Australian Journal of Crop Science AJCS

AJCS 8(6):992-998 (2014) ISSN:1835-2707

Quality control to seeding systems and densities in peanut crop

Cristiano Zerbato*, Carlos Eduardo Angeli Furlani, Murilo Aparecido Voltarelli, Rafael Scabello Bertonha, Rouverson Pereira da Silva

Department of Rural Engineering, Universidade Estadual Paulista–UNESP/FCAV, Prof. Paulo Donato Castellane Access way, 14884-900 – Jaboticabal, SP–Brazil

***Corresponding author: cristianozerbato@hotmail.com**

Abstract

The mechanisation of peanut cultivation has evolved over the years, but there are still obstacles that affect the quality of mechanised operations. Among these, sowing is essential for ensuring an adequate plant stand and the successful implantation of crops. The objective of this study was to use Statistical Process Control (SPC) to evaluate the quality of the operation of peanut seeding systems and densities. The parameters included the number of days to emergence, the longitudinal distribution of seedlings, the initial stand of plants and the crop yield. The experiment was conducted using a completely randomised block design including two seeding systems (manual and mechanical), three seed densities (10, 14 and 18 seeds m^{-1}) and eight replications in the year 2013. The seeding systems maintained a quality standard for the average number of days to seedling emergence. Compared to the longitudinal distribution of the seedlings in the control group, the mechanised seedings presented higher percentage of flawed spacing, which did not affect the crop yield. The initial stands of plants were similar between the two seeding systems, and the seed density of 14 seeds m^{-1} resulted in values that were similar to those of the higher seed density rate of 18 seeds m^{-1}. Similar behaviour was observed for pod production. In conclusion, the mechanised seeding showed a satisfactory quality standard and the seed density rate of 14 seeds m^{-1} presented an agronomic performance similar to that of 18 seeds m^{-1} and higher than that of 10 seeds m^{-1}.

Keywords: *Arachis hypogaea* L., crop management, seeder-fertiliser, statistical process control.

Abbreviations: AD_Anderson-Darling Normality Test (N: Normal distribution; S: Skew distribution); Ck_Kurtosis coefficient; Cs_ skewness coefficient; CV_Coefficient of variation; CY_crop yield; D1, D2 and D3_densities of plants (10, 14 and 18 seeds m^{-1}); DS _double spacing; FS_flawed spacing; FWA_Front wheel assist; H_Seeding by hand; ha_hectare; ISP_initial stand of plants; kW_ Kilowatts, LCL_Lower control limit; M_Mechanical seeding; m_meter; $\overline{MR}$ _moving range; NDE_number of days to seedling emergence; NS_normal spacing; σ_Standard deviation; SPC_Statistical Process Control; UCL_Upper control limit; $\overline{X}$ _average.

Introduction

Peanut was a prominent crop in Brazil during the 1970s, but outdated cultivation technology standards caused problems for peanut cultivation, to be replaced by another crops, such as soybeans. However, the peanut industry is currently experiencing a transitional period, with the introduction of new technologies and the replacement of manual techniques with mechanised farming systems.

However, there are concerns about the accuracy and quality of mechanised seeding. Studies have shown that the uniform longitudinal distribution of seeds contributes to an adequate plant stand and consequently improves the productivity of crops. Non-uniform seed spacing leads to an inefficient utilisation of resources such as light, water and nutrients (Jasper et al., 2011). In manual seeding, there is strict control over seed spacing, which prevents non-uniform seed spacing.

According to Nakagawa et al. (2000), the plant population affects productivity because it influences the production components. Therefore, the seeding configuration, which is characterised by the spacing between and within the rows, would also significantly influence the behaviour of these variables because it is a determinant of the population density.

The spacing studies of crop cultivars at creeping size are scarce, variable and even contradictory, which do not help much the mechanisation (Godoy et al., 1986; Tasso Junior et al., 2004 e Godoy et al., 2005). However, whichever spacing is being used, there will be considerable losses in crop production if the operation of mechanised seeding is not optimised. There are also other factors that affect the quality of a seed, such as weather conditions and seed performance.

Quality maintenance and improvement are essential to the success of any production system, especially mechanised operations that have high levels of variability due to uncontrollable factors. According to Nagumo and Milan (2006), control charts and histograms can be used to analyse the critical quality indicators of a process.

The use of Statistical Process Control (SPC) to assess/ monitor the quality of mechanised agricultural operations is still incipient, especially when dealing with peanut crop implantation. However, studies have been conducted using SPC in legumes, such as in mechanical bean (Silva et al., 2013) and soybean harvesting (Chioderoli et al., 2012). In these studies, the tools that typically being used to identify non-random causes or special causes are control charts due to the instability of the process (Montgomery, 2004; Peloia et al., 2010).

The quality of mechanised peanut seeding operations in Jaboticabal was studied by Toledo (2008) using control charts in which some of the resulting crops were considered stable, indicating the quality of the seeding operation.

Considering the importance of seeding quality for a successful peanut cropping and due to the scarcity of related research, the aim of this study was to use SPC to evaluate the operational quality of seeding with respect to the agronomic characteristics of the crops in different systems and population densities of the peanuts.

Results

Descriptive statistics

Table 1. presents the data for the variables number of days to seedling emergence (NDE), normal spacing (NS), flawed spacing (FS), initial stand of plants (ISP) and crop yield (CY). Descriptive analysis of the NDE showed a normal data distribution according to the Anderson-Darling test with a low range and standard deviation. Furthermore, the mean and median values are visibly close with a low coefficient of variation between 0 and 10% (Pimentel-Gomez and Garcia, 2002). Fig. 1a shows that this variable had a normal distribution curve, indicating a normal NDE.

The NS and FS variables (Table 1) showed an asymmetrical distribution. This behaviour was mostly characterised by a negative coefficient of kurtosis that was well below zero, resulting in a flattened distribution curve with respect to the standard normal distribution (Fig. 1b and 1c), or a platykurtic distribution. The coefficient of variation was medium for NS and too high for FS (Pimentel-Gomez and Garcia, 2002).

The ISP (Table 1) showed a normal distribution according to the Anderson-Darling test, with a symmetrical distribution curve (Fig. 1d), despite the high amplitude values and standard deviations and a slight flattening of the curve, characterised by a negative kurtosis coefficient.

Although there was a slight elongation of the distribution curve to the right hand side caused by a positive Skewness coefficient (Fig. 1e), the CY variable (Table 1) showed a symmetrical frequency data distribution in the normality test. Despite the high standard deviation and range the mean was close to the median.

Statistical process control (SPC)

For some of the quality indicators, outliers can be observed in the statistical control charts. These data were maintained in all of the statistical analyses because these outliers are part of the process and can help to identify the occurrence of unique causes.

Number of days to seedling emergence (NDE)

Observing the control charts for the NDE (Fig. 2a), the process was kept under control, indicating that variability can only be assigned to common causes (random) during the seeding process, i.e., those intrinsic to the process. This fact demonstrates from the viewpoint of quality control that both of the seeding systems, regardless of the plant densities used, were able to maintain an adequate quality standard. In this case, homogeneity of seedling emergence was observed for each evaluated treatment.

In the manual seeding of the three seed densities, the NDE mean was higher. The control chart of the moving range also indicated greater variation in relation to process variation, represented by the longest distance between the upper and lower control (Fig. 2b). This may be due to the fact that manual seeding did not have a rigorous control for seeding depth. Therefore, some seedlings emerged more quickly than others, causing greater variability.

Longitudinal distribution of seedlings

For the NS and FS (Fig. 3I and 3II), where double spacing did not appear, the individual value chart for a quality indicator are exactly the opposite of each other because the NS and FS have a sum of 100%. Furthermore, as the moving range is obtained from the difference between two consecutive observations, the process variation is the same for these two variables for each evaluated treatment.

All of the treatments showed points within the control limits for the individual values and for the moving range. Therefore, the process is considered stable with random variations caused by natural factors inherent in the process (Fig. 3b I and II). Therefore, the seeding systems and seeding densities both maintained a quality standard in terms of the longitudinal distribution of seeds, even though some treatments showed greater variation than others, which is represented by the distances between the control limits (UCL and LCL) in the moving range and by the homogeneous distribution around the mean of the crops with a 14 seeds m^{-1} seed density.

It is important to note that manual seeding showed a noticeably higher average NS (Fig. 3a, I) and a consequently smaller FS (Fig. 3a, II), regardless of the seeding system.

Initial stand of plants (ISP)

Fig. 4a shows that an increase in seeding density increases the ISP. All of the quality indicators remained under control with the points and observations located within the specified limits, except for the manual seeding under a seed density of 18 seeds m^{-1}, in which observation 17 exceeded the UCL, suggesting instability of the process. This meant that the process was out of control due to unique causes that were not inherent in the process. Also, they were not so significant that they could destabilise the process variation because the observations were between the control limits on the moving range chart.

However, because this point is far from the others and the variation of the process for this treatment was smaller than the others (moving range chart), it can be considered an outlier. These outliers may be above or below the mean in the answer and explanatory variable and may be regarded as values that do not represent the real behaviour of the data set. However, these cases occurred during the process and should be investigated.

Crop yield (CY)

For the pod yield (Fig. 5a), considering the seed density, we observed that only a density of 18 seeds m^{-1} showed points that exceeded the UCL. Observation 17 for manual seeding and observation 41 for mechanical seeding led to instability of this variable due to unique causes that were extrinsic to the process. Interestingly, the same sample plot that resulted in a point out of the control for the ISP (n. 17) had a similar result for pod yield, suggesting that these points were interconnected. Where there was an outlier value for seed density, a similar discrepancy was observed for productivity at the same point or sampling observation.

Furthermore, similar to ISP variable, the average yield of the 14 and 18 seeds m^{-1} seed densities were similar to one

Table 1. Descriptive analysis for the number of days to seedling emergence (NDE), normal spacing (NS), flawed spacing (FS), initial stand of plants (ISP) and crop yield (CY).

Variable	Mean	Median	σ	Range	CV (%)	Cs	Ck	AD
NDE	13.63	13.59	0.395	1.571	2.90	0.11	-0.77	N
NS	78.38	80.96	14.73	43.18	18.80	-0.18	-1.71	A
FS	21.57	19.04	14.79	43.18	68.56	0.18	-1.71	A
ISP	126903	133333	27001	100741	21.28	-0.23	-0.94	N
CY	2673.9	2693.7	646.1	2783.7	24.16	0.60	-0.10	N

σ – Standard deviation; CV (%) – Coefficient of variation; Cs – Coefficient of skewness; Ck – Coefficient of kurtosis; AD – Normality test of Anderson-Darling (N: normal distribution; A: asymmetrical distribution); NDE – average number of days to seedling emergence; NS – Normal spacing; FS – Flowed spacing; ISP – Initial stand of plants; CY – Crop yield.

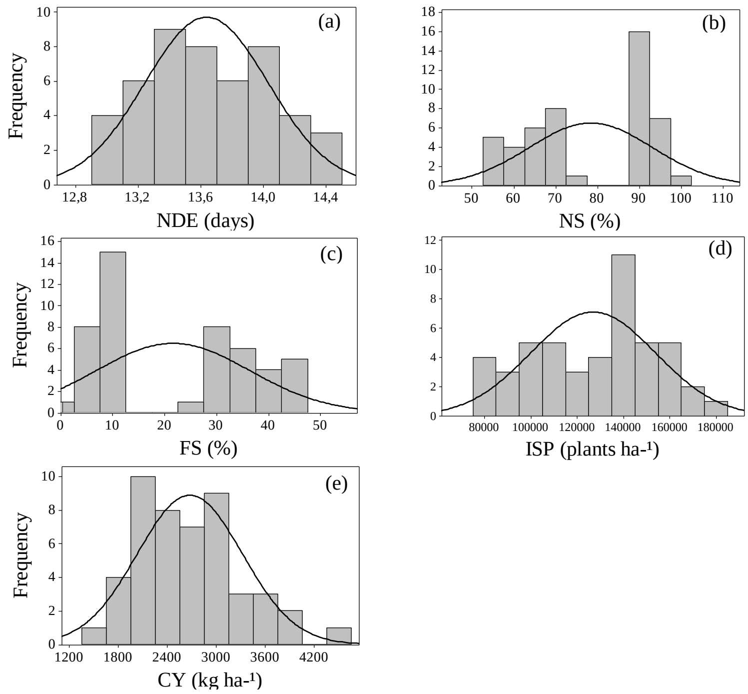

Fig 1. Histograms and distribution curves of the NDE (a), NS (b), FS (c), ISP (d) and CY (e).

another and were more distant from the yield obtained from a seed density of 10 seeds m^{-1}.

Discussion

According to Leon et al. (2005), a behaviour analysis of a data set with certain parameters in operational evaluations associated with the parameters of descriptive statistics. It serves to give an overview of a particular variable, allowing for the evaluation of sample variability. Finally, it helps to detect the possible unsatisfactory cases. Bai and Ng, (2005) reported an association between the skewness and kurtosis coefficients for the prediction of data behaviours that are monitored over time, which can infer the variability and/or the logic data distribution of the results of a particular process or operation.

According to Silva et al. (2009), for number of days to seedling emergence (NDE), the seeding depth should be 2 to 3 times larger than the seed size. It is important that the depth does not exceed 5 cm because the peanut seed undergoes epigeal germination and seeding depths can deplete the energy needed to raise the cotyledons to the soil surface. This phenomenon may have occurred in the manual seeding, causing a delay in seedling emergence. However, for all of the treatments in our study, the NDE was closer to that found by Torriba (2012), indicating that under normal circumstances the peanut takes between 7-14 days to emerge from the soil.

Considering longitudinal distribution of seedlings, the results may be related to external causes from the seeder. During conventional tillage, seeder driving wheel slippage may have occurred; thereby, not depositing the seeds in the correct place. This could have increased the spacing between seeds and caused flaws in longitudinal distribution when the seeds were mechanically sowed.

According to Garcia et al. (2011), seeder wheel slippage may be affected by many factors such as soil conditions. In evaluation of a precision seeder, Vale et al. (2008) observed that driving wheel slippage of the seeder in conventional tillage was higher than in a no-tillage system. This phenomenon does not occur in manual seeding and the seeds are placed in the correct spacing. There is an increase in the normal spacing, which does not reach 100% because only seed germination presents a qualifying process with respect to the longitudinal distribution of seeds.

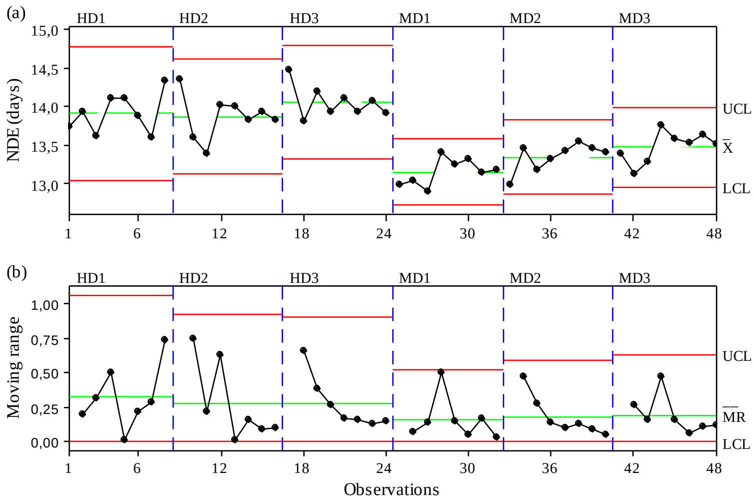

Fig 2. Control charts for quality indicator NDE: (a) Charter of individual values for process monitoring. (b) Charter moving range for monitoring process variability. UCL: Upper control limit. LCL: Lower control limit. $\bar{X}$: average of individual values. $\overline{MR}$: average of individual moving range. H: Seeding by hand. M: Mechanical seeding. D1, D2 e D3: densities of plants (10, 14 and 18 seeds m^{-1}).

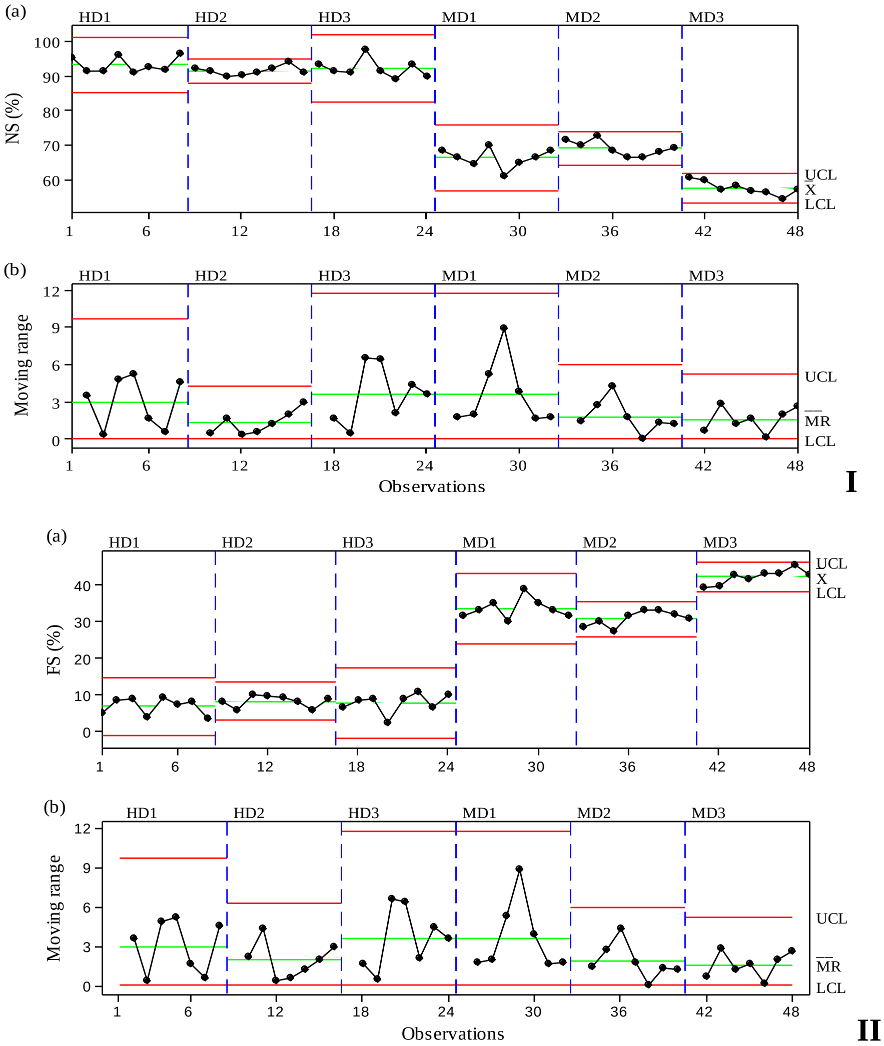

Fig 3. Control charts for quality indicator NS (I) and FS (II) in percentages: (a) Charter of individual values for process monitoring. (b) Charter moving range for monitoring process variability. UCL: Upper control limit. LCL: Lower control limit. $\bar{X}$: average of individual values. $\overline{MR}$: average of individual moving range. H: Seeding by hand. M: Mechanical seeding. D1, D2 e D3: densities of plants (10, 14 and 18 seeds m^{-1}).

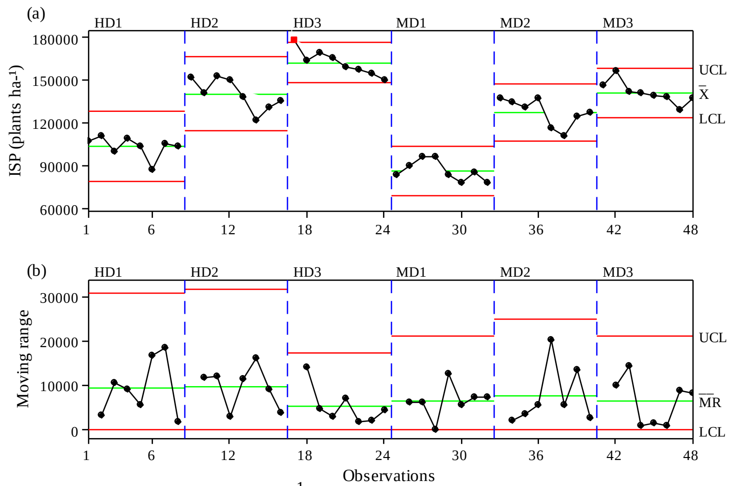

Fig 4. Control charts for quality indicator ISP (plants ha^{-1}): (a) Charter of individual values for process monitoring. (b) Charter moving range for monitoring process variability. UCL: Upper control limit. LCL: Lower control limit. $\overline{X}$: average of individual values. $\overline{MR}$: average of individual moving range. H: Seeding by hand. M: Mechanical seeding. D1, D2 e D3: densities of plants (10, 14 and 18 seeds m^{-1}).

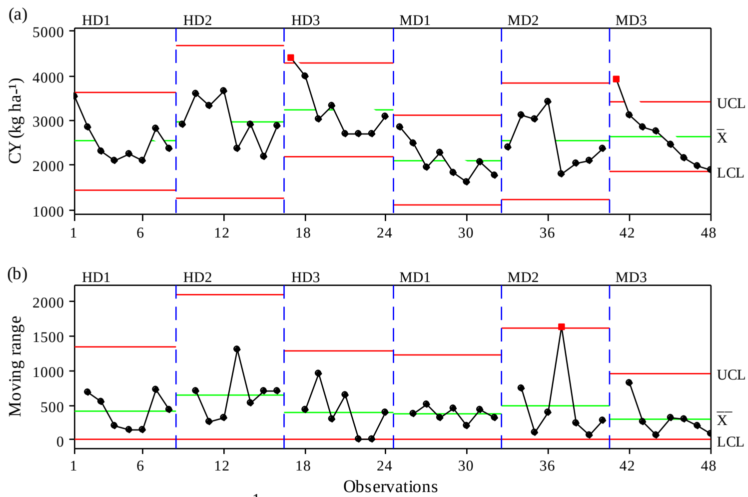

Fig 5. Control charts for quality indicator CY (kg ha^{-1}). (a) Charter of individual values for process monitoring. (b) Charter moving range for monitoring process variability. UCL: Upper control limit. LCL: Lower control limit. $\overline{X}$: average of individual values. $\overline{MR}$: average of individual moving range. H: Seeding by hand. M: Mechanical seeding. D1, D2 e D3: densities of plants (10, 14 and 18 seeds m^{-1}).

The unique cases could be explained by the occurrence of one or more of the "6 Ms" in the initial stand of plants (machines, methods, materials, measurements, the nature and manpower). However, for this situation in particular, the point out of the upper limit control and the high process variations in all of the treatments were related to the material factor (peanut plants) and mother nature (availability of water, light and nutrients), which are associated with intraspecific competition, determining each peanut cultivar and the plant densities that provide greater productivity and better use of available resources (Silva and Beltrão, 2000). When points with higher density were sampled, less competition effect may have occurred, and sampling points with lower populations may have happened with high competition effects, causing variability in the moving range chart.

It is important to note that for the ISP, regardless of the seeding system, a seed density of 18 seeds m^{-1} did not result in high values of plant density as would be expected. The seed density of 14 seeds m^{-1} achieved results more similar to the 18 seeds m^{-1} seed density than to the 10 seeds m^{-1} seed density. Brown et al. (2005) found that the final stand of peanut plants is a factor among many production characteristics that may influence productivity. Balkcom et al. (2010) found that a seed density of at least 13 seeds m^{-1} is recommended to reduce productivity losses associated with the density of peanut plants.

For crop yield (CY), the results may be related to the characteristics of undetermined growth and creeping peanut variety, compensating for the reduced number of a component and maximising others, i.e., for the two higher seed densities, while the lower density reduced the plant population. Then, the yield per plant was increased, resulting in an equal yield per area. This phenomenon was observed in both seeding systems. Therefore, a smaller number of seeds can be planted per hectare.

According to Peixoto et al. (2008), there was no significant difference in productivity between 10 and 15 plants m^{-1} of the "Vagem Lisa" variety. The plants in the lower seed density had a higher exploration area in the ecological substrate, permitting the greater penetration of sunlight, intensifying photosynthesis and enabling more efficient plant growth, consequently increasing the yield per plant.

Knowledge of the compensatory effect between productivity components is an important point to recommend as a management technique to better exploit the grain yield of different varieties. Romanini Júnior (2007), worked on a Red Latosol and evaluating seed densities of 9, 12, 15 and 18 seeds m^{-1} of the same variety, did not find any influence from seed density on the peanut pod yield. The same result was found by Silveira et al. (2009), evaluating the densities of 5, 10 and 15 plants m^{-1} in "Vagem Lisa" and BRS Havana varieties in a Red-Yellow Latosol in the Recôncavo Baiano-Brazil. With respect to process variation, we observed that there was a point, exceeding the upper limit from mechanical seeding, with a seed density of 14 seeds m^{-1} in the moving range chart. When this situation occurred, regardless of the behaviour of the individual values chart, the process was considered unstable due to the high range at this point (observation 37). The solution to this problem is continuous monitoring of the process to reduce such variation because if this point did not exist, the variability would potentially be lower. However, for the same seed density, the manual system showed the greatest process variation, even maintaining statistical control, as was represented by the largest distance between the specified control limits.

Materials and Methods

Plant materials and experimental conditions

This study was conducted at the Farm for Education, Research and Production, UNESP/Jaboticabal, Brazil, at approximately 21 º 14' South latitude and 48 º 17' West longitude with an altitude and slope of 560 meters and 4%, respectively. The soil of the experimental area was classified as a Eutroferric Red Latosol with a clay and undulated relief, according to Andrioli and Centurion (1999). The soil has 469 g kg^{-1} of clay, 307 g kg^{-1} of silt and 224 g kg^{-1} of sand.

According to the update of the classification Köppen-Geiger (Peel et al., 2007), the climate is Aw, defined as tropically humid with a rainy season in the summer, an arid climate in the winter and an average temperature of approximately 22º C. This region experienced 705 mm of rainfall and an average temperature of 23.8º C during the experiment, which was measured by our own meteorological station.

Peanut seeds (*Arachis hypogaea L.*) of the IAC Runner 886 variety were planted in soil under conventional tillage with a disk harrow at a depth of 0.20 m with two light diskings. This variety was used to be the most planted by farmers of the study area. Prior to tillage, sub-soiling was conducted at a depth of 0.40 m to break through the compacted layers that were approximately 35 cm deep. The seeds were treated with thiamethoxam at 100 g 100 kg^{-1} and showed 85% germination in the laboratory, as determined by the Laboratory of Seed Analysis - UNESP/Jaboticabal.

The water content of the soil was evaluated according to Buol et al. (2011) which was 0.23 kg kg^{-1} in the 0 to 0.20 m layer at the time of seeding. This depth was used because peanut pods are usually found in this layer, which is considered to be the crop's arable layer.

Treatments

A randomised block experimental design was used, with a 3x2 factorial design, 8 replicates and 48 plots. The treatments consisted of three plant densities (10, 14 and 18 seeds m^{-1}) and two seeding systems (manual and mechanical). Each plot covered an area of 240 m^2, with 20 m length and 12 m width, and was passed over three times with a tractor-seeder set. The plots were evaluated in the central 4 rows. Among the plots, 15 m was left in a longitudinal direction for manoeuvring and stabilising the machinery.

Tractor and seeder characteristics

A Valtra BM 125i, 4×2 FWA tractor with engine power of 91.9 kW at 2300 rpm was used. The tractor was operated in 3rd L gear at 1900 engine rpm and an average speed of 5.7 km h^{-1}. The precision seeder was a Marchesan COP Suprema 7/4 that was equipped for conventional seeding with a 48-hole disc seeder of 55 mm each. For fertilising, 350 kg ha^{-1} was used with a formulation of 02-20-20, operating with four rows spaced at 0.90 m with a 5 cm seeding depth.

Manual seeding was conducted with the help of a graduated rule with furrow openings made with seeder double discs. Seed depositions and furrow closings were also performed manually in the same spatial arrangements as the mechanical seeding.

Analysed variables

The analysed variables included the following: the average number of days to seedling emergence (NDE), the longitudinal distribution of seedlings (NS: normal spacing; FS: flawed spacing; DS: double spacing), the initial stand of plants (ISP) and the crop yield (CY). The longitudinal distribution of the seedlings was determined using a classification proposed by Kurachi et al. (1989) and by daily counts of the peanut NDE (Edmond and Drapala, 1958). The ISP of the seedlings was considered from the last day of the evaluation of the NDE, i.e., after the stabilisation of seedling emergence, and the values were converted to plants per hectare. The real yield was determined according to Silva and Mahl (2008) by the number peanut pods of all of the plants in a 2 m^2 area. The water content of the pods was adjusted to 8%.

Statistical analysis

The data were analysed using descriptive statistics and histograms of the distribution curve of the data, allowing for a general view of the data behaviour. The arithmetic mean, median, standard deviation, range and coefficient of variation, skewness and kurtosis coefficient were calculated for this purpose. The data normality was verified using the Anderson-Darling test, and asymmetries were processed to achieve normality with the equation: $x' = 1/\sqrt{x}$. The statistical method used to determine process quality was the Statistical Process Control (SPC), using control charts for each variable whose central line was the general average (charts of individual values) and mean range (charts of process variation), as well as the upper and lower control limits, defined as the UCL and LCL, which were calculated according to the standard deviation of the variables (the UCL was the mean plus three times the standard deviation, and the LCL was the mean minus three times the standard deviation, when greater than zero).

Conclusions

Peanut seeding systems, regardless of seed densities, were able to maintain a quality standard in the average number of days to emergence. The longitudinal distribution of seedlings remained under statistical control with mechanical seeding presenting higher percentages of flawed spacing. The initial population of peanut plants and crop yields were similar between the seeding systems with a seed density of 14 seeds m^{-1} obtaining values closest to the higher seed density. Mechanical seeding showed satisfactory quality compared to manual seeding with a seed density of 14 seeds m^{-1}, representing an agronomic performance similar to a density of 18 seeds m^{-1} and above the 10 seeds m^{-1}.

Acknowledgments

The authors thank the National Council for Scientific and Technological Development and Coordination of Improvement of Higher Education Personnel, by grants granted to authors.

References

Andrioli I, Centurion JF (1999) Detailed survey of the soils of the Jaboticabal Faculty of Agricultural Scienses and Veterinary. Paper presented at the XXVII Brazilian Congress of Soil Science, Brazilian Society of Soil Science, Brasília, 11-16 July 1999.

Bai J, Ng S (2005) Tests for skewness, kurtosis, and normality for time series data. J Bus Econ Stat. 23:49-60.

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

Brown SL, Culbreath AK, Todd JW, Gorbet DW, Baldwin JA, Beasley JP (2005) Development of a method of risk assessment to facilitate integrated management of spotted wilt of peanut. Plant Dis. 89:348–356.

Buol SW, Southard RJ, Graham RC, McDaniel PA (2011) Morphology and compositions of soils. In: Buol SW, Southard RJ, Graham RC, McDaniel PA (eds) Soil genesis and classification. 6th edn. Wiley-Blackwell, Oxford, pp 35-88.

Chioderoli CA, Silva RP, Noronha RHF, Cassia MT, Santos EP (2012) Grain losses and distribution of straw in mechanized harvesting soybeans. Brag. 71:112-121.

Edmond JB, Drapala WL (1958) The effects of temperature, sand and soil acetone on germination of okra seed. P Am Soc Hortic Sci. 71:428-434.

Garcia RF, Vale WG, Oliveira MTR, Amim RT, Braga TC (2011) Influence of displacement speed on the performance of a precision seeder in North Fluminense. Acta Sci-Agron. 33:417-422.

Godoy IJ, Rodrigues Filho FSO, Gerin MAN (1986) Peanut Agricultural instruction for São Paulo state. In: Godoy IJ (ed) Boletim 200 Instituto Agronômico, 3rd edn. Campinas, São Paulo, pp 23.

Godoy IJ, Minotti D, Resende PL (2005) Peanut production quality. In: Godoy IJ (ed) Viçosa: Centro de Produções Técnicas. Viçosa, Minas Gerais, pp.168.

Jasper R, Jasper M, Assumpção PSM, Rocil J, Garcial C (2011) Speed soybean seeding. Eng Agric. 31:102-110.

Kurachi SAH, Costa JAS, Bernardi JA, Coelho JLO, Silveira GM (1989) Technological evaluation of seeding and/or fertilizing: treatment of test data and longitudinal distribution of seeds. Brag. 48:249-62.

Léon A, Rubio G, Serna G (2005) Autoregressive conditional volatility skewness and kurtosis. Q Rev Econ Financ. 45:599-618.

Montgomery, DC (2004) Methods and philosophy of statistical process control. In: Montgomery DC (ed) Introduction to statistical quality control, 6th edn. Wiley, Arizona, pp 179-213.

Nagumo GK, Milan M (2006) Quality function deployment (QFD) applied to seedlings of coffee (*Coffea arabica* L.). Eng Rur. 17:45-51.

Nakagawa J, Lasca DC, Neves GS, Neves JPS, Silva MN, Sanches SV, Barbosa V, Rosseto CA (2000). Plant density and peanut production. Sci Agr. 57:67-73.

Peel M, Finlayson B, McMahon T (2007) Updated world map of the Koppen-Geiger climate classification. Hydrol Earth Syst Sc. 11:1633-1644.

Peixoto CP, Gonçalves JA, Peixoto MFSP, Carmo DO (2008) Agronomic traits and yield of groundnut at different spacings and sowing dates in Bahia reconcave. Brag. 67:673-684.

Peloia PR, Milan M, Romanelli TL (2010) Capacity of the mechanical harvesting process of sugarcane billets. Sci Agr. 67(6):619-623.

Pimentel-Gomes F, Garcia CH (2002) Statistics applied to agronomic and forestry experiments. In: Pimentel-Gomes F (ed) Exposure to examples and guidelines for use by applications. 1st edn. Fealq-Esalq, Piracicaba, pp 309.

Romanini Junior A (2007) Influence of plant spacing on growth, production and yield of peanut keeper, Runner IAC 886 cultivar. M.S. Dissertation, Department of Rural Enginnering, Jaboticabal Faculty of Agricultural Scienses and Veterinary, São Paulo State University, pp 47.

Silva MB, Beltrão NEM (2000) Population levels and settings on peanut crop planting in rainfed conditions in the rough Mesorregião Borborema in the State of Paraíba. Rev Bras Oleag Fibr. 4:23-34.

Silva ORRF, Sofiatti V, Queiroga VP, Cartaxo WV (2009) Peanuts: the producer asks, Embrapa answers. In: Silva ORRF (ed) Embrapa Technological Information, 1st edn. Embrapa, Brasília, pp 240.

Silva RP, Cassia MT, Voltarelli MA, Compagnon AM, Furlani CEA (2013) Quality of mechanized harvesting of beans (Phaseolus vulgaris) in two tillage systems. Rev Cienc Agron. 44:61-69.

Silva RP, Mahl D (2008) Report of the research project: Losses in mechanical harvesting peanut crop 2007/2008. In Silva RP (ed) Research Report, 1st edn. Laboratory of Machinery and Agricultural Mechanization of Fcav-Unesp, Jaboticabal, pp 47.

Silveira PS, Peixoto CP, Lima VP, Silva APP, Bloisi AM, Borges VP (2009) Peanut yield under different plant densities. Rev Bras Agroecol. 4:2003-2006.

Tasso Junior LC, Marques MO, Nogueira GAA (2004) Cultura do amendoim. In: Tasso Junior LC (ed) Jaboticabal Editora Funep. 1st edn. Funep, Jaboticabal, pp 1-220.

Toledo A (2008) Spatial variability and diagnosis of process quality in groundnut sowing, M.S. Dissertation, Department of Rural Enginnering, Jaboticabal Faculty of Agricultural Scienses and Veterinary, São Paulo State University, pp 96.

Torriba (2012) Practical Guide for the production of peanuts. In Torriba (ed) Organization of Horticultural Producers S.A. 1st edn. Raposa, Portugal, pp 17.

Vale WG, Garcia RF, Thiebaut JTL, Amim RT, Tourino MCC (2008) Performance and sample dimension for evaluating a planter in no-tillage and conventional tillage. Acta Sci-Agron. 30:441-448.