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Quality of mechanized peanut digging in function of the auto guidance

Santos A. F.*, Kazama E. H., Ormond A. T. S., Tavares T. O. and Silva R. P.

Department of Rural Engineering, São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Jaboticabal, Brazil.

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Within the context of precision agriculture, the use of automatic guidance is without a doubt one of the most popular tools among farmers, however, are few producers of peanuts using this technology, the benefits from this technology can bring significant gains for culture even more when thinking about reducing the indices of losses in the digging. Thus, it objective was to evaluate the variability of quantitative losses of peanut mechanized digging with use the autopilot, using the Statistical Process Control. The treatments consisted of absence of autopilot use in sowing and digging, pilot's absence at sowing and presence in the digging, pilot use at sowing and absence in the digging and the pilot use in sowing and digging. In each treatment, 15 points of each variable was collected from distance of 50 m apart. Visible, invisible and total losses in the digging and parallelism were evaluated. The reduction of the plant material on the vibratory mat affected the levels of visible losses. Total losses are strongly correlated with the invisible losses. The use of the autopilot allows the operator to pay more attention to the digging operation improving the quality of the operation. The average error found between passes of the mechanized set using autopilot was 0.35 m. The variability of the losses as well as of parallelism was reduced when using the autopilot in two operations, providing a higher quality process.

Key words: RTK (Real Time Kinematic), automatic guidance, precision agriculture, statistical process control.

INTRODUCTION

South central region of Brazil is a place where peanuts are mostly sown, especially, São Paulo is the foundation where approximately 110 thousand hectares of peanut are grown. The state is the largest producer with about 81% production.

However, even in small and less expressive form, crop production extends to other regions. Tocantins is the only state in the northern region that has areas with the peanut crop, with productivity forecast of 3.9 t ha^{-1} for 2014/2015, showing highly competitive production

*Corresponding author. E-mail: adaofeliped@gmail.com.

conditions, seeing that the average national production is 3.0 t ha^{-1} and it is 1.6 t ha^{-1} in the world (Conab, 2015).

Independent of region, the production results are directly affected by losses during the dug up, in most cases due to excess maturation caused by harvest delay, which encourages the weakening of gynophore and consequently the pods are retained in the soil. Ince and Guzel (2003) reported that soil water content at the time of digging contributes to gynophore weakening, resulting in an exponential increase in losses, since the extent of decrease of the soil water content reduces the tear resistance of the gynophore and consequently increase the total losses of harvest.

Apart from these main factors, the incidence of weeds at the time of digging, maintenance of knives, displacement speed, vibration in the shaking conveyor and maturation, should also be given special attention because it can contribute to increase in loss (Bragachini and Peiretti, 2008), as well as the digging line deviations of the mechanized set during the operation, fact related to the operator's experience (hours worked in the digging operation), being that higher experience, lowers deviations and consenquently lowers total losses coming from the factor manpower.

However, with technology advancement and easy access to the application of precision agriculture in various sectors of production, mainly at harvest, has become a viable alternative, but without much study of the peanut crop when compared with sugarcane in which 39% of mills uses the automatic guidance (Silva et al., 2011).

The use of this kind of technology can be fundamental to reducing losses in the peanut harvest, especially when you have an alignment of sowing with the digging operation, because the operator has difficulty maintaining the tractor aligned with culture. Balkcom et al. (2010) emphasize that this fact is due to the high production of biomass that covers the soil and impedes vision of the operator. To Sun et al. (2010) when using the guidance system with RTK signal accuracy of 2.5 cm, it is possible to make a precise adjustment for subsequent operations, besides increasing the operational capacity provided by the use of this system (Oliveira and Molin, 2011) and improvements in the quality of operation.

Thus, considering that the process has the quality as the final objective, Montgomery (2009) affirms that a definition which will be well accepted as the term quality is to reduce the variability and therefore lower the variation and increase the reliability and acceptance of the product or service. The evaluation of the quality of agricultural operations mechanized through the SPC (Statistical Process Control) can bring improvements to the process.

Several studies used the SPC as a tool to assess the quality of the mechanical harvesting process and demonstrate a potential tool to be applied in agriculture (Noronha et al., 2011; Chioderoli et al., 2012; Bertonha et al., 2014; Voltarelli et al., 2015), mainly because of the possibility of correcting failed points, which considerably increases the final quality of the process, as well as the net return to agricultural activity.

From that exposed, it presupposes that the losses in mechanical harvesting of peanuts have temporal variability that can be reduced with the use of automatic guidance, which is aimed at evaluating the quality of digging mechanized peanuts with and without the use of autopilot at sowing and digging, using the losses as quality indicators through statistical process control techniques.

MATERIALS AND METHODS

The experiment was conducted on the farm of Córrego do Meio, in the municipality of Alvorada-TO, located in the geographical coordinates 12°28'48" S and 49°07'29" O, with an altitude of 289 m. The cultivar was IAC 503, vegetative runner group, creeping size, indeterminate growth habit, sown in the spacing of 0.90 m between rows, sowing density of 21 seeds by meter, in soil predominantly sandy texture (Embrapa, 2013).

The sowing for all areas was performed by a tractor John Deere brand, model 6110 J to 149.5 kW of engine power (110 cv) and seeder PHT4 Supreme. The digging up was carried out by mechanized set, which was a digger/inverter BM Dumont 4 × 2 (4 lines and 2 windrows) pulled by tractor JD 6145J (145 hp). Mechanized sets were equipped with electric autopilot with RTK correction, precision 2.5 cm antenna StarFire™ and GreenStar™ monitor. These were activated in the treatments with pilot and disabled to perform the pilotless treatments, both in sowing, as the digging, and the guidance in sowing done by the line marker and the digging by the vision and experience of the operator to perform the operation.

The design followed the standard adopted by statistical process control, in which samples are collected over time, consisting of four treatments in different areas, as follows:

- Absence of autopilot use in sowing and at dug up (S/S pilot);
- Pilot use at sowing and absence at dug up (C/S pilot);
- Pilot Absence at sowing and presence at dug up (S/C pilot); and
- Pilot use at sowing and dug up (C/C pilot).

For each treatment, up to 15 points distance was collected from one another by 50 m, totaling 60 sample points.

The variables used to assess the quality of the process were visible digging losses (VDL), invisible (IDL) and the total digging losses (TDL) that correspond to the sum of visible and invisible losses. To collect the loss manually, a metal frame of approximately 2 m^2 (3.9 × 0.5 m) was placed across the windrow, and the visible and invisible losses were collected with a hoe at a depth of 0.15 m. The definition of the width of the frame corresponds to the working width of the digger-inverter. After collection, the pods were packed in plastic bags, weighed and identified.

The samples were sent to the Machines and Agricultural Mechanization Laboratory (LAMMA) of Unesp/Jaboticabal, where they were placed in an electric oven at 105°C for 24 h until they reached constant mass (Brasil, 2009). After drying, the mass of the pods was determined again, getting the values of the losses which were extrapolated kg ha^{-1}, with subsequent correction for 8% water content value used for peanut storage in hulling (Martins and Lago, 2008). The loss values were calculated in kg ha^{-1} and percentage in relation to productivity.

For sampling productivity in the four areas, the same frame of approximately 2 m^2 previously described was used. It was placed on the windrows at a different sample point where the losses were determined. After this, cutting and bagging of all materials contained within the frame of the area and from the pods found within the sampling area was done with productivity of 8% water content calculated, and adding it to the productivity of harvest with the total losses from the digging up in this area (gross productivity).

For evaluation of the maturation, 100 pods were withdrawn randomly from the samples used to estimate the yield; next, the colour of the mesocarp was exposed through the Hull Scrape method through jet pressure water (Williams and Drexler, 1981).

Parallelism was measured after the digging operation, taking into account the working width of the digger/inverter (3.60 m) between the past tractor-digger set, obtained from the center of a windrow to the center of another windrow.

The water content was obtained by reading the probe of a TDR (Time Domain Reflectometer) which was used to determine the water quantity in the soil; TDR determines the dielectric constant of the soil by measuring the time (t) it takes for an electromagnetic pulse emitted in parallel conductive bar length L, fixed in the soil to reach its final level and return to the point of emission (Silva and Gervasio, 1999).

The analysis of the variability of peanut mechanical digging process was performed using SPC with the help of Minitab® software. The tools used were the control charts for variables. The selected control chart model was the Single Mobile Amplitude (I-MR: Single-Moving Range), which contains two graphs: the top, corresponding to the individual values sampled at each point and the lower obtained by amplitude calculated between the two successive observations. The control limits were established considering the variation in the data due to uncontrolled causes in the process (special causes), and was calculated based on the standard deviation of the variable, as demonstrated in Equations 1 and 2.

$$UCL = \bar{x} + 3\sigma \quad (1)$$

$$LCL = \bar{x} - 3\sigma \quad (2)$$

where UCL is the upper control limit; $\bar{x}$ is the general mean of the variable; δ is the standard deviation; LCL is the lower control limit.

The best estimator of δ for R graph is given by: MR / d_2, d_2 being one tabulated value and MR is the mean of the amplitudes. For the preparation of control charts, it is assumed that the data of a process under control are stationary and uncorrelated, providing graphics that can be planned in a way with predictable and reasonable performance and detecting points off reliably control. When the data is auto correlated, dependencies were observed between them, and this leads to an above average value which tends to be followed by an above average value, the same happening for trends below average. This means that as a condition in which there is little difference in each consecutive pair of points, reducing mobile range, which implies lower limits, increasing the rate of false alarm is important (Montgomery, 2009; Vaccaro et al., 2011).

The normality of the data is a fundamental supposition for development of $\bar{x}$ and R graphics. This approach can be difficult in some cases and many analysts would probably prefer to use the standard procedure based on the assumption of normality, since it is known that the effect of the removal of such a supposition is not very serious (Montgomery, 2009), so there was analysis of normality by Ryan-Joiner test at 5% and if necessary the transformation of the data.

RESULTS AND DISCUSSION

The following were analyzed in the data: visible digging losses (VDL), invisible digging losses (IDL), total digging losses (TDA), parallelism and the soil water content present with absence of autocorrelation, as observed in the figures that the bars do not extend beyond the dotted line in red (Figure 1).

Data normality was also observed for the variables, except for the total losses in the treatment C/S (with autopilot at sowing and absence at digging) getting 0.027, an amount close to 5% (normality), being considered by the assumption that the data follow a normal distribution according Montgomery (2009) (Table 1). From the confirmation of basic assumption for the use of control charts, the statistical process control was used as a tool to analyze the digging processes of peanuts.

Individual control charts and the mobile range for the visible losses, invisible and total, were stable for all treatments (Figure 2).

The visible loss showed quality similar process for treatments S/S, C/S and C/C. It was observed that the S/C treatment showed higher variability in the visible losses. This process can be related to the fact that the green peanut mass was substantially lower (27.765 kg ha^{-1}) compared to treatment S/S, C/S and C/C (37.437, 53.700, and 39.125 kg ha^{-1}, respectively).

Whereas the green mass dampens the vibration of peanuts on the vibrating mat, reducing the detachment of gynophore even when the pods have a high percentage of maturation. This fact is proved when analyzing maturation in the treatments, where the mean maturation values were 83, 84, 79, and 83% for S/S, S/C, C/S, and C/C, respectively, so even when the treatment S/C presenting a lower percentage of maturation, there was a higher detachment of fruit due to less dampening pods in the vibratory mat.

Thus, taking into account that the maturation is the main indicative for the start of management of peanut crop, Sanders et al. (1980) point as the ideal time for the pull-off when the pods present values between 70 and 75% maturation physiological (mesocarp after scraping presents color from light brown to black). However, according Onemli (2005), the maturation of the pods may be influenced by climatic factors, especially, cloudiness and precipitation factors that can increase the flowering period of peanut plants, a fact that decreases proportionally to the maturity of pods, retarding the start of the harvest.

Similarly, processes for the invisible loss (Figure 2B) are under control. It is noted that the process variability is reduced as the autopilot system is used; so, the best quality is obtained by C/C system, followed by use of the pilot in at least one of the operations (C/S, S/C) and finally, only the experience of the operator (S/S).

In this way, when using autopilot in only one of the operations (C/S) reduction of variability in invisible losses is noted compared to using only the autopilot operation in the digging (S/C). The lower variability obtained when sowing was performed with autopilot is justified

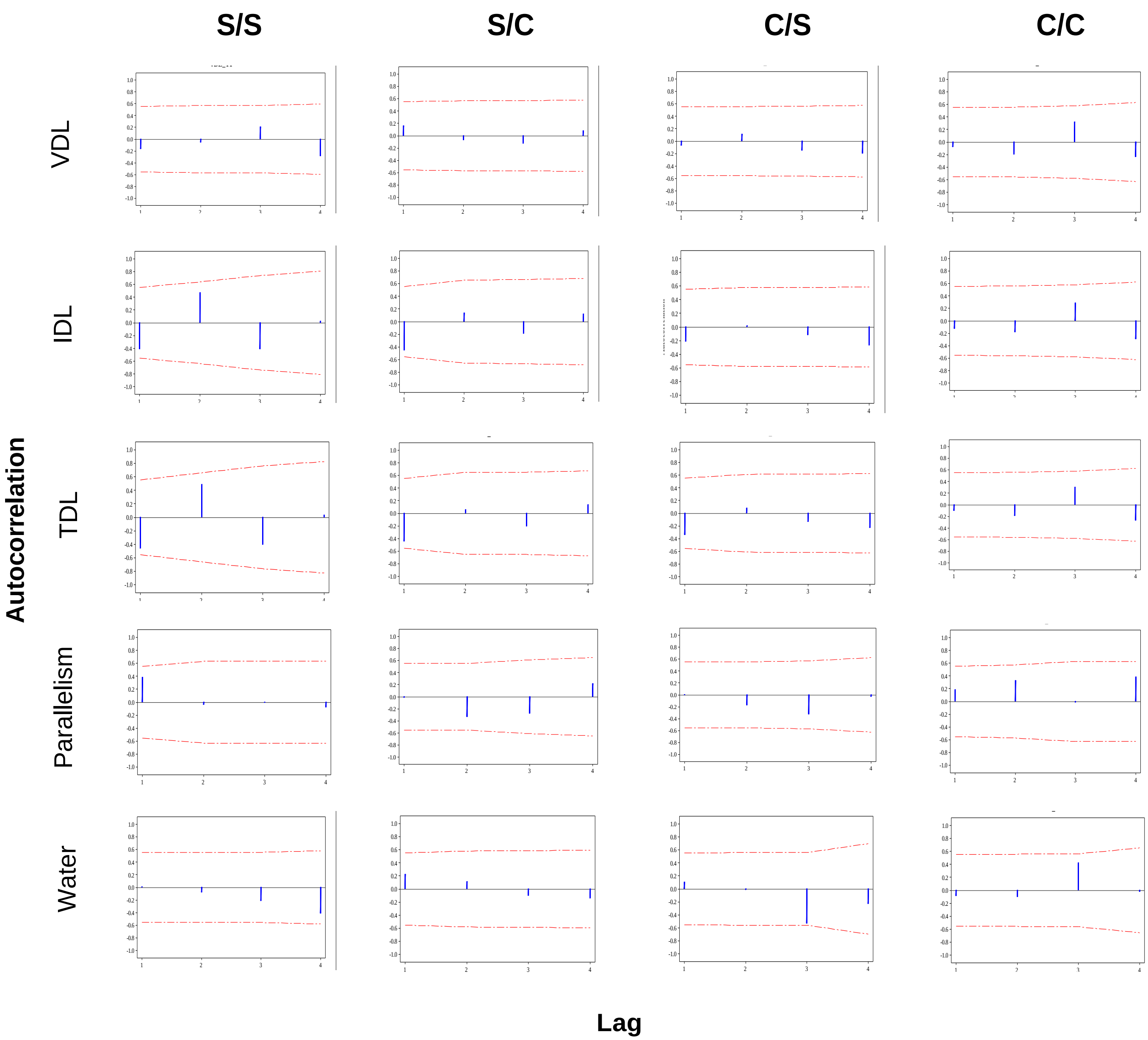

Figure 1. Autocorrelation function of visible loss in digging, 5% significance limit due to the absence of autopilot at sowing and digging up (S/S), absence of autopilot at sowing and presence at digging up (S/C), presence of autopilot at sowing and absence at digging up (C/S) and presence of autopilot at sowing and digging up (C/C).

Table 1. Normality test at 5% by the Ryan-Joiner test (similar to Shapiro-Wilk) due to the absence of autopilot at sowing and digging up (S/S), absence of autopilot at sowing and presence at digging up (S/C), presence of autopilot at sowing and absence at digging up (C/S) and presence of autopilot at sowing and digging up (C/C).

Variable	S/S	S/C	C/S	C/C
VDL	>0.100	>0.100	>0.100	0.054
IDL	>0.100	>0.100	>0.100	0.079
TDL	0.074	>0.100	0.026	0.054
Parallelism	>0.100	>0.100	>0.100	>0.100
Water content	>0.100	>0.100	>0.100	>0.100

*Values higher than 0.05 are considered normal to test.

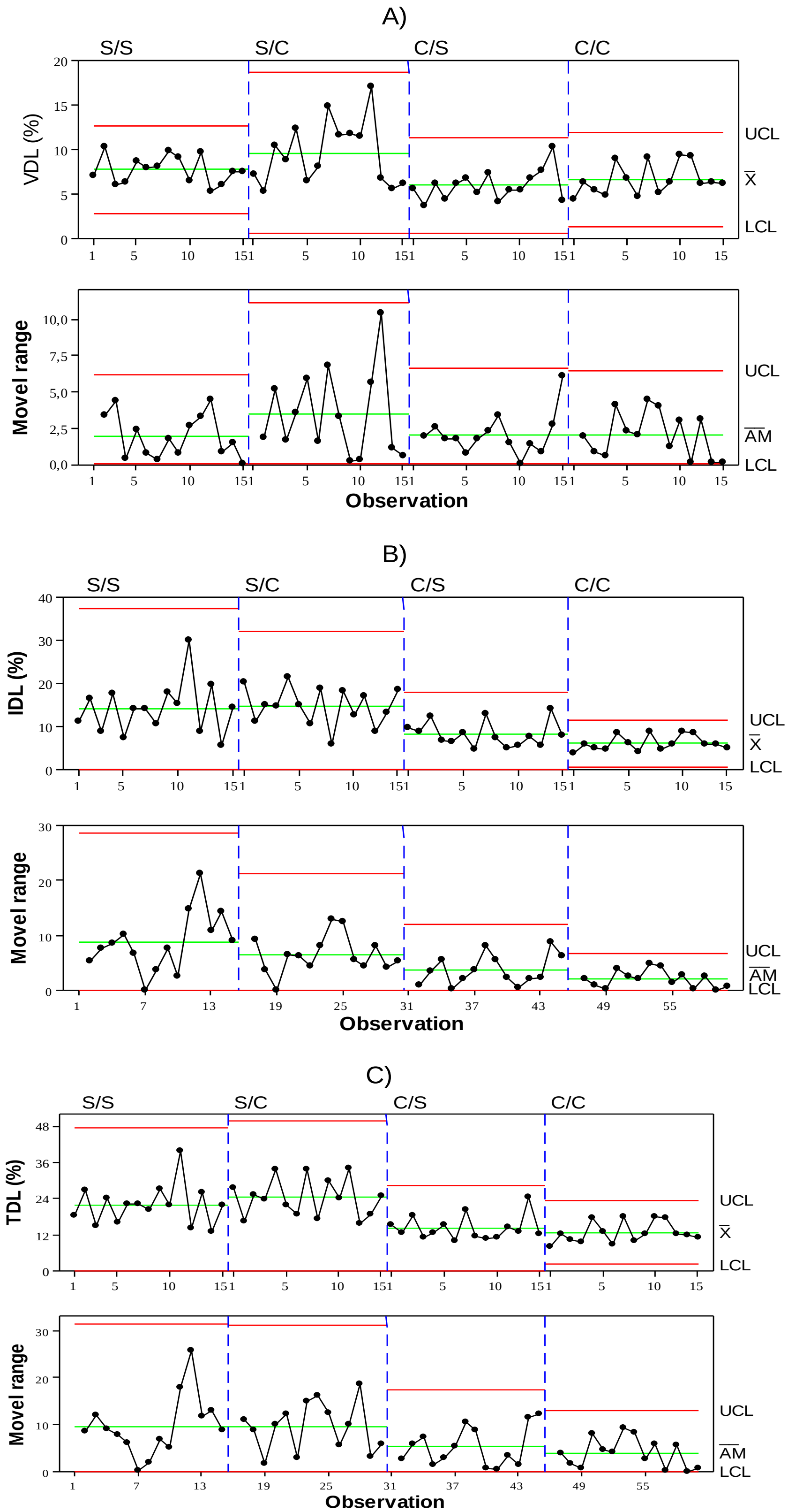

Figure 2. Control charts for losses in the digging due to the absence of autopilot at sowing and digging (S/S), no autopilot at sowing and presence in the digging (S/C), autopilot presence at sowing and absence in the digging (C/S) and presence of autopilot at sowing and digging (C/C). Visible digging losses (a) invisible digging losses (b) and total digging losses (c).

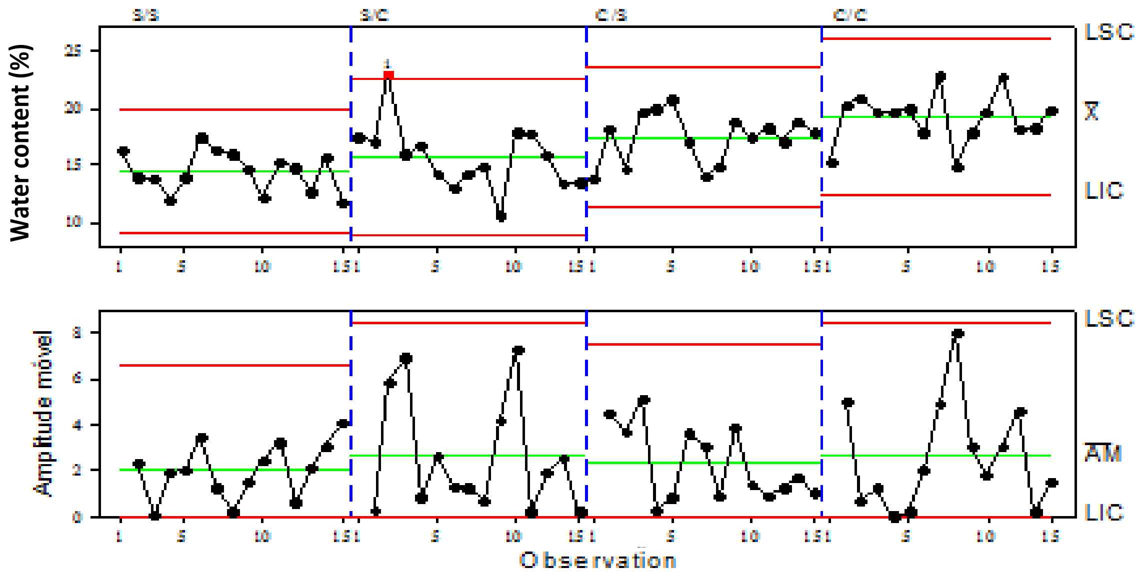

Figure 3. Control charts of soil water content due to the absence of autopilot at sowing and digging (S/S), no autopilot at sowing and presence in the digging (S/C), autopilot presence at sowing and absence in the digging (C/S) and presence of autopilot at sowing and digging (C/C).

by the fact that the sowing lines maintain a uniform standard throughout the operation, which facilitates digging operation, even when this is done with the help of the operator (pilotless). Furthermore, there is a better use of inputs and higher economic yields per sown area (Holpp, 2007).

Based on the moving range, charts (Figure 2B) confirm that the variability was reduced when sowing aligned with the digging using the autopilot (C/C). The reduction of variability in this process was due to the precise positioning of the tractor-digger set over peanut rows coming from the sowing operation. With the alignment of the two operations, the operator is not concerned with having to keep aligned tractor with row crop, and then you can give attention to possible faults in the digger, as straw accumulation and depth of work, ensuring reduction in the invisible loss rates and consequently the total.

It is noteworthy that the total losses (Figure 2C) are mainly influenced by the invisible losses. Presenting correlation of these variables of 0.96, correlation coefficient is considered strong and positive. The obtained relations from the invisible loss on total losses were 65, 61, 58 and 48% of total losses for treatments S/S, S/C, C/S and C/C, respectively, indicating that even in sandy soil, 60% of total losses, on average, comes from the invisible losses.

Thus, the use of the autopilot at sowing, aligned with the digging, can be a good tool in reducing losses in the pull-off, without letting pods retained in the soil, for alignment error.

These results are in accordance with those found by Zerbato et al. (2014a) that studying the use of autopilot (RTK signal) in peanut digging concluded that its use can reduce 24.9% of invisible losses, regardless of displacement speed. In the same way, Jackson et al. (2011) found a reduction in losses of 26% of the peanut pods productivity in crops sown and digging without autopilot in southern Georgia, USA.

For the digging performed without a pilot (S/S), average of invisible losses around 14.2% was obtained; this high rate of loss may have been influenced by the water content in the soil (14.39%, Figure 3). This value is below that recommended by Santos et al. (2010) that establish a range of 18 to 20% in clayey soil.

However, in sandy soils, commonly found in the state of Tocantins, can be inferred that based on the results, water content in the soil below 20% may represent significant increase in the rates of total losses in the digging. The water content in the soil has great variability in space and time, even when it belongs to the same pedological unit (Ávila et al., 2010).

In this sense, Zerbato et al. (2014b) afirms that higher soil water content can reduce the losses in the digging, but when it is too high it hinders the performance of the machines. In corroboration, Kad et al. (2008) in the India, report that the water content in the soil is near 25% at the time of digging difficult operation for soil of the region.

Regarding the average productivity, it can be considered as good, 5070, 6143, 5842, and 6294 kg ha^{-1} for treatment S/S, S/C, C/S and C/C, respectively at 135 days after sowing. Being that values found corroborate those observed by Santos et al. (2013), 6041.5 to 7020.9 kg ha^{-1} using the cultivar runner, digged between 120 and 140 days after sowing. Still, Ortiz et al. (2013) evaluated the use of autopilot in two sowing systems and found

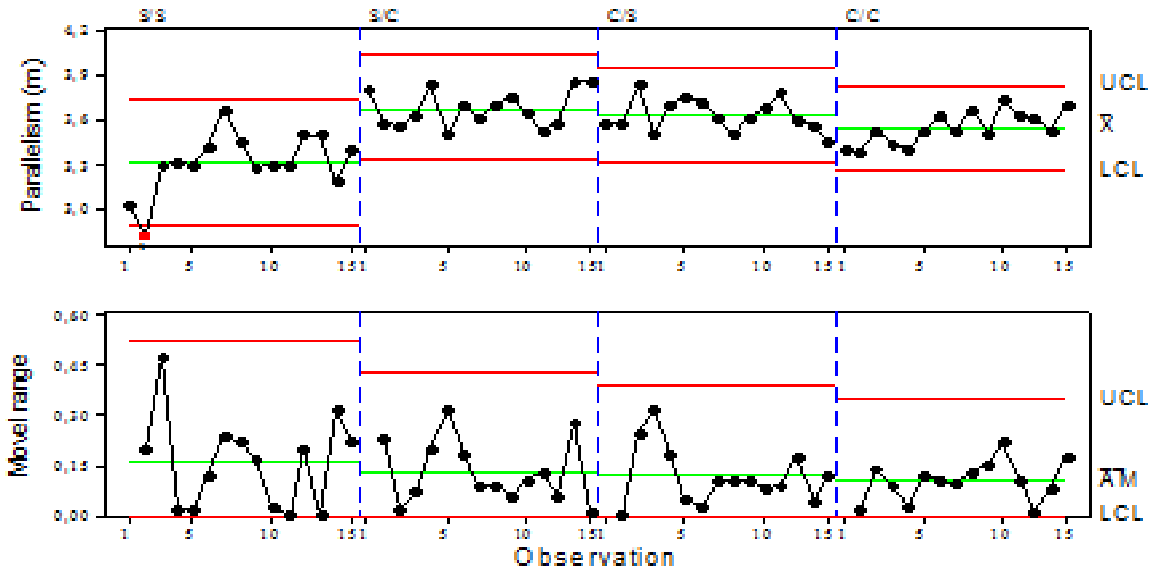

Figure 4. Parallelism control charts due to the absence of autopilot at sowing and digging (S/S), no autopilot at sowing but present in the digging (S/C), autopilot presence at sowing and absence in the digging (C/S) and presence of autopilot at sowing and digging (C/C).

productivity ranging from 3690 to 4324 kg ha^{-1}, while Assunção et al. (2008) obtained 4400 kg ha^{-1} in irrigated conditions.

The lowest yield was found in treatments S/S and C/S can be attributed to the occurrence of weeds, even making periodic control areas, these interfere in the development of peanut plants, with accentuated reduction in these two treatments. Everman et al. (2008) emphasize that one of the factors that affect the growth and development of peanut crops are weeds, and may occur up to 80% reduction in productivity. Gunri et al. (2014) point out that the weeds grow faster than peanuts, and competition in the early stage reduces the development of crops reflecting a reduction in productivity.

Parallelism demonstrated instability (Figure 4), with a point out of control in treatment S/S, caused probably by manpower factor, where the operator even with experience (eighth season) deviated attention to the digger and caused slipping the longitudinal axis of the tractor with the culture.

This carelessness resulted in reduction between the windrows formed by the digger, making them closer to one another (2.82 m) between the past of set, which should pass 3.60 m. This error of 7.8 cm justifies the increased variability of the total losses in this treatment.

For the other treatments, the process can be considered stable, not showing points out of control, that is, the causes of variation are intrinsic in the process. The use of autopilot in the two operations (C/C) showed lower variations with respect to amplitude, when compared with treatment (S/C and C/S).

It was expected tha the guidance error in this treatment was only 0.03 m, but it presented a deviation from of 0.035 m, because the distance from the rover to the fixed base. However, when comparing the positioning error when autopilot (S/S) is not used, the average error was 0.084 m. Baio (2012) evaluating the average error of the autopilot in sugarcane harvest in two periods of work, found an average error of 0.030 m, while the manual system of this value increased significantly to 0.183 m.

The quality of the operation in relation to reducing the overlap of past tractor-digger system, reduced with the use of autopilot, following the same pattern of reduced variability presented in the total losses graphics. In this way, it is presumed that the use of the autopilot reduces variability in total losses in peanut digging and increases the quality of the operation, by reducing the parallelism errors. This fact is most evident when using the autopilot at sowing and digging due to positioning precision of the machines, and synchronization of operations.

Vellidis et al. (2013) in the same conditions of soil of the present work, also found lower losses in peanut using mechanical digging autopilot, and these results justified by the smaller error deviation tractor-digger system, provided by the accuracy of the RTK signal. Ortiz et al. (2013) also using RTK signal, emphasized that the use of automatic guidance with error 2.5 cm, can give net return of 94 and 404 US$ ha^{-1} for producers, against deviation of 18 cm operated manually.

Conclusions

It can be inferred that the alignment of sowing with peanut digging with the autopilot use provides reduction of variability in total losses and consequently a better quality process.

The use of autopilot maintained the parallelism of mechanized set in digging the closest of regulated, with less variability and less positioning error.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Assunção HF, Escobedo JF, Carneiro MAC (2008). Eficiência de uso da radiação e propriedades óticas da cultura do amendoim. Pesqui. Agropecu. Trop. 38(3):215-222.

Ávila LF, Mello CR, Silva, AM (2010). Continuidade e distribuição espacial da umidade do solo em bacia hidrográfica da Serra da Mantiqueira. Rev. Bras. Eng. Agríc. Ambient. 14(12):1257-1266.

Baio FHR (2012). Evaluation of an auto-guidance system operating on a sugar cane harvester. Prec. Agric. 13(1):141-147.

Balkcom KS, Arriaga FJ, Balkcom K, Boykin DL (2010). Single and twinrow peanut production within narrow and wide strip tillage systems. Agron. J. 102(2):507-512.

Bertonha RS, Silva RP, Furlani CEA, Nascimento JM, Cavichioli FA (2014). Perdas e teor de água das vagens no arranquio mecanizado de amendoim. Energia Agric. 29(3):167-173.

Bragachini M, Peiretti J (2008). Mejoras en la Eficiencia de Cosecha de Maní. Gacetilla de Prensa: 09/2008 – Marzo. http://www.cosechaypostcosecha.org/data/gacetillas/2008/20080319_mani.asp. Acessed28 maio 2015.

BRASIL (2009). Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. Regras para análise de Sementes. Brasília, 395p.

Chioderoli CA, Silva RP, Noronha RH, Cassia MT, Santos EP (2012). Perdas de grãos na distribuição de palha na colheita mecanizada de soja. Bragantia 71(1):112-121.

CONAB (2015). Companhia Nacional De Abastecimento. Acompanhamento da Safra Brasileira – Grãos Safra 2014/2015 – 12°Levantamento, junho/2015. Available in:< http://www.conab.gov.br/OlalaCMS/uploads/arquivos/13_10_09_14_34_18_boletim_portugues_setembro_2013.pdf> Acessed em: 15 de maio de 2015

EMBRAPA (2013). Empresa Brasileira de Pesquisa Agropecuária. Sistema Brasileiro de Classificação de Solos. 3. ed. Brasília: Embrapa 353 p.

Everman WJ, Clewis SB, Thomas WE, Burke IC, Wilcut JW (2008). Critical period of weed interference in Peanut. Weed Technol. 22(1):63-67.

Gunri SK, Sengupta A, Nath R, Bera PS, Puste AM (2014). Evaluation of post emergence herbicides on summer groundnut (Arachishypogaea L) in new aluvial zone of West Bengal. Afr. J. Agric. Res. 9(40):2971-2974.

Holpp M (2007). Work-economics and financial aspects of parallel guidance systems for tractors. In: European Conference on Precison Agriculture, Skiathos. Proceedings Skiathos: John Stafford 6p.

Ince A, Guzel E (2003). Effects of gynophore breaking resistance on losses in mechanized peanut harvesting In: International Conference on Crop Harvesting and Processing. Louisville, Kentucky. ProceedingsSt Joseph: ASABE. P 1103.

Jackson JL, Beasley JP, Tubbs RS, Lee RD, Grey TL (2011). Fallbedding for reduced digging losses and improved yield in strip-till peanut. Pean Sci. 38(1):31-40.

Kad VP, Nikam SP, Salve VA (2008). Performance evaluation of power tiller drawn groundnut digger.Inter. J. Agric. Eng. 1(2):107-109.

Martins L, Lago AA (2008). Conservação de semente de Cedrela fissilis: Teor de água da semente e temperatura do ambiente. Rev. Bras. Sement. 30(1):161-167.

Montgomery DC (2009). Introdução ao controle estatístico da qualidade. 4ª ed. Rio de Janeiro: LTC, 513 p.

Noronha RHF, Silva RP, Chioderoli CA, Santos EP, Cassia MT (2011). Controle estatístico aplicado ao processo de colheita mecanizada diurna e noturna de cana-de-açúcar. Bragantia 70(4):931-938.

Oliveira TC, Molin JP (2011). Uso de piloto automático na implantação de pomares de citros. Eng. Agríc. 31(2):334-342.

Onemli F (2005). The correlation analyses of some climate values with flowering and earliness index in peanut (*Arachis hypogaea L.*). J. Tekirdag Agric. Faculty 2:273-281.

Ortiz BV, Balkcom KB, Duzy L, Santen EV, Hartzog DL (2013). Evaluation of agronomic and economic benefits of using RTK-GPS-based auto-steer guidance systems for peanut digging operations. Prec. Agric. 14(4):357-375.

Sanders TH, Williams EJ, Schubert AM, Patte HE (1980). Peanut maturity method evaluations .I. Southeast. Pean Sci. 7(2):78-82.

Santos EP, Silva RP, Bertonha RS, Noronha RHF, Zerbato C (2013). Produtividade e perdas de amendoim em cinco diferentes datas de arranquio. Rev. Ciênc. Agron. 44(4):695-702.

Santos EP, Silva RP, Furlani CEA, Bertonha RS, Medeiros RS (2010). Perdas na colheita mecanizada de amendoim. In: Congreso Latinoamericano y del Caribe de Ingeniería Agrícola. annals, Vitória: SBEA.

Silva CB, Moraes MAFD, Molin JP (2011). Adoption and use of precision agriculture technologies in the sugarcane industry of São Paulo state, Brazil. Prec. Agric. 12(1):67-81.

Silva EL,Gervásio ES (1999). Uso do instrumento TDR para determinação do teor de água em diferentes camadas de um Latossolo roxo distrófico. Rev. Bras. Eng. Agríc. Ambient. 3(3):417-420.

Sun H, Slaughter DC, Perez-Ruiz M, Gliever C, Upadhyaya SK, Smith RF (2010). RTK GPS mapping of transplanted row crops. Comput. Elect. Agric. 71(1):32-37.

Vaccaro GLR, Martins JC, Menezes TM (2011). Análise estatística da qualidade de níveis de tensão em sistemas de distribuição de energia elétrica. Produção 21(3):539-552.

Vellidis G, Ortiz B, Beasley J, Hill R, Henry H, Brannen H (2013). Using RTK-based GPS guidance for planting and inverting peanuts. In: J.V. Stafford (Ed.), Precision Agriculture – Proceedings of the 9th European Conference on Precision Agriculture (9ECPA), Lleida, Spain.

Voltarelli MA, Silva RP, Cassia MT, Ortiz DF, Torres LS (2015). Qualidade do corte basal de cana-de-açúcar utilizando-se de três modelos de facas. Eng. Agríc. 35(6):528-541.

Williams EJ, Drexler JSA (1981). A non destructive method for determining peanut pod maturity. Pean. Sci. 8(2):134-141.

Zerbato C, Furlani CEA, Silva RP, Voltarelli MA, Santos GO (2014a). Perdas no arranquio mecanizado em função do uso do piloto automático e velocidades de deslocamento. XI Latin American Congress y del Caribe de Ingenieria Agricola, XXIII National Ingenieria Agricola Congress. annals, Cancún, Quintana Roo, México, 6 al 10 de octubre de 2014a.

Zerbato C, Silva VFA, Torres LS, Silva RP, Furlani CEA (2014b). Peanut mechanized digging regarding to plant population and soil water level. Rev. Bras. Eng. Agríc. Ambient. 18(4):459-465.