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Peanut mechanized digging regarding to plant population and soil water level

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Key words:
Arachis hypogaea L.
crop losses
digger-inverter
operating performance

ABSTRACT

The largest losses in mechanical harvesting of peanuts occur during the stage of digging, and its assessment is still incipient in Brazil. Therefore, the aim of this study was to evaluate the quantitative losses and the performance of the tractor-digger-inverter, according to soil water content and plant populations. The experiment was conducted in a completely randomized block design with a factorial scheme 2 x 3, in which the treatments consisted of two soil, water content (19.3 and 24.8%) and three populations of plants (86,111, 127,603 and 141,144 plants ha^{-1}), with four replications. The quantitative digging losses and the set mechanized performance were evaluated. The largest amount of visible and total losses was found in the population of 141.144 plants ha^{-1} for the 19.3% soil water content. The harvested material flow and the tractor-digger-inverter performance were not influenced by soil water content and plant population. The water content in the pods was higher in 24.8% soil water content only for the population of 86,111 plants ha^{-1}; the yield was higher in the populations of 141.144 and 127.603 plants ha^{-1}, in the 19.3 e 24.8% soil water content, respectively.

Palavras-chave:
Arachis hypogaea L.
arrancador-invertedor
desempenho operacional
perdas na colheita

Arranquio mecanizado de amendoim associado à população de planta e ao teor de água do solo

RESUMO

As maiores perdas na colheita mecanizada ocorrem na operação do arranquio sendo que sua avaliação ainda é incipiente no Brasil. Objetivou-se, portanto, neste trabalho, avaliar as perdas quantitativas e o desempenho do conjunto trator-arrancador-invertedor em função de teores de água do solo e populações de plantas. O experimento foi conduzido em delineamento experimental em blocos casualizados com esquema fatorial 2 x 3 em que os tratamentos foram constituídos de dois teores de água no solo (19,3 e 24,8%) e três populações de plantas (86.111, 127.603 e 141.144 plantas ha^{-1}), com quatro repetições. Avaliaram-se as perdas quantitativas no arranquio e o desempenho do conjunto mecanizado. A maior quantidade de perdas visíveis e totais foi encontrada na população de 141.144 plantas ha^{-1} para o teor de água do solo de 19,3%. O fluxo de material colhido e o desempenho do conjunto trator-arrancador-invertedor não foram influenciados pelos teores de água do solo e populações de plantas. O teor de água das vagens foi maior no teor de água do solo de 24,8% somente para a população de 86.111 plantas ha^{-1}; a produtividade foi maior nas populações de 141.144 e 127.603, nos teores de água de 19,3 e 24,8%, respectivamente.

INTRODUCTION

Peanut (*Arachis hypogaea* L.) production in Brazil has grown significantly, from 183.4 t in 1998 to 296.7 t in 2011/12 crop, with an average production of around 2,926 kg ha^{-1}. The state of São Paulo, SP, Brazil, is responsible for 82% of domestic production and the region of Jaboticabal, SP, represents 25% of the state production and 20% of national production, usually cropped in sugarcane plantations renovations.

Besides having a short cycle (120 - 140 days after seeding) and best prices on fresh, processed and oil consumption, the peanut crop also presents an enormous potential for the production of biodiesel (Santos et al., 2006). However, in order to enable the peanut exploration, it is necessary to implement some actions such as: increasing the volume of production, increase productivity, reduce costs and expand the planted area (Peres et al., 2005), besides the determination of the adequate plant population, development and improvement of the harvest system.

The peanut harvest is performed in two stages, called digging and picking-separating. The first operation to perform the harvest itself, after the crop reach the ideal maturation, while picking-separating is carried out after a period of drying in the field.

The operation of digging is crucial to ensure maximum productivity because even when the harvest occurs at the maturity optimal point, plants contain pods beneath the soil surface and indeterminate growth at different stages of maturation, which may influence the loss in the mechanical digging (Dorner, 2008). These losses are influenced by several factors including crop diseases, pests, soil water content and plant population.

Due to the difficulty of determining the maturity optimal point for harvest, producers worldwide have had great economic losses linked to an erroneous decision, based on the number of days after sowing peanut (Rowland et al., 2006).

The high water content in the pods and soil also directly influences the harvest. Therefore, it is important to state that the digging with higher water content in the soil can reduce losses, but on the other hand, can hinder the performance of the machine operation.

Large losses are generated in the field every year, yet little attention is paid to conduct research, both as regards the appropriate time as to quantify losses during digging.

Losses on peanut crop are not frequently diagnosed in Brazil and, therefore, there are no pre-set standards or recommended levels regarding losses that can be used by farmers as acceptable for harvesting peanuts. Besides the need for more research, attention should be paid to the adjustments of the machines and the characteristics of the product harvested by machine, which may influence the increased losses. It was aimed in this study to evaluate the possible effect of two soil water contents and three plant populations regarding losses in the peanut mechanized digging and operational performance of the tractor-digger-inverter.

MATERIAL AND METHODS

The experiment was conducted in the area of Teaching, Research and Production Farm of UNESP/Jaboticabal, in the state of São Paulo, Brazil, in March 2012, located near the geographical coordinates 21° 14' South latitude and 48° 16' West longitude, with an mean altitude of 560 m and an average slope of 4%. The experimental area is classified as typical eutroferric Red Latosol A, with a loamy texture and soft wavy terrain, according to Andrioli & Centurion (1999). The soil granulometric analysis, in the layer of 0 to 0.20 m, was performed at the Laboratory of Soils UNESP/Jaboticabal, with the following contents: clay (469 g kg^{-1}), silt (306 g kg^{-1}) and sand (224 g kg^{-1}).

According to the classification of Köppen, the climate of region is Aw, defined as tropical humid with the rainy season in the summer and the dry season in the winter, with an average annual temperature of around 22 °C. During the experiment, this region showed rainfall of 705.5 mm and mean temperature of 23.8 °C, measured at the Meteorological Station of UNESP-Jaboticabal.

The factorial scheme of 2 x 3 under a completely randomized block design was adopted, with six treatments and four replications. The treatments consisted of two soil water contents (SWC 1: 19.3 and SWC 2: 24.8%), obtained through the application of different water depths using sprinkler irrigation system over the plots two days before harvesting, according to three peanut population of plants (86,111, 127,603 and 141,144 plants ha^{-1}), referred to as P1, P2 and P3, respectively, for a total of 24 plots.

In mechanized sowing IAC Runner 886 peanut seeds were used, with spacing between rows of 0.9 m. Each plot occupied an area of 240 m^2 – 20 m long by 12 m wide. Among the plots in the longitudinal direction were left, 15 m, designated to maneuvers and stabilization of displacement speed of the tractor-digger-inverter set.

For the digging, the Valtra BM125i, 4 x 2 tractor, 91.9 kW (125 HP) of power in the engine tractor, operating at 1400 rpm in gear L3, weighing 5,400 kg was used. The harvest was performed 140 days after sowing (DAS), using the mounted digger-inverter, model C-200 (2 rows x 1 windrow), with a working width of 1.8 m. This rotation was chosen according to recommendations of the digger-inverter manufacturer, to work with rotation of 350 rpm at power take-off.

The variable water content in the pods, maturation, visible, invisible and total losses during digging, productivity, harvested material flow, speed, effective field capacity and hourly and effective fuel consumption were evaluated.

For determining the soil water content during digging, samples were collected using a Dutch auger in the layer of 0 to 0.15 m, packed in aluminum containers. This depth was used because the peanut pods are generally present until this layer. The soil water content was obtained according to the methodology recommended by EMBRAPA (1997). The water content in the pods at the time of digging was performed by removing 50 pods of windrows at each sample point just after the passage of the digger-inverter and determined after drying in an oven.

To measure the losses a frame with sample area of 2 m^2 (1.11 x 1.80 m) was used. This frame measurement was determined

Table 1. Maximum (Tmax), minimum (Tmin) and medium (Tmed) temperatures; mean and accumulated water precipitation for each development period of peanut crop in function of days after seeding (DAS)

Stages	DAS	Tmax	Tmin	Tmed	Mean daily precipitation	Accumulated precipitation
		(°C)			(mm)	
Emergence	0-7	29.67	18.91	23.75	18.81	131.70
Development	7-28	29.86	17.84	23.41	3.75	105.10
Flowering	28-62	29.32	18.94	23.08	7.79	288.40
Grain filling	48-90	29.33	18.93	23.21	7.24	318.90
Maturation	90-120	30.49	18.81	23.93	4.03	120.90
Harvest	120-140	31.04	19.10	24.25	1.77	53.20

to achieve the exact width of the digger-inverter, which is positioned over two rows of the crop. Thus, the following variables were determined: Digging visible losses (UVL): performed after digging, the windrow is lifted carefully, and in this location the frame was positioned, and then collected all the pods and loose grains that were on the ground within the frame; Digging invisible losses (UIL): with the frame positioned in the same location, the soil was dug up with the aid of a hoe to approximately 0.15 m depth, followed by sieving the soil and separation of pods that were not torn; and the Digging total losses (UTL): determined from the sum of digging visible and invisible losses.

The actual harvest was determined by means of digging of all peanut plants contained in the frame area of 2 m^2, collecting then the pods that were over and under the soil to a depth of approximately 0.15 m, placing them, after sieving, in paper bags for subsequent weighing to obtain the productivity. The moisture content of all samples was adjusted to 8% (peanut storage water content), and subsequently, these values were extrapolated to kg ha^{-1}, according to Eq. 1:

$$\mathrm{Mf} = \frac{100 - \mathrm{WC}}{100 - \mathrm{WCp}} \times \mathrm{Mi} \qquad (1)$$

in which:

M_f - final mass corresponding to the sample weight with water content of 8%, kg

WC - water content of collected sample, %

WCp - peanut storage water content, 8%

M_i - initial mass corresponding to the collected sample weight, kg

To determine the maturation of peanut, the "Hull Scrape" method (Williams & Drexler, 1981) was used, which consists of scraping the exocarp of the pod, exposing the mesocarp. In each plot, five plants were randomly uprooted, of which all fully developed pods were selected, 100 pods were removed from this sample after scraping for conducting the evaluation.

Soon after the digging and windrowing, all matter contained in the green frame was packed and sent to the laboratory for determination of mass using electronic scales with accuracy of 0.01 g. The material flow was estimated in the digging from the values of green matter obtained by the Eq. 2:

$$\varphi\mathrm{mr} = \frac{\mathrm{VM} \times \mathrm{n} \times \mathrm{s} \times \mathrm{ds} \times (1 + \mathrm{R})}{10{,}000} \qquad (2)$$

in which:

φ_{mr} - harvested material flow, kg s^{-1}

VM - collected vegetable matter, kg ha^{-1}

n - number of windrows formed

s - spacing between crop lines, m

ds - displacement speed, m s^{-1}

R - pods relation – MV, dimensionless

10.000 - unit adequation factor

The actual displacement speed of the tractor digger-inverter set was measured by radar; model RVS II, installed on the right of the tractor, arranged in a 45° angle with the horizontal. The sensor was connected to an acquisition and storage system (model Micrologger CR23X), acquiring data at a frequency of 1Hz, obtaining about 12 values per plot (one value every second), calculating the arithmetic average.

The effective field capacity (EFC) was obtained according to the working width of the tractor-digger-inverter and displacement speed (Eq. 3).

$$\mathrm{EFC} = \mathrm{WW} \times \mathrm{s} \times 0.36 \qquad (3)$$

in which:

EFC - effective field capacity, ha h^{-1}

WW - working width of the digger-inverter, m

s - real displacement speed, m s^{-1}

0.36 - unit adequation factor

Fuel consumption was determined in volume unit (ml) by the difference between the volumes measured before the fuel injection pump and in its return, obtaining the volume actually used by the tractor during transit. The values of fuel flow were obtained as described by Lopes et al. (2003).

The actual fuel consumption (EFC) was calculated based on the fuel consumption and the effective field capacity and is expressed as L ha^{-1} (Eq. 4).

$$\mathrm{EC} = \frac{\mathrm{HC}}{\mathrm{EFC}} \qquad (4)$$

in which:

EC - effective fuel consumption, L ha^{-1}

HC - hourly consumption, L h^{-1}

EFC - effective field capacity, ha h^{-1}

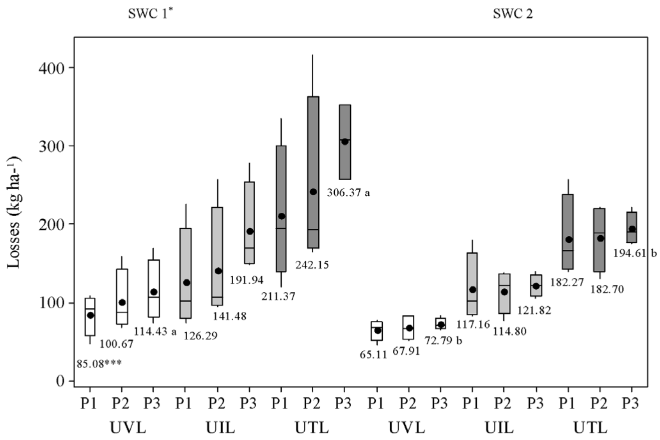
Measures of central tendency (average and median), dispersion (standard deviation and coefficient of variation) and the coefficient of asymmetry and kurtosis were calculated. The investigation of the normality of the data was performed by the Anderson-Darling test, and when asymmetric were transformed to achieve normality, using the formula: $y' = 1/\sqrt{y}$.

These averages were compared by the Tukey test at 0.05 probability when there was significance in the analysis of variance by the F-test of Snedecor, and they were represented by the diagrams of boxes (box plot).

RESULTS AND DISCUSSION

Descriptive analysis for visible, invisible and total losses, (Figure 1) shows the average and median values are far apart for SWC 1, especially for P2 and P3, unlike the SWC 2, which showed lower variability among the populations analysed.

The coefficient of variation values of 35.87, 40.16 and 34.90% were very high (>30%) for the variables UVL, UIL and UTL, respectively. However, a study conducted by Silva



Variable	σ**	Median	Ck	Cs	CV (%)	AD
UVL	30.25	79.57	2.66	1.51	35.87	1.065^A
UIL	54.40	115.20	1.44	1.40	40.16	1.270^A
UTL	76.80	196.40	0.75	1.15	34.90	1.035^A

*Treatments: SWC 1 (19.3) and SWC 2 (24.8): Soil water content P1 (86,111), P2 (127,603), P3 (141,144): plant populations (plants ha^{-1}).

** σ – Standard deviation; Ck – Kurtosis Coefficient; Cs – Asymmetry coefficient; CV – Coefficient of variation ; AD – Normality test of Anderson-Darling (A: Asymmetric distribution); ● – Arithmetic average.

***Letters absence indicates no significance among treatments; Different lowercase letters differ among each other by Tukey's test at a probability of 0,05 for soil water level treatment, and capital letters representing difference between plant populations. Interaction was not significant.

Figure 1. Descriptive statistics for losses during peanut digging: visible, invisible and total

(2010), assessing the variability of losses in digging mechanized peanut, found that others researches have reached coefficients of variation of up to 136%, which shows that in this study the coefficients obtained were not as high compared with the same analysis for other jobs.

Through the normality test of Anderson-Darling, it is concluded that the data showed the asymmetric distribution for all losses in peanut digging. The coefficient of asymmetry (Cs) and kurtosis (Ck) were distant from zero, indicating data abnormality. The positive coefficients of asymmetry indicate that the data distribution curve appears more elongated to the right and the data were concentrated to the left compared to the normal distribution curve. The coefficient of kurtosis indicates positive leptokurtic distribution, i.e., higher than normal probability of having extreme values and close to the average.

According to Figure 1, it can be verified that for UVL and UTL there were differences between the two soil water content only for P3, and such losses were greater in SWC 1, obtaining 114.43 kg ha^{-1} (3.9%) and 306.37 kg ha^{-1} (10.5%) for UVL and UTL respectively. This may be related to the fact that the lower soil water content with the lower spatial arrangement of plants from larger population, i.e., less plant spacing which results in increased booth, there was a greater demand for power for digging, compromising the stalk of the pod, which in turn, by passing through the digger-inverter vibrating belt suffered another strain, resulting in the detaching of the pod from its peduncle, increasing visible losses in SWC 1, and consequently the total losses.

The loamy soil, when in the higher water content, have lower hardness and greater disruption compared with the lowest water content, so peanuts are pulled more easily, leading to lower visible losses, minimizing the invisible and consequently reducing the total. Behera et al. (2008) evaluated the mechanical digging and found that the losses reduced gradually with the increase of the soil water. However, in the evaluations performed, the best results were obtained at 24.8% (SWC 2) and can be extended, to the studied soil, this recommendation up to this value.

It is observed in Figure 2 that the mean hourly and effective consumption during peanut digging showed normal distributions, while speed and effective field capacity (EFC) showed asymmetric distributions, according to the normality test of Anderson-Darling.

The mean values of the coefficient of variation were considered average for hourly and effective consumption (13.84 and 12.28%, respectively) and low for speed and EFC (2.52 and 2.52%). The average and median values are close to all variables, indicating low variability of the data collected. The mean values of skewness and kurtosis coefficients are close to zero for all variables, indicating symmetrical and mesokurtic distribution, respectively, despite the asymmetry indicated by the Anderson-Darling test.

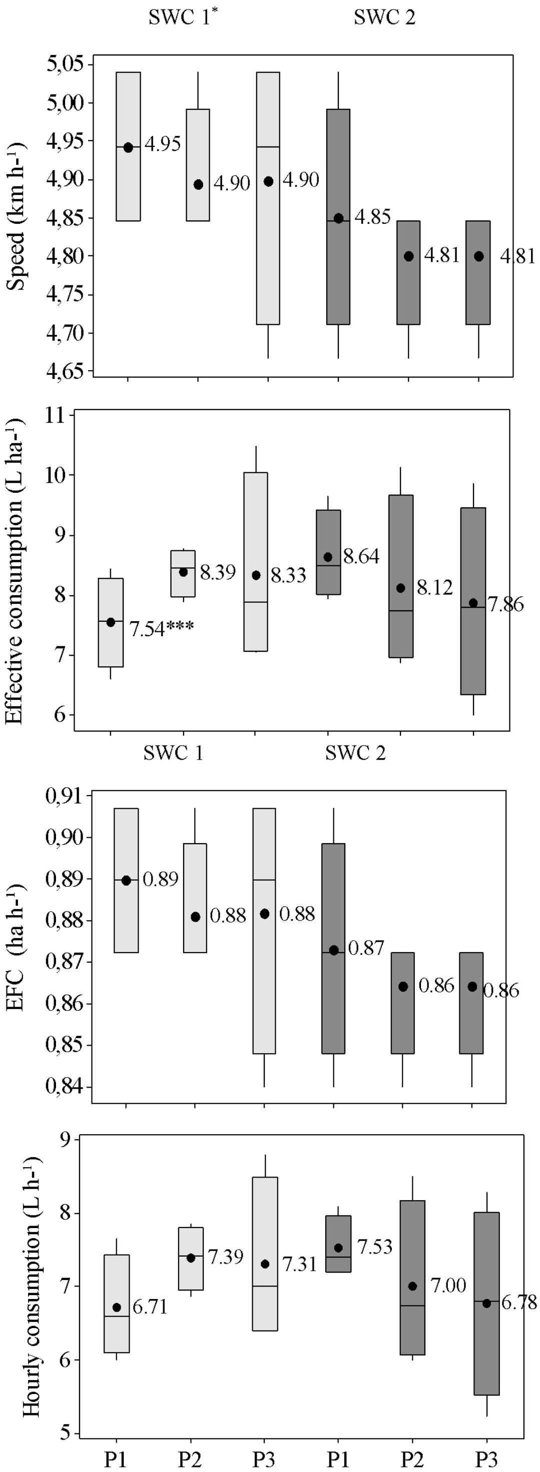
Accordingly to Figure 2, there was no difference between treatments for all variables, indicating that the operation was carried out homogeneously, and that, therefore, they probably did not affect the losses in digging. Because of the coefficients of variation were low, it is proved the low variability of the data and homogeneity of the sample area. This fact demonstrates that none of the soil water content affected the performance of the tractor-digger-inverter in the operation.

Therefore, the average speed was 4.9 km h^{-1}, the effective average field capacity of 0.87 ha h^{-1}, the effective average consumption of 8.15 and 7.12 L h^{-1}.

For average values of the variables, maturation, pod water content, harvested material flow and peanut digging productivity, it is observed by means of Figure 3, that only the harvested material flow showed an asymmetric distribution according to the normality test of Anderson-Darling, unlike other variables that showed a normal distribution. The average values of coefficients of variation were considered very high for the harvested material flow, high for productivity, and medium for maturity and water content in the pods.

The average and median parameter values are next for the maturation, water content in the pods and harvested material flow variables and have a low standard deviation, while for productivity it is far and with high standard deviation, indicating high variability in the data collected. The coefficients of skewness and kurtosis are close to zero for all variables, which can be justified by the normality test of Anderson-Darling indicating that the distributions of variable data were normal, except for the harvested material flow that showed a positive coefficient of skewness, and positive coefficient of kurtosis indicating leptokurtic distribution.

There was no difference between treatments for maturation, and the average obtained was 72.5% (Figure 3) registering with all treatments above 70% of mature pods, recommended as being the range in which there is the greatest potential for



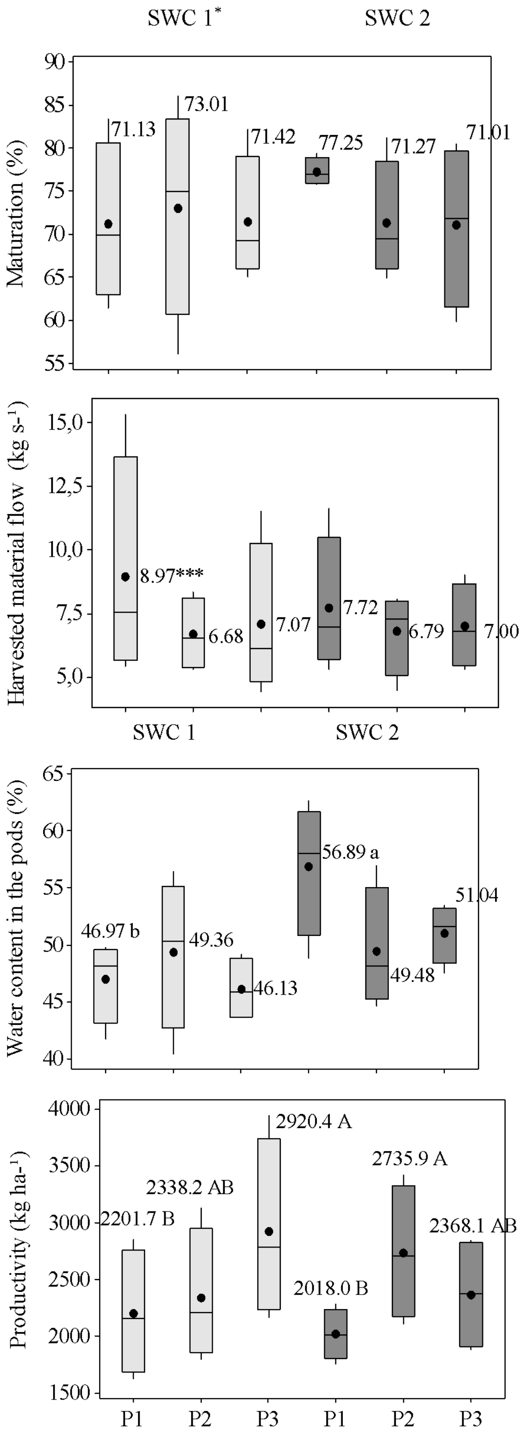
Variable	σ**	Median	Ck	Cs	CV (%)	AD
Speed	0.120	4.85	-0.49	0.03	2.52	2.378^{A}
EFC	0.022	0.87	-0.49	0.03	2.52	2.378^{A}
Effect. Cons.	1.130	8.25	-0.20	0.32	13.84	0.306^{N}
Hourly Cons.	0.870	7.20	-0.32	-0.05	12.28	0.261^{N}

[*] Treatments: SWC 1 (19.3) and SWC 2 (24.8): Soil water content (%); P1 (86.111), P2 (127.603), P3 (141.144): plant populations (plants ha^{-1}).

[**] σ – Standard deviation; Ck – Kurtosis Coefficient; Cs – Asymmetry coefficient; CV – Coefficient of variation ; AD – Normality test of Anderson-Darling (N: normal distribution; A: Asymmetric distribution); ● – Arithmetic average.

[***] Letters absence indicates no significance among treatments

Figure 2. Descriptive statistics for displacement speed, effective field capacity and hourly and effective fuel consumption



Variable		Median	Ck	Cs	CV (%)	AD
Maturation	7.87	73.32	-0.62	-0.26	10.86	0.205^{N}
Water content in the pods	5.51	49.22	0.00	0.46	11.02	0.383^{N}
Harvested material flow	2.54	6.86	3.17	1.64	34.47	1.059^{A}
Productivity	595.00	2334.00	0.19	0.83	24.46	0.542^{N}

[*] Treatments: SWC 1 (19.3) and SWC 2 (24.8): Soil water content (%); P1 (86.111), P2 (127.603), P3 (141.144): plant populations (plants ha^{-1}).

[**] σ – Standard deviation; Ck – Kurtosis Coefficient; Cs – Asymmetry coefficient; CV – Coefficient of variation ; AD – Normality test of Anderson-Darling (N: normal distribution; A: Asymmetric distribution); ● – Arithmetic average.

[***] Letters absence indicates no significance among treatments. Different lowercase letters differ among each other by Tukey's test at a probability of 0.05 for soil water level treatment, and capital letters for sowing density

Figure 3. Descriptive statistics for maturation, water content in the pods, harvested material flow and productivity

productivity and lower losses. The lack of difference indicates that both populations of plants regarding the soil water content at the time of digging did not interfere with the pod maturation, and, therefore, did not affect the harvesting losses.

According to Önemli (2005), the peanut maturation is strongly affected by climate. Among the factors involved, the soil water content is directly related to the reduction in harvesting mature fruit; however, in this study it did not happen, since all treatments were in the ideal range of maturity for harvest.

For P1, the water content in the pods was higher in SWC 2, which may have resulted in higher water content of the peduncle, hindering its detachment because of the greater resistance of the plant gynophore, which is favorable for lower losses during digging. The fact that it occurred in the smaller population may be related to the fewer pods produced in the subsurface, causing the greater effect of wetting pods when compared to higher plant populations, which are more difficult to be wetted because of the production of larger quantity of pods.

On the other hand, the high water content in the pods directly influences the collection, since these materials will remain for longer periods in the field until they reach the optimal water content for collection, thus they can suffer damage as, for example, breaks. The average water content in the pods obtained in SWC 1 was 47.5%. In SWC 2, was found values higher than the average of 52.5%, above the generally recommended, which is 35 to 45%.

There was no difference for the harvested material flow, which was explained by the fact that the variety used is creeper and has indeterminate growth, which may have led to the offsetting effect of plant development in smaller population compared to the higher one, by the possibility of having less competition, thus the vegetative material to be harvested in digging became close to all populations.

The average obtained from harvested material flow of 7.4 kg s^{-1} was close to that found by Simões (2009) with an average of 6 kg s^{-1}, which was considered as appropriate, because the peanut crop has little amount of stems at the time of digging. In the literature, there are no studies that address the harvested material flow during the peanut harvest. Results with similar crops, regarding to the process of harvesting, were found in the bean crop by Silva et al. (2008), who observed values of total flow (vegetative material + pods) of the order of 11.5 and 10.2 kg s^{-1} for crops in conventional tillage and direct plantation, respectively.

Productivity of P2 did not differ from one another in SWC 1, however, the lowest productivity was observed in comparison with P1 to P3. As for SWC 2, the lowest yield was also in P1; however the highest was in P2. The final stand of peanut plants is one factor among several production characteristics that can influence productivity (Brown et al., 2005). Balkcom et al. (2010) found that a seeding rate of 13 seeds m^{-1} is not recommended to reduce productivity losses associated with populations of peanuts and also the attack of diseases, agreeing with the results, shown for the two soil water content.

Through Table 1 is possible to observe that the weather was atypical during the crop year with high temperatures, low and poorly distributed rainfall over the crop cycle, verified by the low daily rainfall average for each plant period of development, being harmful mainly to development and flowering, consequently to final productivity. Thus still being within national average productivity.

Higher yields can affect the values of total losses, by reason of the greater amount of pods in digging, allowing greater losses for the same detachment, which was observed for UVL and UTL in SWC 1, in P3 treatment.

CONCLUSIONS

1. The largest amount of visible and total losses was found in plant population of 141,144 plants ha^{-1} for the soil water content of 19.3%.

2. The soil water content and plant populations did not affect the performance of the tractor-digger-inverter.

3. The yield was higher in populations of 141,144 and 127,603 plants ha^{-1}, for soil water content of 19.3 and 24.8%, respectively.

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