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Performance evaluation of a peanut harvesting machine in Guilan province, Iran

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Abstract

The objective of this study is determination of the effect of soil moisture content, forward speed and conveyor slope on pods loss in peanut harvesting. For this purpose, the percent of exposed pods loss, unexposed pods loss, undug pods loss and damaged pods loss were obtained according to related standard. The results revealed the effect of soil moisture content and forward speed were significant on the pods different loss while, the effect of conveyor slope wasn't significant for all variables. The Interaction effect of forward speed and soil moisture content was only significant on the percent of exposed pods loss. As a result of this study, the sensible reduction of the pods loss total is possible by reducing the unexposed pods loss that was only related to the soil moisture content. Thus, the soil moisture content in harvesting must be controlled. Also results were revealed the averages of exposed pods loss can decrease by using the minimum conveyor slope at the minimum forward speed and vice versa.

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Introduction

Peanut (*Arachis hypogaea* L.), also known as groundnut, is a self-pollinating, indeterminate, annual herbaceous legume crop (Burns, 2010). As the alternative name implies, peanut produces its fruit (pods) below ground. The pods are usually located up to a depth of 7 - 10 cm that referred to as pod zone (Ademiluyi *et al.,* 2011). Peanut mostly grown due to its oil, protein and carbohydrates (Abdzad Gohari *et al.*, 2010). The oil of peanut is one of the most important vegetable oil in regions where other oily vegetables cannot grow up (Hosseinzadeh Gashti *et al.*, 2012). Peanut has several uses as whole seeds or is processed to make peanut butter, oil, and other products (Putnam *et al.,* 2013). Peanut is one of the most important oilseed plants in the world that it seeds contain 40 - 50% fat, 20 - 50% protein and 10 - 20% carbohydrate depending on the variety (Okello *et al.*, 2010). Peanut is currently grown on over 22.2 million hectares worldwide with a total production of over 35 million tons (Raoa *et al.*, 2013). More than half of the production area is in arid and semi-arid regions (Reddy *et al.*, 2003). Peanut was harvested when most of the leaves turned yellow and pods became hard (Arakama, 2013). This is when it is 120 – 150 days after planting depending on the variety (Oyelade *et al.*, 2011). This operation is usually delayed by the greatest amount of pods reaches maturity but should occur before excessive sprouting or over-maturity. This operation causes peanut losses and usually the ripen peanuts are left in the ground. The amount of peanuts losses depend on the plant age and their health (Sanders and Bett, 1995, McNeill, 1996). Harvesting when 75-80% of pods have turned dark inside the shell will usually give the best grade and yield (Jordan *et al.*, 2008). Heavy digging loss is unavoidable when the pegs are weakened due to over maturity or premature defoliation caused by disease, or when the soil is very dry and hard (Roberson *et al.,* 2010). In the traditional method of groundnut harvesting, the vines are uprooted by hand or hand tool with the entire root system (Ademiluyi *et al.*, 2011). This operation is the most important and labor intensive operations in peanut cultivation. This problem has been overcome by using of machinery. There are two mechanical harvesting methods in the world. In the first method, peanuts harvest in two stages while the second method does this work in one stage. In two stages harvesting, the vines dig, shake and finally invert. This tree action carried out by one machine that known as digger/shaker/inverter. The harvested peanuts left on the field for two or three days of sun drying. Finally, peanut combine lifts dried peanuts from the ground and threshes them. In one stage harvesting, all the mentioned steps in two stages harvesting are integrated by peanut combine.

Iran is one of the largest producers of peanut in the Middle East (Nabavi-Pelesaraei *et al.,* 2013). Its cultivation is about 3000 hectares with annual kernel production of 6,000 tons that about 2500 hectares of it located in Guilan province (Hosseinzadeh Gashti *et al.*, 2009). Some of peanut cultivation operations in Guilan province carried out mechanized while peanut harvesting is done manually yet. During peanut harvesting in Guilan province, due to rice harvesting in neighboring regions and non-availability of labor in time, delayed harvesting resulted in heavy loss to the farmer. One of the solutions is to mechanize harvesting operation in peanut cultivation. It also reduces the cost of peanut harvesting and increase profit and productivity. For this purpose, a digger/shaker/inverter machine import to Guilan province but was not so applied by farmers. The high losses during of harvesting were a reason for non-application. This machine does the three indicated functions in two stages harvesting. As the tractor moves forward, the two V-shaped blades cut the taproot just below the pods and becomes loose the soil and crops, the elevator lifts the loosened crops from the ground and loose dirt removes by shaker action and finally inversion rods and wheels invert the crop to assist sun drying (Fig. 1).

The crop properties and operating conditions are the two design parameters that affects on machine performance. The soil moisture content is one of the crop properties that have much significant effect on machine performance. Ademiluyi *et al.* (2011) evaluated the performance of a tractor drawn groundnut digger/shaker in three levels of soil moisture content. The results showed soil the moisture content is a major factor influencing the digging efficiency of the implement and the soil moisture content between 12% - 15% will be preferable to work. Timeliness of operation is very vital in groundnut production and groundnut harvesting using the digger/shaker will produce a very low value of digging efficiency, when groundnut crops are not harvested during their right time of harvest. Also, the forward speed and conveyor slope angle are two operating conditions that have many significant effects on machine performance. Ibrahim *et al.* (2008) developed a multipurpose digger for harvesting root crops and evaluated it in peanut harvesting at three levels of forward speed (1.4, 1.8 and 2.3 km/h) and three different slope angles (12, 18 and 24 deg.), once using the vibrating movement and once without using it. The results of this study revealed developed digger can be operated efficiently under harvesting depth of 15 cm, forward speed of 2.3 km/h and slope angle of 12 deg. with using vibrating movement. Padmanathan *et al.* (2006) designed a tractor operated groundnut combine harvester and evaluated it at different operating conditions. The results of their work revealed maximum harvesting efficiency of 92.3 percent obtained at 1000 mm width of harvester and forward speed of 1.5 km/h. Field capacity and theoretical field capacity calculated 0.15 and 0.198 ha/h thereupon field efficiency was 75.75%. Also, the operation of groundnut combine harvester resulted in 39.00 and 96.00 percent saving in cost and time respectively, when compared to the conventional method of manual digging and stripping. In another research, Dawelbeit and Wright (1999) designed a vibratory peanut digger and tested it at two soil types, two tractor speeds (2.4, 4.8 km/h), two frequencies of vibration (9, 16.7 Hz) and two amplitudes of vibration (3.2, 9.6 mm). The results revealed soil conditions, tractor speed, and amplitude of vibration significantly affected the draft but frequency not affected. Also, vibration did not significantly affect percent peanut ground losses. Also Garg *et al.* (1990) evaluated the performance of tractor-operated groundnut diggers. The results revealed the total labour requirement in the case of the groundnut digger windrower was almost half of that of the digger with corrugated roller. Also, no appreciable difference in cost of digging (Rs 246-262/ha) was observed between the two types of mechanized digging while it was Rs 375/ha for manual harvesting.

The objectives of this study were determination of effect of soil moisture content, forward speed and conveyor slope on pods different loss and presenting of the solutions for reducing of pods different loss.

Materials and methods

Field characteristics

This study was carried out in Astaneh-e Ashrafiyeh city of Guilan province. A total area of 0.30 hectares of silt loam soil (24% of sand, 59% silt and 17% clay) was used for the main study. The used peanut crop for the study was planted on April 22th, 2013. Row spacing and plant spacing were 75 and 15 cm, respectively.

Factors of machine evaluation

The studied factors for machine evaluation were two levels of soil moisture content (19.9 and 19.3%), three levels of forward speed (1.4, 1.8 and 2.2 km/h) and three levels of conveyor slope (35, 38 and 41 deg.). For this purpose, the field was divided into two different experimental plots. For each levels of moisture a factorial experiment was carried out with forward speed and conveyor slope factors in a randomized complete block design with three replications. Then in analysis of data, the moisture levels were integrated each other and combined analysis was performed on them. Trials were carried out on each of the plots at two days interval. First and second harvesting were done at 142 and 144 days after planting, respectively. A Massey Ferguson tractor was used for pulling the groundnut digger/shaker/inverter. Three soil samples and three pods sample were taken from each plot in order to determine of soil and pods moisture content, respectively. Forward speed was determined by taking the time in a specified distance and conveyor slope was defined by means of conveyor height and length. Also, cinematic index (the ratio of the conveyor linear speed to forward speed) at different speeds was determined by measuring of conveyor linear speed.

Sampling and determination of losses

The percent of damaged pods loss, exposed pods loss, unexposed pods loss and undug pods loss were determined by a sample that had taken from each of 54 sub-plots. A 1m² frame was used as marked area for taking samples. The Indian standards test cods (IS: 11235 – 1985) were used for determination of this loss. The following formula was used in the computations:

$$A = B + C \quad (1)$$

$$\text{The percent of damaged pods loss} = \frac{C}{A} \times 100 \quad (2)$$

$$\text{The percent of exposed pods loss} = \frac{D}{A} \times 100 \quad (3)$$

$$\text{The percent of unexposed pods loss} = \frac{E}{A} \times 100 \quad (4)$$

$$\text{The percent of undug pods loss} = \frac{F}{A} \times 100 \quad (5)$$

Where,

A = total amount of pods collected from the plant in the sampled area.

B = amount of clean pods collected from the plant dug in the sampled area, exposed pods lying on the surface and the buried pods.

C = amount of damaged pods collected from the plants in the sampled area.

D = amount of detached pods lying exposed on the surface.

E = amount of detached pods remained inside the soil in the sampled area.

F = amount of pods remaining undetached from the undug plants in the sampled area.

Results and discussion

The average of soil and pods moisture content is presented in Table 1. As it can be seen, the two days delay of harvesting was reduced the soil and pods moisture content. The soil moisture content had slight increased due a light shower at two days interval. Analysis of variance results of the data are showed in Table 2. The results revealed the effect of soil moisture content was only significant on the percent of exposed and unexposed pods loss at the 5% level (Table 2).

Table 1. The average of soil and pods moisture content.

Harvesting's type	Soil moisture content	Pods moisture content
Harvesting at 142th day	19.9	48.4
Harvesting at 144th day	19.3	46.6
Soil and pods moisture content are based on dry and wet, respectively.		

Table 2. Analysis of variance of treatments effects on pods different loss.

SOV	Mean-square				
	df	% of exposed pods loss	% of unexposed pods loss	% of undug pods loss	% of damaged pods loss
Soil moisture content	1	266.4^{*}	2332^{*}	20.07^{ns}	1.299^{ns}
Replication (s. m. c.)	4	21.80^{ns}	133.0^{ns}	69.27^{ns}	1.169^{ns}
Forward speed	2	70.96^{**}	88.37^{ns}	88.77^{ns}	0.051^{ns}
Conveyor tilt	2	1.517^{ns}	38.38^{ns}	93.62^{ns}	0.917^{ns}
F. s. × c. t.	4	44.37^{*}	41.54^{ns}	60.30^{ns}	0.254^{ns}
S. m. c. × f. s.	2	44.65^{*}	13.04^{ns}	8.292^{ns}	0.181^{ns}
S. m. c. × c. t.	2	5.907^{ns}	11.39^{ns}	46.72^{ns}	1.935^{ns}
S. m. c. × f. s. × c. t.	4	20.18^{ns}	68.52^{ns}	21.98^{ns}	0.505^{ns}
Error	32	11.36	52.19	51.58	0.594

^{ns} is not significant * and ** are significant at 5 and 1 % probability levels, respectively.

According to Table 3, the average of exposed pods loss in the soil moisture contents of 19.9% and 19.3% were 6.617% and 11.06%, respectively. In Guilan province, the manual harvesting is commonly done when the peanuts are in the over mature while the delay of peanut mechanical harvesting results in the exposed pods loss due to weakened pegs. This loss also may occur as the plants are being elevated and shaken to remove dirt, and as the peanuts are placed in windrows (Roberson *et al.*, 2010). The average of unexposed pods loss was 12.13% in soil moisture content of 19.9% while it was increased to 11.06% in soil moisture content of 19.3% (Table 3). The decrease of soil moisture content and subsequently the decrease of digging efficiency was a reason for the increase of unexposed pods loss. Also, the weakened pegs were another reason that pods rip and remain in the soil. The effect of forward speed was only significant on the percent of exposed pods loss at the 1% level; while the effect of conveyor tilt wasn't significant for all variables (Table 2). The average of exposed pods loss at different forward speeds is shown in Table 4. As it can be seen, the percent of exposed pods loss and cinematic index are related to each other while the percent of exposed pods loss was not related to the forward speed and the conveyor linear speed. The cinematic index of 1.545 (1.8 km/h) has the percent lowest of exposed pods loss and the exposed pods loss was increased with the increase of the cinematic index. The difference between 1.545 and 1.882 cinematic indexes was significant and the average of exposed pods loss was calculated as 6.772% and 10.73% for ones, respectively (Table 4).

Table 3. The average of pods different loss at two levels of soil moisture content.

Soil moisture content	% of exposed pods loss	% of unexposed pods loss	% of undug pods loss	% of damaged pods loss
19.9	6.617[a]	12.13[a]	2.218[a]	0.936[a]
19.3	11.06[b]	25.27[b]	0.999[a]	0.626[a]

The numbers of each column that have a common letter aren't significant at the 5% level.

Table 4. The average of exposed pods loss at different cinematic indexes.

Conveyor linear speed	Forward speed	Cinematic index	% of exposed pods loss
2.634	1.4	1.882	10.73[a]
2.781	1.8	1.545	6.772[b]
4.129	2.2	1.877	9.011[ab]

The numbers of the column that have a common letter aren't significant at the 1% level.

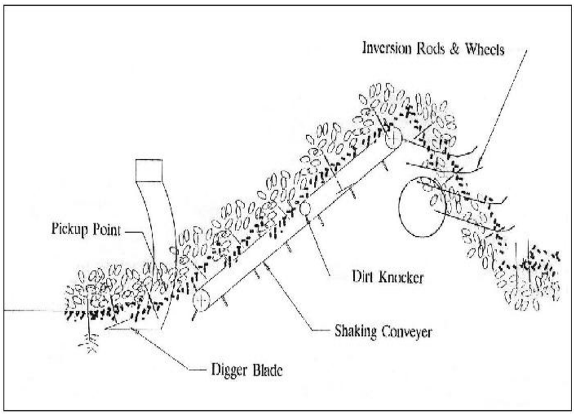

Fig. 1. Peanut digger/shaker/inverter schematic.

Interactions of forward speed with soil moisture content and forward speed with soil moisture content were only significant on the percent of exposed pods loss at the 5% level (Table 2). The average of exposed pods loss at different forward speeds and soil moisture contents is shown in Fig. 2. As it can be seen, the amount of exposed pods loss at all levels of soil moisture content of the 19.9% was less than the soil moisture content of 19.3%. Also, the lowest percent of exposed pods loss in both soil moisture contents was belonged to the forward speed of 1.8 km/h (cinematic index of 1.545). The reduced digging efficiency in the lower soil moisture contents was a reason and weakened pegs were another reason for increasing exposed pods loss. Also, in the cinematic index of 1.545 get a smooth flow of vines over the conveyor and it reduces the exposed pods loss while this operation doesn't occur in the high cinematic indexes.

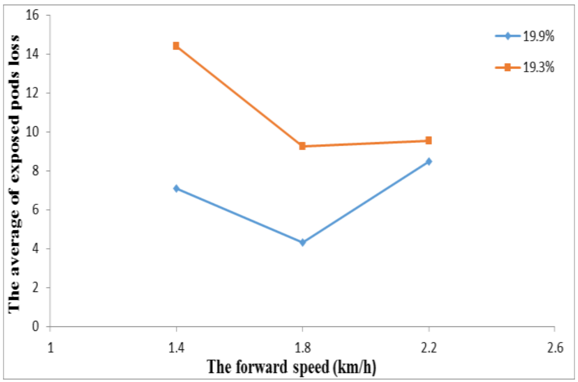

Fig. 2. The average of exposed pods loss at different forward speeds and soil moisture contents.

Fig. 3 shows the average of exposed pods loss at different forward speeds and conveyor tilts. It can be deduced from Fig. 3, that the conveyor tilt and the average of exposed pods loss are directly related to one another at minimum forward speed while those are inversely related to each other at maximum forward speed. At forward speed of 1.4 km/h, the maximum of exposed pods loss was belonged at maximum conveyor tilt and vice versa, while at forward speed of 2.2 km/h, the maximum of exposed pods loss was belonged to the minimum conveyor tilt and vice versa. As a result of this, the averages of exposed pods loss can decrease by using the minimum conveyor tilt at the minimum forward speed and vice versa. At the low forward speeds and the high conveyor tilts don't get a smooth flow of vines over the conveyor and pods touch the ground, consequently those rip from the vines.

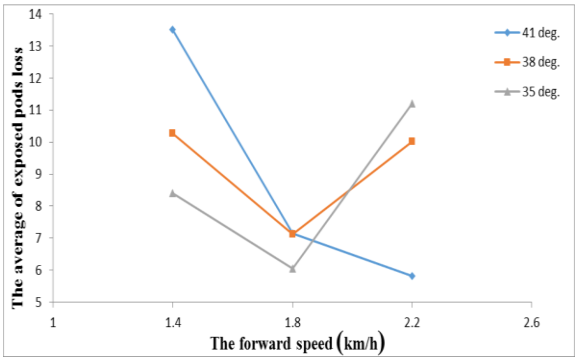

Fig. 3. The average of exposed pods loss at different forward speeds and conveyor tilts.

The share of pods different losses in the pods loss total is shown in Fig. 4. The highest percentage of the pods loss total was for the unexposed pods loss which was calculated about 62%, followed by the exposed pods loss (30%), the undug pods loss (5%) and the damaged pods loss (3%). As a result of it, the sensible reduction of the pods loss total is possible by reducing of the unexposed pods loss that was only related to the soil moisture content. Thus, the soil moisture content as harvesting must be controlled and the field must be irrigates if the soil moisture content wasn't inadequate.

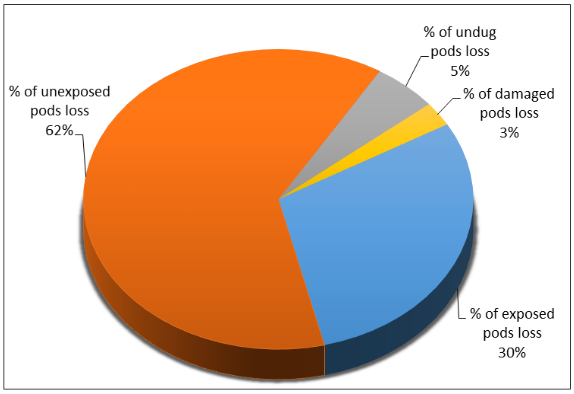

Fig. 4. The share of pods different losses in the pods loss total.

Conclusions

The recent study results revealed the soil moisture content is an important factor in peanut mechanical harvesting that has a significant effect on the pods loss total. As the delay of peanut mechanical harvesting increases the exposed pods loss due to weakened pegs then peanut must harvested in the optimal time. The effect of forward speed has significant effect on the percent of exposed pods loss and the cinematic index of 1.545 (1.8 km/h) has the percent lowest of exposed pods loss. In the cinematic index of 1.545 get a smooth flow of vines over the conveyor that it was reduced the exposed pods loss. Also, the averages of exposed pods loss can be decreased by using the minimum conveyor tilt at the minimum forward speed and vice versa. In the low conveyor tilts and the high forward speeds get a smooth flow of vines over the conveyor and pods don't touch the ground, consequently those rip from the vines. The highest share of the pods loss total was belonged to the unexposed pods loss that only related to the soil moisture content and can be reduced through prevent from delay harvesting and control of soil moisture content as harvesting.

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