 3. The spacing average for the proposed speeds was higher than the ideal average stand, which allows stating that the transplantation process was out of control. For the speed of 1.62 km h⁻¹ (Figure 3A), all figures from the distance between stands were above UCL, the longer distance between plants was 70 cm (27.55 in) for observation 4. This longer distance between plants promoted a more favorable scenario for passthrough operation, which is performed according to the visual criteria from passthrough workers.

Such results can be explained by the mechanism of seedling transplantation on the soil. According to Silva *et al.* (2014), the performance of mechanized transplantation operation of coffee showed that the raise in the operational speed could have impaired seedling planting because of the greater difficulty in feeding the vertical disc in the transplanter by the plantation auxiliaries. Otherwise, speeds below the ideal ones result in the reduction of the activation of the mechanism which also presented problems related to seedling planting, resulting in longer distances between them.

Abidine *et al.* (2004) evaluated the interaction between the spacing of the plow blade and the operation speed during an automatically-driven transplanting process for tomato seedlings, showed that there are no significant differences in the spacing between plants, considering low operation speeds (5.6 km h⁻¹) and high speeds (11.2 km h⁻¹).

In relation to the speed of 3.15 km h⁻¹ (Figure 3B), most of the values relative to the distance between plants were greater than UCL, except observation 7. Despite the uncontrolled spots, the distribution of seedlings in the transplantation lines presented the lowest amplitudes for the distance in between plants amongst all speeds.

According to Figure 3C, for the speed of 4.00 km h⁻¹, the majority of values for the distances in
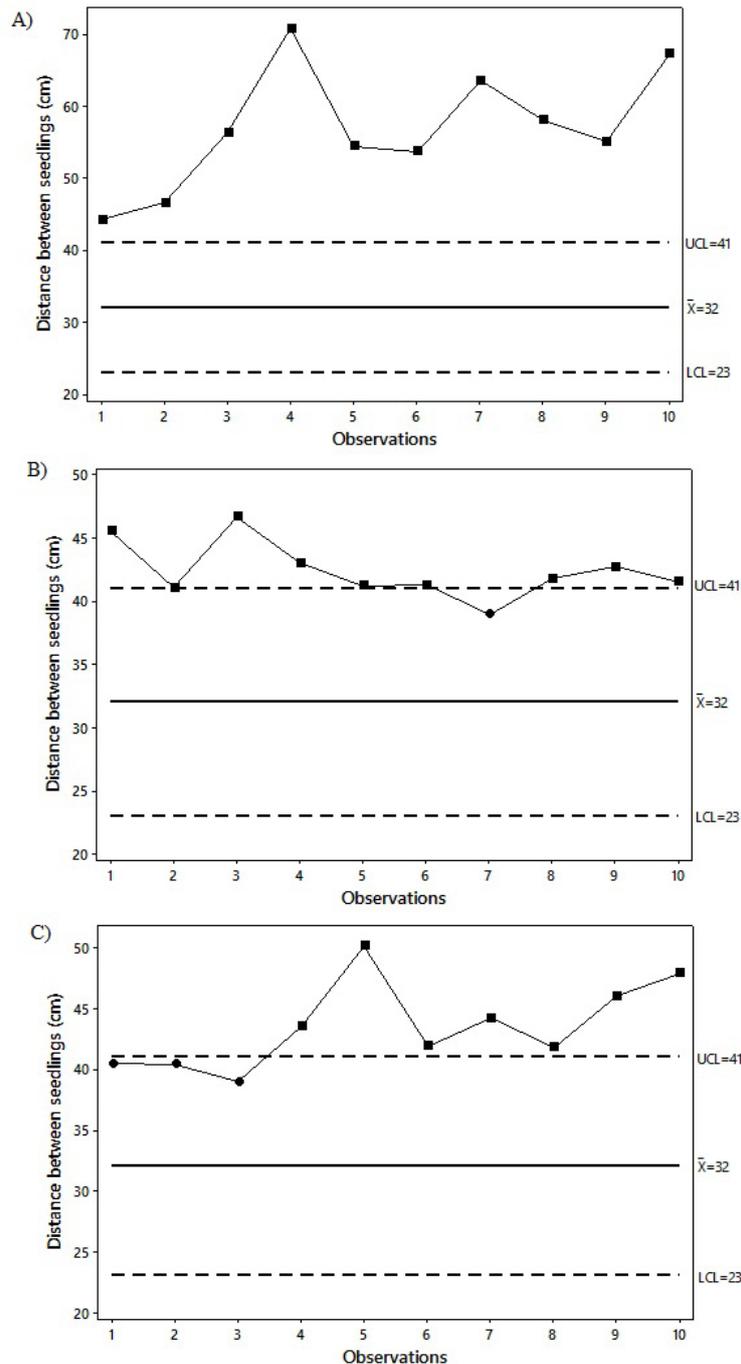
Figure 3. Control chart with the thresholds given in standard deviation function to an average distance of 32 cm between plants for: A) speed of 1.62 km h^{-1}; B) speed of 3.15 km h^{-1}, and C) speed of 4.00 km h^{-1}. X=Average; UCL = Upper Control Limit, and LCL = Lower Control Limit

between plants presented results above the UCL, which is similarly to the speed of 3.14 km h^{-1}. However, the average for the distance between plants was 2.8% higher than the speed of 3.15 km h^{-1}.

The speed of 1.62 km h^{-1} has similar values to those found by Zamani (2014) when evaluating a

transplanter at three operational speeds (1, 1.5 and 2 km h^{-1}), regarding two planting depths for seedlings (5 and 10 cm = 1.96 and 3.93 in), concluded that higher speeds resulted in longer distances between plants (from 49 to 51 cm = from 19.29 to 20.07 in).

The evaluating of the operational behavior showed that the distribution performance of the

transplanters and seeders is influenced by the operational speed. In this context, Cortez *et al.* (2006) performed a study to evaluate the most adequate moving speed for a tractor-seeder set regarding the type of the dose-mechanism. The authors found better results for speeds of = up to 8 km h^{-1} and of up to 11 km h^{-1} for mechanic and pneumatic sets.

Despite being different, the behavior of transplanters and seeders are similar when it comes to the distribution of seeds or seedlings regarding the differences in operational speeds. However, literature have few studies on the evaluation and operational behavior of the transplanters.

In relation to the effect of operational speed on the distribution, Garcia *et al.* (2006) concluded that the sowing operational speed only affects productivity when the stand changes in harvest; the change on uniformity in seed distribution through speed increase did not result in significant differences for this parameter. This logic is based on the fact that without an ideal number of plants there will be no consistent final production.

Based on the above, it has been observed that the evaluated operational speeds will be subjected to the passthrough operation. The speed of 1.62 km h^{-1} is more susceptible to the performance of this operation, and consequently, the greater the number of transplanted seedlings all over the area, the larger the spacing between plants, which influences significantly the quantity of seedlings transplanted by temporary workers.

Such context can be applied to this study in the sense that lower operation speeds results in a larger distance between transplanted plants, therefore, a higher influence on manual passthrough and a greater change in the value of the final stand.

On the other hand, Montgomery (2004) states that the ECP is a tool that can only be used when the data shows normality. The author also suggests the use of the weighted exponential moving average (WEMA) to analyze the non-normal processes. The ECP directly aids the quality control in the stages of the process, in special, the repetitive processes as it aims to guarantee the stability and the continuous enhancement of the process (Fernandes *et al.*, 2010).

CONCLUSIONS

- It can be concluded from the conditions in which the experiment was conducted that despite the efficiency shown by the transplanter, regarding the number of seedlings deposited in the soil, the passthrough operation is needed to check overturned seedlings, possible transplantation flaws or seedlings buried in the soil.

- The operation speeds affect the distribution between plants in the transplanting line, and consequently, the final stand after the passthrough.

- The operational speeds close to 3.0 km h^{-1} were the ideal for semi-mechanized transplantation, delivering shorter spacing between seedlings and less necessity of a passthrough due to the higher efficiency in seedling distribution.

- Lower operational speeds results in larger distance between plants besides the higher non-uniformity among the distances found in the study, which favors the passthrough and result in a greater variation of the final stand under this condition.

REFERENCES

ABIDINE, A.Z.; HEIDMAN, B.C.; UPADHVAVA, S.K.; HILLS, D.J. Autoguidance system operated at high speed causes almost no tomato damage. **California Agriculture**, Davis, v.58, n.1, p.44-47, 2004.

CHIODEROLLI, C.A.; SILVA, R.P.; NORONHA, R.H.F.; CASSIA, M.T.; SANTOS, E.P. (2012). Perdas e grãos e distribuição de palha na colheita mecanizada de soja. **Bragantia**, Campinas, v.71, n.1, p.112-121, 2012.

CORTEZ, J.W.; FURLANI, C.E.A.; SILVA, R.P. Semeadoras de precisão. **Cultivar Máquinas**, Pelotas, v.56, p.16-19, 2006.

CUNHA, D.A.; CUNHA, J.P.B.; MACHADO, T.A.; NEVES JÚNIOR, V.O.; QUEIROZ, L.F.; COUTO, R.F. Transplantio ideal. **Cultivar Hortaliças**. Pelotas, v.72, p.23-25. 2012.

FERNANDES, A.E.S.; COSTA, C.E.S.; SOUZA, E.S.O. O uso de controle estatístico de processo na gestão de qualidade. Estudo de caso: Grupo Coringa - AL. **INGEPRO – Inovação. Gestão e Produção.** v.3, n.6, p.1-10. 2010.

FILGUEIRA, F.A.R. Novo manual de olericultura: Agrotecnologia moderna na produção e comercialização de hortaliças. 3ed. Viçosa: Universidade Federal de Viçosa, 2008.

GARCIA, L.C.; JASPER, R.; JASPER, M.; FORNARI, A.J.; BLUM, J. Influência da velocidade de deslocamento na semeadura do milho. **Engenharia Agrícola**. Jaboticabal, v.26, n.2, p.520-527. 2006.

GENAIDY, M.A.I. Performance of small cotton transplanter under egyptian conditions. **Misr Journal of Agricultural Engineering**. Cairo, v.25, n.1, p.1-14. 2008.

IBGE - Instituto Brasileiro de Geografia e Estatística. Levantamento Sistemático da Produção Agrícola. Rio de Janeiro: IBGE. 2018.

LIMA, G.G.S.; NASCIMENTO, A.R.; AZARA, N.A. Produção de mudas. In: CLEMENTE, F.M.V.T.; BOITEUX, L.S. Produção de tomate para processamento industrial. Brasília: Embrapa, 2012.

MACHADO, T.A.; SANTOS, F.L.; VALENTE, D.S.M.; FERNANDES, H.C.; CUNHA, J.P.B. (2015). Transplantio semi-mecanizado de mudas de tomate em função da velocidade de operação. **Revista Agro@mbiente On-line**, Boa Vista, v.9, n.1, p.48-56, 2015.

MADEIRA, N.R.; MELO R.A.C. Sobre a palha. Cultivar Hortaliças e Frutas. Pelotas, v.60, p.20-23. 2010.

MADEIRA, N.R.; SILVA, P.P.; NASCIMENTO, W.M. Cuidados no transplante de mudas. In: NASCIMENTO, W.M.; PEREIRA, R.B. Produção de mudas de hortaliças. Brasília, Embrapa, 2016.

MONTGOMERY, D.C. Introdução ao controle estatístico da qualidade. 4 ed. Rio de Janeiro: LTC. 2004.

RIPOLI, T.C.C.; RIPOLI, M.L.C.; MOLINA JUNIOR, W.F. Máquinas Agrícolas: Noções Básicas. Piracicaba: Degaspari, 2010.

ROCHA, F.E.C.; TSUJIMOTO, T.; MENEZES SOBRINHO, J.A. Plantadora de alho com mecanismo tipo correia dentada. **Informativo Agropecuário EMBRAPA**. Sete Lagoas, v.15 n.169, p.33-37. 1991.

SILVA, R.P.S.; VOLTARELLI, M.A.; CASSIA, M.T.; VIDAL, D.O.; CAVICHIOLI, F.A. Qualidade das operações de preparo reduzido do solo e transplantio mecanizado de mudas de café. **Coffee Science**. Lavras, v.9, n.1, p.51-60. 2014.

TOLEDO, A.; TABILE, R.A.; SILVA, R.P.; FURLANI, C.E.A.; MAGALHÃES, S.C.; COSTA, B.O. Caracterização das perdas e distribuição de cobertura vegetal em colheita mecanizada de soja. **Engenharia Agrícola**. Jaboticabal. v.28, n.4, p.710-719. 2008.

ZAMANI, D.M. Development and evaluation of a vegetable transplanter. **International Journal of Technical Research and Applications**. v.2, n.6, p.40-46. 2014.

ZHANG, F.; LIU, Z.; LI, Y.; FENG, X. (2012). A controlling method for a U-turn mode of automated rice transplanters. In ASABE, Dallas, 2012.