

A NEW SMALL POTATO PLANTER FOR EGYPTIAN AGRICULTURE

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1. Introduction

The potato is a major strategic crop in Egypt, second only to cotton. It represents about 25% of total Egyptian agricultural exports, while cotton accounts for 40%. It is ranked as one of the most important vegetable crops. At the same time, despite the increase in potato yield from 16.68 t/hectare in 2004 to 21.5 t/hectare in 2006, potato production does not meet the dramatic increase in population and exportation. In fact, potato tuber planting methods in Egypt can be divided into manual (traditional) and mechanical methods. But, unfortunately, the manual method of potato planting still represents more than 85% all potato-cultivated area [Agric. St. Yearbook 2008] and is very laborious, tedious, and slow. It requires about 160 man/hour hectare.

Special attention must be given to establishing a new suitable technique for potato planting that influences the yield. There is a trend toward planting tuber pieces of potato with previously grown sprouts. Increasing the productivity of potato in a shorter period is the main goal. This can be achieved by using suitable technology. The suggested technique is divided into two main steps. The first includes the method of tuber cutting, while the second investigates sprout growing methods. The need of planting tuber with previously grown sprouts refers to the fact that the potato field is planted three times per year in the same field and the interfering periods between them not enough for good aeration and soil preparation. Therefore, it is important to try to reduce the growing stage by using previously grown sprouts in planting [Ismail 2004; Hatem 2002; Alojzy 1989].

A new potato planter was developed for use in

Egypt. Imported planters' feeding systems are unable to reduce damage during planting because the tubers are dropped from too high, resulting in more deviations in the uniformity of potato placement. In order to increase potato production and potato quality, there is a need to develop and use modern and improved potato machinery technology, especially sprouting tuber planters because sprout tuber planting achieves early germination, which leads to early harvesting and helps create strong roots and dispose of un-sprouted tubers.

Buitenwerf [2006] and Iritani [2002] created a theoretical model to determine the origin of uniformity deviations in potatoes placement (presence of voids and double potatoes). The model calculates the time interval between each successive potato touching the ground. Spacing was shown to affect yield when the coefficient of variation reaches 37%. Celik [2007] and James [1999] evaluated four types of seeders based on tuber spacing, depth uniformity, and plant emergence at three forward speeds (3.6, 5.4, and 7.2 kmh⁻¹); results indicated that the forward speed only significantly affected the mean emergence time ($P<0.05$). As forward speed increased, mean emergence time decreased. But Grieppentrog [1998] and Karayel and Ozmerzi [2002] demonstrate uniform seed spacing and depth results in better germination and emergence and increased yield by minimizing competition between plants for available light, water, and nutrients.

Ismail [2006] showed that only 10% of the variation in tuber mass was attributable to tuber size when spacing was 30 cm. The resultants also showed that the most suitable tuber piece size must be in the range of 30-50 g when spacing was 25±5 cm and added that the life-period of potato plant takes is approximately 120 days. This period can be divided into the following three stages:

Stage one: starts from the first day of planting until the appearance of the tubers. It takes about 6 to 8 weeks;

Stage two: takes about two weeks from the appearance of potato tubers; and

Stage three: starts from tuber formation until harvesting time.

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Stage one is considered the longest stage. Therefore, it is important to try to reduce the duration of this stage by using previously grown sprouts in planting. Applying this technique requires modification of the potato planter.

In all available potato planter machines built in Egypt, usually in local workshops, the damage to the tuber pieces that have grown buds will increase as a function of the friction between the tuber and the guide surface of the feeding system. Nevertheless, this phenomenon affects the quality of planting.

The aims of this study are as follows:

1. To develop and modify a small potato planter using a feeding system with chain-spoons to plant potato tuber pieces with previously grown sprouts;
2. To study the behaviour of the modified planter during its action considering the new geometric parameters.

2. Design consideration

A classical design of a chain-spoon feeding system is set vertically, and the buckets are provided with indented spoons. A single tuber is manually fed to every spoon, which lifts upward. Then, the tuber is dropped down on the back of the next spoon in the conveyor. The analysis of the planter points out that the chain-spoons expose the tuber pieces to friction between its surface and the conveyor guide until it leaves the feeding unit. The tuber pieces will be exposed to damage every revolution of the feeding system. Mainly, there are three zones of damage, as indicated in Figure 1.

2.1 First Damage Zone

Primary observation during one revolution of the

chain-feed system indicated that the tuber piece is conveyed to the maximum point on the chain-feed and then is dropped for a fraction of a second. Then, the conveying velocity of the chain-spoon will push the tuber toward the next spoon. The direction analysis of the falling of tuber pieces, as shown in Figure 1-A, considers that the direction of motion, with neglected air resistance, is subjected to the conveying velocity of chain-spoon, the mass of tuber piece, and gravity.

2.2 Second Damage Zone

The tuber on the spoon back, Fig. 1-B, will be exposed to the following during conveying:

- a) Friction force between the feeding guide and the tuber surface;
- b) The mass of tuber pieces.

On the whole, the forces are in the opposite direction of tuber motion.

2.3 Third Damage Zone

The geometrical analysis of the fall from the feeding device to the furrow bottom plays an important role in determining the values of tuber damage. Logically, the motion of the exiting tuber chain-feed is relative to the two velocity vectors, namely the peripheral speed of this unit and the forward speed of the planter.

An analysis of the maximum kinetic energy upon the tuber pieces will occur at the maximum tuber speed at the moment it leaves the feeding unit; at the free fall height and at the mass of the potato.

To avoid these disadvantages, the structure of a new chain feeder was developed. The spoons were replaced with simple cups (Fig. 2). They are designed to convey the tuber and to keep it from movement until

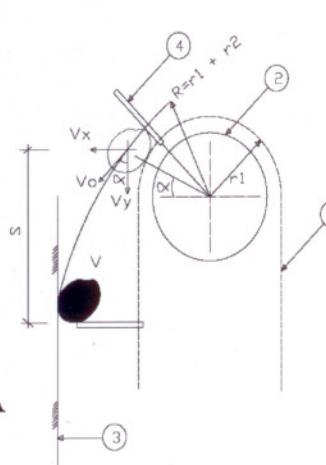


Fig. 1-A

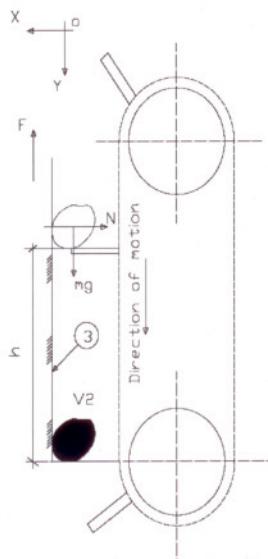


Fig. 1-B

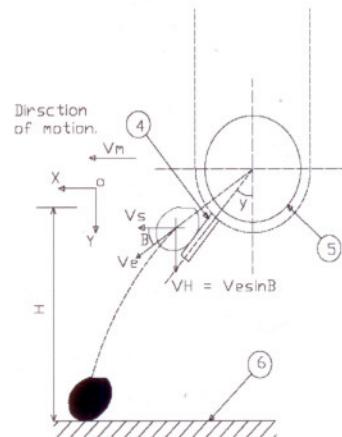


Fig. 1-C

Fig. 1 - A: The first damage zone. Fig. 1-B: The second damage. Fig. 1-C: The third damage. 1- Chain-feed device. 2- Driven gear. 3- Guide surface. 4- Spoon. 5- Driver gear. 6- Soil surface

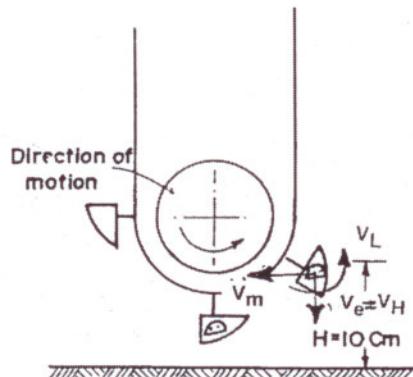
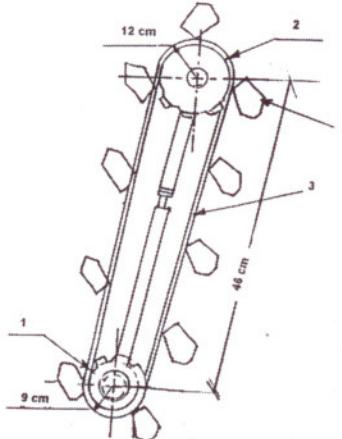


Fig. 2 - Reducing the free fall height of tuber pieces. 1- Driver gear 2- Driven gear 3- Chain 4- Cup

exiting from the feeding system. Consequently, the tuber did not:

- a) Drop down on the next spoon in the conveyor (first zone of tuber damage);
- b) Act upon the friction force between its surface and the feeding system guide (second zone of tuber damage).

To overcome tuber damage in the third zone, the exiting tuber angle and the free fall height may be minimized. Then, the following attempts are carried out:

- 1) In the new design, the tuber exiting unloading angle (Fig. 2) makes the tuber drop vertically.
- 2) The free fall height "H" was reduced from 30 to 10 cm.

3. Materials and methods

3.1 Developed Potato Planter

The chain-feed of the potato planter was developed to plant tuber pieces with grown buds. The steel frame consists of parts that can be easily assembled and modified (Fig. 3): The structure is made of two main square beams with a cross-section of 100×100 mm; one in front (800 mm length) and the second one in the back (1500 mm). The main beams were connected to each other via two units (1300×300 mm) containing the two feeding systems. Two furrow openers

(shoe shape type) are fixed in the front beam (Fig. 3). Each of them can be adjusted to control the depth of the furrow. The feeding system consists of two units; each unit contains ten cups (Fig. 2). The closing system consists of three furrow closing units located at the back end. The transmission system was constructed to control the number of cubes per revolution and was adapted to yield rows of tubers every 25 cm. To prevent slipping, a chain-sprocket transmission system is used to transmit the motion from the planter wheel ($D = 440$ mm) to both feeding devices. The tuber box is designed to easily feed the tubers.

3.2 Reference Potato Planter

A classical potato planter with a typical chain feed system is used for a comparative analysis. The machine was built in the University of Mansoura's workshop with the same frame as the new one but with a classical chain feed and geometrical configuration that is usually used in Egyptian potato planters. Also, this planter's feed system holds ten potatoes.

3.3 Planter preparation

The planter is calibrated and adjusted to achieve 25 cm between tubers in a row, 71 cm between two rows, and 6 cm planting depth, referring to a previous test [Ismail 2004].

3.4 Tuber Preparation

The sprouts are left to grow on the tuber. After that, the tubers are cut into pieces. Each piece has one or more buds. Six plant benches are installed inside a glass room to be used for germination tests. Each room has a surface area of 1 m² (2m long × 0.5 m wide). The surface of the plant benches contained a straw bed. The tuber pieces are distributed on them with a row distance of 10 cm and tuber distance in the rows of 5 cm. A tank of water is connected to the plant benches using a 12 mm diameter plastic tube to keep the straw bed wet. Temperature and straw bed moisture content were regulated under the control system.

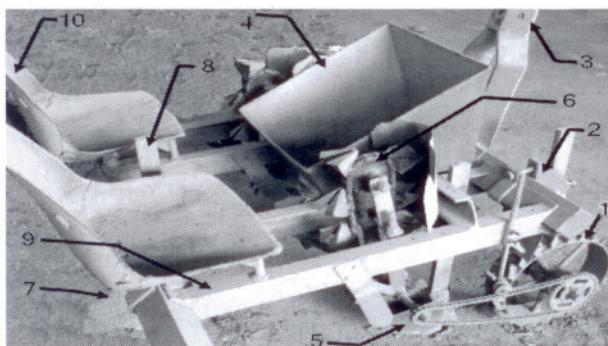


Fig. 3 - The developed potato planter.
1- Land wheel 2- Control beam 3- Hitching point 4- Tuber box 5- Furrow opener 6- Feeding device 7- Closing device 8- Beam 9- Frame 10- Labor chair

3.5 Experimental methodology

The experimental study provides a comparison between a classical potato planter and the new one. Each test is repeated three times.

The field is divided into plots (22.5 × 50 m) and sub plots (7.5 × 50 m). The experiments are carried out at El-Tawella, Dakahilia Governorate private sector farm.

The mechanical analysis of the experimental soil was 21.05 % sand, 30.0 % silt, 47.2 % clay, and 1.75 % coarse sand at a depth from zero to 20 cm. The plots are selected at random from each treatment after plowing; harrowing and soil leveling is done traditionally.

The following measurements evaluate the investigated potato planter:

1- Tuber spacing is evaluated by measuring the space between tubers in rows for each test. The frequency of tuber spacing is computed according to an analysis of the single-variable method.

2- Tuber void (%) is the void when the distance (S_c) between planted tubers in rows is twice greater than of pre-adjusted distances (25 cm). Tuber voids are calculated for each treatment by estimating the number of S_c in each experimental plot as follows:

$$V_t = \frac{m_n}{M} \times 100$$

Where:

V_t = percentage of tuber void, %;

M = theoretical number of cups at limited time of working feeding mechanisms; and

m_n = number of spacing (S_c) ≥ 2S_t ≥ 50 cm at the same limited time.

3- Tuber doubles (%) are calculated when the distance between tubers in a row (S_c) is half or less than the pre-adjusted space in the row (S_t) I.e., $S_c \leq (S_t/2) \leq 12.5$ cm; it is calculated using Ismail's [2004] method.

4- The quality evaluation of the potatoes is done by determining shatter bruises via visual examination. The length of each bruise in the skin is measured using a handheld caliper. The bruise depth is located by slicing the potato tuber perpendicularly and along the depth of the cut. The depth is then measured using a handheld caliper. The shatter index (SI) is estimated using the formula below [Grant 1985]:

$$SI = \sum_{n=1}^{n=N} \frac{d_1 \times h_1 + \dots + d_n \times h_n}{N}$$

Where:

d = Length of shatter, mm

h = Depth of shatter, mm

N = Number of observations per tuber

4. Results and discussion

4.1 Tuber spacing in rows

The spaces between tuber pieces in a row are evaluated as a tuber deviation percentage, which is estimated using the feeding devices before and after modifications are shown in Figure 4. With the classical configuration (Fig. 4.A), the result indicated that 50.62 % (sum of the tuber deviation (%)) between 20 cm and 30 cm of tuber pieces of 40 g are distributed in spaces use 20-30 cm (the pre-adjusted space of 25 cm). The remaining 49.38 % is distributed outside this range. The corresponding remainder percentage is about 68 % for the feeding device after modification (Fig. 4.B). This may be because the free fall height in old designs is higher than in developed ones. From the above result, and with respect to the theoretical trend, the suggested feeding mechanism is suitable under Egyptian conditions (tuber pieces 40 g).

4.2 Tuber voids

The results of the tuber void ratio (V_t , %) versus planting speed are shown in Figure 5. The figure displays the results obtained from both machine designs; there is no significant difference in the field void because the two planters have the same productivity feed chain (10 tubers).

The general trend of this relationship is that the percentage of tuber void increased as planting speed increased. Interestingly, the increasing rates of V_t in tuber pieces weighing 50 g is higher than in those of

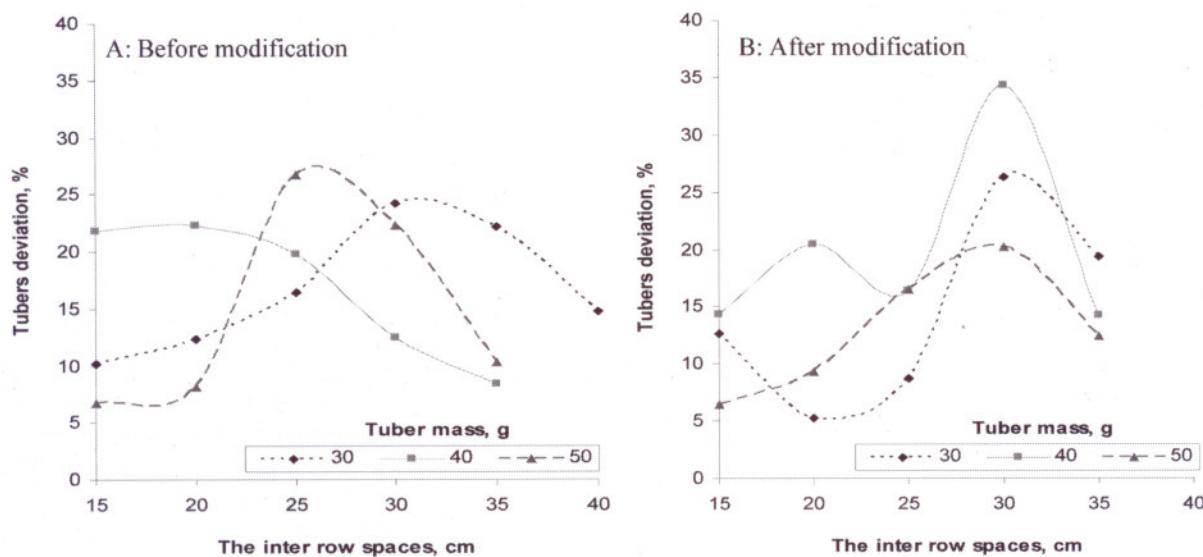


Fig. 4 - Tuber deviation frequency: before (A), after (B) planter modification.

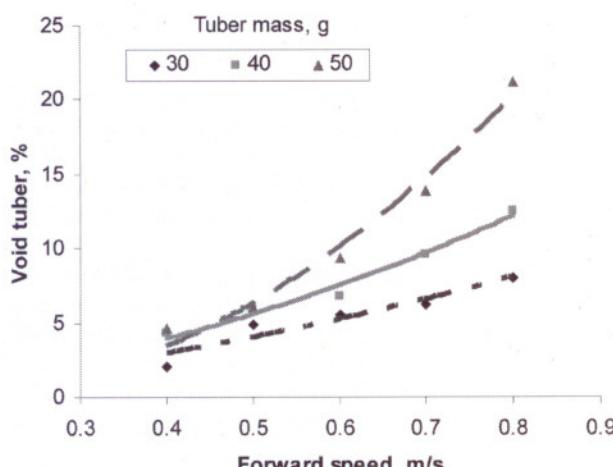


Fig. 5 - Tuber void ratio (V_t %) versus planting speed.

tuber pieces weighing 40 and 30 g. These differences may be due to the low ability of workers for catching larger-sized tubers. In addition, Figure 5 shows that the void ratio is largely valid within a planting speed range of 0.6 to 0.8 m/s, more than those from 0.4 to 0.6 m/s for all tuber masses. These variations are due to the relatively higher peripheral speed of feeding mechanism. The average V_t of tuber mass of 50 g, which is the highest ($10.76\% \pm 5.95\%$), followed by tuber pieces of 40 g ($8.2\% \pm 3.54\%$), and tuber pieces of 30 g ($5.2\% \pm 2.05\%$).

4.3 Tuber doubles

The contour plot of the tuber doubles (percentages) versus planting speed with different masses of tuber pieces (30, 40 and 50 g) are illustrated in Figure 6.

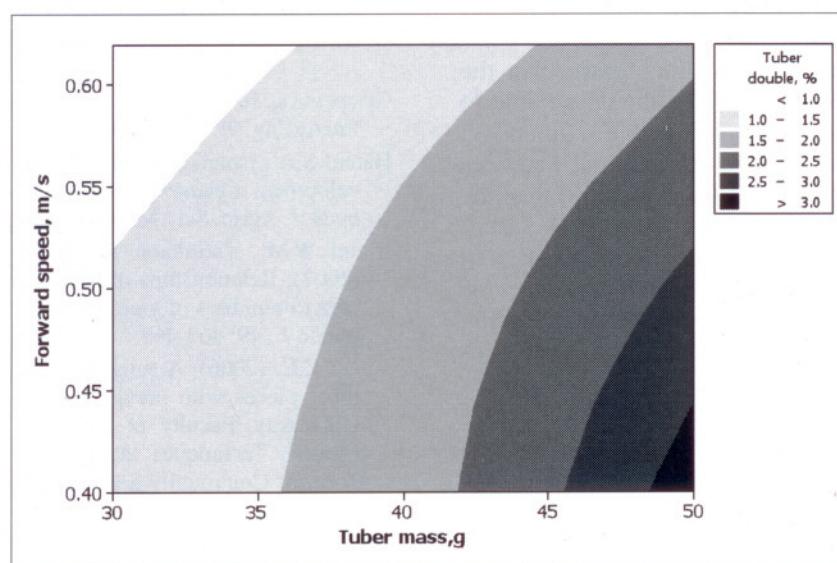


Fig. 6 - Contour plot of tuber double vs. forward speed and tuber mass.

Feeding system, rpm	The developed potato planter			The old design		
	Length of shatter, mm	Depth, mm	SI, %	Length of shatter, mm	Depth, mm	SI, %
5	-	-	-	-	-	-
10	3	1	1.5	7	5	17.5
15	11	3	31.0	21	7	73.5
20	13	4	46.0	27	7	94.5

TABLE 1 - Shatter bruise occurrences on both the new and old design of the potato planter.

The tuber double percentages are lower when planting tubers weighing 30 g versus with those weighing 40 g or 50 g. This behaviour may be attributed to the fact that workers can handle large pieces easier than small ones. Moreover, the results revealed that the tuber doubles decrease with increasing planting speed. Also, in this case, there is no difference between the two machine designs.

4.4 Tuber resistance to damage

The shatter bruise is measured as a dependent variable to evaluate the investigated potato planter. The shatter bruise (SI-index) is improved by using the developed feeding system shown in Table 1. Significant differences ($P_r < 0.05$) were found in the shatter bruise when comparing investigated and common potato planters.

The table shows how the new configuration is able to yield potatoes with a much better quality index.

5. Conclusion

A new configuration of a potato planter feeding system was designed, developed, and tested for Egyptian agriculture. It was now oriented to use tuber pieces with sprouts grown. A new system for moving the tuber with tablespoons to avoid damage to the product was inspired by theoretical considerations [Buitenwerf 2006; Iritani 2002].

The results, related to the correct position in the field, showed that the new system should be able to place a major percentage of tubers between 20 and 30 cm in accordance with proper agricultural practices for ideal growth [Ismail 2006; Karayel 2002] than the reference planter.

The study of tuber voids or tuber doubles showed no significant differences between the two machine models because the productivity of the two feeding systems did not change (10 tuber each). The ideal tuber size, however, is 30 g, since there were minor changes in voids at different speeds and fewer occurrences of double tubers; the most common Egyptian tuber piece dimension is 40 g; the results obtained are comparable to the considerations already reported in the literature [Altuntas 2005].

The study of the quality of the samples, carried out by identifying the shatter index (SI%), has instead led

to the conclusion that changes help avoid damage to the tubers and its growth. Table 1 shows that at low speeds, the modified system has blurred the damage, while at high speed it is maintained at around 50% compared to the reference planter.

The new system of tuber filing, therefore, increases the quality of productivity in Egyptian conditions.

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SUMMARY

Reducing the tuber period for potato plants by planting previously grown sprouts is a new technique. Applying this new agricultural methodology requires modification of the potato planter. The theoretical analysis was carried out to obtain information that can help avoid tuber damage during feeding and until it exits the feeding system. Starting from these considerations, a new potato planter with a spoon-based feeding system was designed and built.

The tests conducted verified that the new system performed well when dividing tuber pieces into rows: considering the best growth spacing for potatoes is

20÷30 cm, the new system has a 68% distribution versus the 50,62 % of the old one.

The tubers' spacing in rows are evaluated based on tuber voids and tuber doubles. The results show that there is no difference between the two systems' configurations, while a general consideration about our machine is that it is better at managing small tuber pieces. The void ratios are largely valid within the range of 0.4 up to 0.8 m/s of planted speeds; moreover, the results revealed that the tuber doubles decrease by increasing planting speed and vice versa with tuber voids.

The quality of the potatoes planted is evaluated using the Shatter Index (SI %), which shows how the new configuration is more delicate with the tuber pieces (1.5 % against 17.5 % at 10 rpm or 46 % against 94 % at rpm 20). The new configuration could be an interesting improvement for potato quality and Egyptian potato production.

Keywords: planter, tuber piece, quality, potato.