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THEORETICAL ANALYSIS FOR EVALUTING AND STUDYING THE FACTORS AFFECTING ON THE MANUAL FEEDING TRANSPLANTING

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ABSTRACT

A theoretical analysis for the factors affecting the manual feeding transplanters has been established. The effect of the transplanter forward speed, seedling flow time, seedling coefficient of friction with the drop tube and the drop tube inclination angle on the seedling resultant velocity have been studied . The drop tube inclination angle have been found in the range of 75 – 85° and 105 – 115° for the acute and the obtuse angles respectively.

For getting the suitable and certain drop tube inclination angle, when transplanting the seedlings for different crops, may be suggest that the drop tube designed to be hinged at the top and have juxtaposition at the bottom. Then the selecting of the right angle, in the field, will be according to the transplanting parameters and the real conditions for the seedling and the field.

Keywords: Manual feeding transplanting; transplanting theoretical analysis; seedling system.

INTRODUCTION

Until now, mechanical vegetables transplanting face many problems affecting the quantity and quality of product. Increasing the vegetables yield can be achieved by using suitable technology. Transplanter is one of the most important parts of agricultural technology, which have two main systems. Namely, first, seedlings with adhering soil planted in the field. It means that, seedling can be transplanted with small bed around the roots (bare root seedlings). Second, vegetable seedling can be transplanted with deep soil blocks.

Many investigations evaluated the factors affecting the vegetables seedling transplanting performance such as: shape and size of seedling, tall soil block around the seedlings root, the diameter of block and the old of seedling grown in soil block as indicated by many researchers, Tamatsu (1982); Saleh (1990); Tayel et al. (2002) and El-Sahhar (2005).

Numerous investigations have been carried out to develop and evaluate transplanting the seedling having deep soil blocks. Huang and Splinter (1968) developed a tobacco transplanter that automatically fed 5.08 cm square by 5.08 cm deep soil blocks containing tobacco seedlings to a drop tube. For tea seedling fell, a large suction blower attached to the drop tube increased the seedlings speed to ensure positive and accurate transplanting. However, two major problems prevented it's use in transplanting lettuce seedling. First, lettuce seedlings at transplanting time have a larger spread of leaf area than tobacco seedling. Dropping lettuce seedlings through a tube under suction pressure could easily damage their fragile leaves. Second, planting cavities created by a water jet to keep the dropped tobacco seedlings from tumbling were too small (4.5 cm square by 3.18 cm deep) to accommodate the lettuce seedlings. Practical limitations on the pressure and the volume of water available made it infeasible to create larger cavities.

Splinter and Suggs (1968 a, b) studied human errors in the hand feeding of bare root transplanters, and determined that the planting errors resulting from doubling, skipping and incorrect plant orientation were inversely related to the machine acceptance time. They realized that the machine acceptance time could be increased for hand-fed transplanters by increasing the number of loading stations. With the ability to feed more than one seedling per planting cycle, the probability of human feeding error should be reduced. Using simulated and bare root seedlings, they found that the major benefits of multiple-loading stations could be achieved within the first three to five loading stations. This would permit about 50 percent increase in planting rate with the same level of error.

A manual feeding transplanter was designed and tested (Hamad et al 1983). The best transplanting and field efficiencies achieved when transplanting speed was 0.6 km/h, soil moisture content was 22 % and feeding rate was 1.1 hill/sec.

Ismail and El-Sheikka (1989) gives a theoretical answer about the optimum operating condition of transplanter machines to sit seedling of bare root. They plotted the monograms from simplified equations for the relationships among the seedling traveling speed, feeding times, number of hills per times, actual planting wide, field capacity and efficiency to serve as a handy tool for quick determination of seedling operation systems.

Dong et al. (2001) designed, fabricated and field-tested a new type of block seedling transplanter with belt feed mechanism. While, Jeffrey et al. (1990) investigated a simple, accurate and reasonable fast lettuce soil block seedling trasplanter. It uses the conventional furrow opener and closer transplanting method. The key element is the planting mechanism, which consists of a seedling chute and a transplanting head. The seedling chute allows the hand feeding of many seedlings within one planting cycle, which reduces the human errors in loading. The transplanter head consists of two butterfly-type, solenoid-powered gates to plant the seedling. The gates permit planting large diameter seedling within the confined row spacing.

Palmer and Wilton (1962) tested different soil block shapes, media and soil stabilizers for durability in mechanized handling and transplanting. The soil media were mixed with water and compressed by using a double-acting pneumatic ram. They concluded that, although the soil blocks were strong enough for hand transplanting, they were probably not strong enough for complete mechanical handling. They recommended the use of a soil stabilizer as a possible solution.

Therefore, the aim of this study are carried out to search on the factors which minimizing the value of the seedling resultant velocity theoretically and to facilitate the estimations for some of the transplanting parameters as it is possible.

THE THEORETICAL ANALYSIS

The simple system to transplanting the vegetable seedlings from the seedlings trays until it sits in soil is the manually feed of seedlings to an inclined drop tube. Several factors affect the performance and quality of the transplanting operation. These factors are the inclination angle of the drop tube, the seedling coefficient of friction with the drop tube, the seedling resultant velocity, seedling flow time through the drop tube, seedling planting time and the transplanter forward speed.

In the follows a theoretical analysis have been done to evaluate these factors and study its effect on the transplanting operation according to the differences in the inclination of the sliding surface (the inclination of the drop tube) and its direction of feeding related to the transplanter forward speed.

1- The Seedling Sliding Velocity

The sliding feeding surface (the drop tube) may have two cases (Figure, 1). The first case is that, the seedling feeding direction is in the same direction of the transplanter forward speed (i.e. the sliding feeding surface make an acute angle in c.w. direction with the soil surface). The second case is that the seedling feeding direction is in the opposite direction of the transplanter forward speed (i.e. the sliding feeding surface make an obtuse angle c.w. in direction with the soil surface).

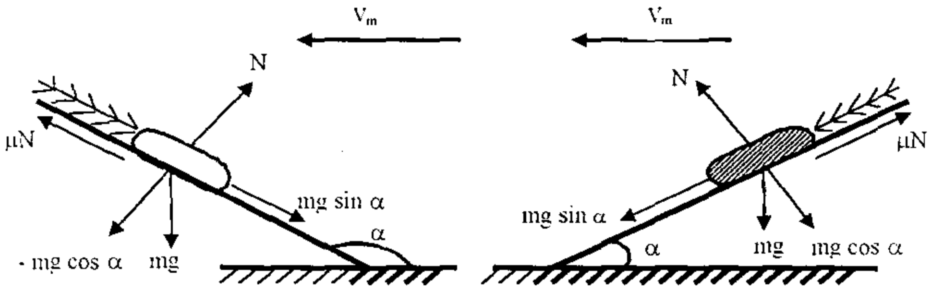


Figure (1) The direction of the sliding surface inclination and the forces acting on the seedling

Referring to Figure (1) the analysis of forces acting on the seedling is:

$$m\,g \sin \alpha = \mu N \qquad \text{.........................(1)}$$

$$m\,g \cos \alpha = N \qquad \text{.........................(2)}$$

The theoretical analysis of the relation between the direction of seedling motions on the sliding surface and its mass are taking the following steps:

1- At acute angle

From the Newton's equation the balancing forces in direction of seedling slides may be as follows:

$$m \cdot a = m\,g \sin \alpha - \mu N$$
$$N = m\,g \cos \alpha$$
$$m \cdot a = m\,g \sin \alpha - \mu\, m\,g \cos \alpha$$

2- At obtuse angle

$$m \cdot a = m\,g \sin (180 - \alpha) - \mu N$$
$$N = m\,g \cos (180 - \alpha)$$
$$m \cdot a = m\,g \sin \alpha + \mu\, m\,g \cos \alpha$$

3- In general cases

$$m \cdot a = m\,g \sin \alpha \pm \mu\, m\,g \cos \alpha$$
$$a = g (\sin \alpha \pm \mu \cos \alpha) \quad \ldots\ldots\ldots\ldots\ldots(3)$$

The equation (3) include the positive and negative sign when the sliding surface make an obtuse angle and an acute angle with the soil surface respectively.

Since: $a = dV / dt$

Then $dV / dt = g (\sin \alpha \pm \mu \cos \alpha)$

$dV = g (\sin \alpha \pm \mu \cos \alpha)\ dt$

$$\int_{V_0}^{V_s} dV = \int_{t_0}^{t} g (\sin \alpha \pm \mu \cos \alpha)\,\mathrm{d}t$$

$$V_s - V_0 = \left[g (\sin \alpha \pm \mu \cos \alpha)(t) \right]_{t_0}^{t}$$

at $V_0 = 0$ and $t_0 = 0$

then $V_s = g\,t (\sin \alpha \pm \mu \cos \alpha) \quad \ldots\ldots\ldots\ldots(4)$

where:

- m : The mass of both the seedling and its roots attached soil, g;
- α : Inclination angle of the feeding device (seedling drop tube), degree;
- N : Normal contact force of seedling, N;
- μ : Coefficient of friction between the seedling and the sliding surface;
- a : Seedling acceleration on the sliding surface, m/s^2;
- g : Gravitational acceleration, m/s^2;
- V_0 : Seedling initial velocity, m/s;
- V_s : The seedling sliding velocity on the sliding surface, m/s;
- t_0 : Initial time, s;
- t : The seedling flow time through the drop tube, s.

The equation "4" represent the general theoretical factor affecting the seedling sliding velocity on seedling tube.

2- The resultant of seedling exit velocity and the transplanter forward speed relationship.

If the seedling velocity out from the sliding surface (V_s) at flow time (t) then, the resultant seedling velocity (V_R) as shown in Figure (2), may be take two directions according to the direction of the transplanter forward speed

(V_m) and seedling sliding velocity (V_s) of the two cases which have been mentioned previously (acute and obtuse angles)

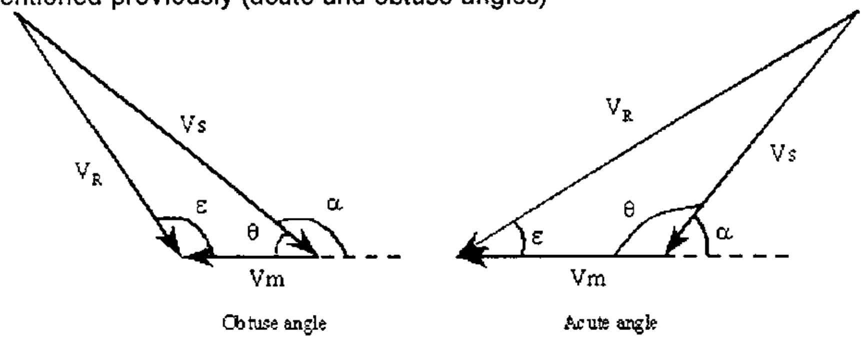


Figure (2) Seedling velocities diagram according to the sliding surface inclination

The resultant seedling velocity (V_R) can be calculated from the seedling velocities diagram at obtuse angle of seedling tube using the cosine law as follows:

$$V_R^2 = V_m^2 + V_s^2 + 2\,V_m\,V_s \cos\alpha \qquad \text{...........(5)}$$

Substituting in this equation the value of (V_S) from equation (4) we get

$$V_R^2 = V_m^2 + [g\,t\,(\sin\alpha \pm \mu\cos\alpha)]^2 + 2\,V_m\,[g\,t\,(\sin\alpha \pm \mu\cos\alpha)]\cos\alpha \quad \text{..(6)}$$

While, from Figure (2) the inclination angle for the seedling resultant velocity at acute angle of seedling tube can be calculated as follows:

$$V_s^2 = V_m^2 + V_R^2 - 2\,V_m\,V_R \cos\varepsilon$$

$$\cos\varepsilon = \left(V_m^2 + V_R^2 - V_s^2\right)/2\,V_m\,V_R \qquad \text{..........(7)}$$

3- Determination of The Seedling Flow Time and Planting Time.

The seedling flow time is a part of the seedling planting time, which consists of three parts. These parts are seedling-feeding time (by the operator) from the seedling tray to the drop tube, the flow time through the drop tube and the drop time from the drop tube to the soil surface.

The planting rate depends entirely on the planting time, which depends on operator skill, condition of seedling and plant spacing than on individual make of transplanter (Robertson, 1978). The planting time range could be estimated from the recommended planting rates by different references (Robertson, 1978; Culpin, 1986; Bernaki et al. 1792; and Klenin, et al., 1985). According to that, the planting time (For one seedling) range is 1 – 3 s/seedling. For seedling flow time no reference is available from the literature. Therefore the flow time could be estimated as follows:

The seedling flow time (t) may be obtained by integrating the equation (4) as follows:

$$V_S = g\,t\,(\sin\alpha \pm \mu\cos\alpha)$$

Since $\qquad V_s = dx / dt$

Therefore:

$$\int_0^L dx = \int_0^t gt(\sin\alpha \pm \mu\cos\alpha)dt$$

$$L = 1/2\, g\, t^2 (\sin\alpha \pm \mu\cos\alpha)$$

$$t = \sqrt{2L / g(\sin\alpha \pm \mu\cos\alpha)} \qquad \text{.............(8)}$$

From equation "8", if the drop tube length (L), "μ" and "α" are know, then the flow time (t) easy to be found.

4- Determination the Values of Some Related Transplanting Factors

From the literatures, previous studies and researches the values of some of the studied transplanting factors can be obtained. These factors were the inclination angle for the drop tube, seedling coefficient of friction with the drop tube and the transplanter forward speed.

4-1- The drop tube inclination angle

For successful seedlings transplanting some researchers recommended a certain angle for the seedling stem inclination from the vertical. Such as Munilla and Shaw (1987) and Bernacki et al. (1972) recommended this angle to be less than 30° from the vertical (i.e. 60° from the soil surface), while Srivastava et al. (1994) recommended this angle to be 15° (i.e. 75° from the soil surface).

Therefore in this study the inclination angle (α) from the soil surface for the drop tube we may recommended the range of 60° - 75° for acute angle and in the range of 105° - 120° for obtuse angle.

4-2- The seedling coefficient of friction with the drop tube

Soehne, 1953 and Nichols, 1931, have found the coefficient of friction for the clay soil with the metal surface (steel). For Soehne it was ranged from 3.8 up to 6 at soil moisture content range 12 – 18 %. For Nicholes, at adhesion phase of the soil with soil moisture range 9 – 13.5 %, it was ranged from 0.4 up to 6.4. With coefficient of friction, 0.4 was close to the friction phase of the soil and coefficient of friction 6.4 was close to the lubrication phase of the soil, while the coefficient of friction 0.5 was at the middle of the range of the adhesion phase of the soil.

Since the seedling roots attached soil its moisture content will be in the range of the adhesion phase of the soil, so in this study the seedling coefficient of friction (μ) with the drop tube (the sliding surface) will be taken in the range of 0.4 – 0.55.

4-3- The transplanter forward speed

Hand feed transplanters (Culpine, 1986) must normally be pulled at very slowly speeds, as low as 1 – 2 km/h (0.27 – 0.55 m/s). Therefore, in this study the transplanter forward speed (V_m) will be taken in the range of 0.25 – 0.55 m/s.

5- The Objectives

The seedling resultant velocity (the ejecting seedling velocity from the seedling tube) is considered the key factor for the good seedling transplanting, according to its inclination angle and its value.

According to the previous sections, the desired inclination angles for the seedling resultant velocity should be from the vertical in the range of 15° – 30° i.e. 60° – 75° and 115° – 120° from the soil surface for the acute and the obtuse angles respectively. In addition, the value of this velocity should be as small as possible for minimizing the impact force for the seedling with the soil surface and consequently avoiding the seedling damage.

Therefore, by applying and running some applications on the previous theoretical analysis the following objectives may be found out or achieved.

1- Searching for the drop tube inclination angle, which could give the seedling resultant velocity the desired inclination angle.
2- Searching for the factors which minimizing the value of the seedling resultant velocity.
3- Simplify and facilitate the estimations for some of the transplanting parameters as it is possible.

APPLICATIONS ON THE THEORETICAL ANALYSIS

1- The Seedling Flow Time

The seedling flow time will be estimated by equation (8) using the recommended values for both the drop tube inclination angles 60° and 75° as acute angles (or 105° and 120° as obtuse angles) and seedling coefficients of friction 0.4, 0.5 and 0.6. And a suggested reasonable values for the drop tube length, as 0.4, 0.6 and 0.8 m, will be used.

Table (1): the estimated seedling flow time (t , s)

α	60° (120°)				75° (105°)			
μ / L, m	0.4	0.5	0.6	average	0.4	0.5	0.6	average
0.4	0.35	0.36	0.38	0.363	0.31	0.31	0.32	0.313
0.6	0.43	0.45	0.46	0.447	0.38	0.38	0.39	0.383
0.8	0.49	0.51	0.54	0.513	0.43	0.44	0.45	0.44
average	0.42	0.44	0.46	0.441	0.373	0.377	0.387	0.379

Table (1) shows that, drop tube inclination angle (α) and length (L) have a great effect on seedling flow time through the drop tube. While for the tested inclination angles the seedling coefficients of friction with the surface of the drop tube have a small effect on the seedling flow time. Because at these angles the drop tube (μ) is close to the vertical position and the seedling is subjected to nearly the free falling (which means there is small friction between the seedling and the drop tube surface). This is clear from table (1), where the flow time decreases as the acute inclination angle increased from 60° to 75° and as the obtuse inclination angle decreased from 120° to 105°. From table (1), the flow time range which could be extracted was from 0.3 to 0.5 second.

2- The Angle of The Seedling Resultant Velocity

Since the desired of the drop tube inclination angle (α) is ejecting the seedling from the drop tube with a velocity its inclination angle from the vertical is 30° until 15° i.e. 60° – 75° or 105° – 120° from the soil surface, for acute or obtuse angles respectively. And referring to the velocities diagram

(Figure 2) the seedling ejecting velocity is the resultant velocity (V_R), which its inclination angle is angle (ε).

Angle (ε) have been calculated using equation (7) for drop tube inclination angle 60° – 75° (105° -120°) at an average of flow time 0.4 s and seedling coefficient of friction 0.5, the results shown in table (2). From these results we can notice that, for the acute inclination angle (α = 60°) and for the obtuse angle (α = 105°) the resultant velocities inclination angles (ε) are very small than the desired angles and the reduction in these angles are going bigger as the transplnter forward speed increased. For the acute angle (α = 75°) and for the obtuse angle (α = 120°), the resultant velocities inclination angles (ε) are in the desired range. These angles decreased with increasing the transplanter forward speed.

Also, the seedling resultant velocities for the acute angle (α = 75°) are very high comparing with the seedling resultant velocities for the obtuse angle (α = 120°). In general, from table (2) and Figure (2), the seedling resultant velocity increased and decreased for the acute and obtuse inclination angle (α) respectively, as the transplanter forward speed increased. Increasing the resultant velocity (V_R) is not desired, since it will increase the impact force of the seedling with the soil.

Table (2): The effect of transplanting factors on the inclination angle (ε°) of the resultant seedling velocity (V_R)

At t = 0.4 and μ = 0.5				
α°	Vs	V_m	V_R	ε°
60	3.02	0.25	2.640	27.00
		0.40	2.770	26.90
		0.55	2.910	24.40
75	4.1	0.25	3.337	74.70
		0.40	3.379	72.34
		0.55	3.428	69.90
105	3.02	0.25	3.220	101.70
		0.40	3.200	98.00
		0.55	3.180	9.60
120	4.1	0.25	2.260	127.40
		0.40	2.170	124.60
		0.55	2.090	121.00

From the previous analysis it is clear that the angles 75° and 120° are better than the angles 60° and 105° for the acute and the obtuse angle respectively. And the obtuse angle 120° is the better than the acute angle 75°.

So, in general the obtuse angles is better than the acute angles and increasing transplanter forward speed is preferable with the obtuse angles than with the acute angles. And for solving the problem of angle (ε) to be close to the target angle, we can suggest that the drop tube to be hinged at the top and have multiposition at the bottom, for selecting the right position for this tube when transplanting the seedling of the different crops according to the field test for transplanter forward speed and the field and the seedling conditions.

Matlab program have been used for estimating the acceptable range for the drop tube inclination angle (α), which could give the seedling resultant velocity an inclination angle close to the target angle 75° (105°). Equation (7) have been solved by Matlab program using average values for seedling coefficient of friction as 0.5 and for seedling flow time as 0.4 s. For transplanter forward speed the range from 0.25 up to 0.55 m/s have been used and the target inclination angle for the resultant velocity is 75° as acute angle and 105° as obtuse angle. Table (3) show the Matlab program solution for equation (7). From this table the acceptable ranges for the drop tube inclination angle were 78° – 82° for acute angles and 108° – 112° for the obtuse angles.

Table (3): The acceptable range for the drop tube inclination angle (α)

ε, degree	75° (105°)		
μ	0.5		
t, second	0.4		
V_m, m/s	0.25	0.4	0.55
α, degree	78.27 - (108.15)	80.3 - (109.8)	82.5 - (111.8)

3- The Effect of Transplanting Factors on The Seedling Resultant Velocity

The seedling resultant velocity (V_R) was found by solving equation (6). This equation have four variables, they were the transplanter forward speed (V_m), the seedling flow time (t), the drop tube inclination angle (α) and the seedling coefficient of friction (μ). To study the effect of these variables on the resultant velocity, equation (6) have been solved three time as follows. Taking in consideration that, from the previous analysis, an average value for the drop tube inclination angle as 80° for the acute angle and 110° as obtuse angle will be used in some of the following solutions.

3-1-The effect of the seedling flow time on the seedling resultant velocity.

For studying the effect of the seedling flow time on the seedling resultant velocity, equation (6) solved three times at three different values of the seedling coefficient of friction (0.4, 0.5 and 0.6). With each value of the seedling coefficient of friction the other variables in equation (6) have the values of 0.3, 0.4 and 0.5 s for the seedling flow time; 0.25, 0.4 and 0.55 m/s for the transplanter forward speed and 80° (110°) as an average for the drop tube inclination angle. Figures (3 and 4) show an example for the results of these three solutions, for the solution when the seedling coefficient of friction is 0.5.

Figure (3) shows the relationships between the transplanter forward speed and the seedling resultant velocity for each values of the seedling flow time. These relationships were linear relationships for the acute angle and obtuse angle. These liner relationships are far from each other which means that the flow time has great effect on the seedling resultant velocity and as the flow time increase (for each forward speed) the resultant velocity increased greatly. The forward speed has bigger effect on the seedling resultant velocity for the acute angle than the obtuse angle.

Figure (3) shows also that, there are simple linear equations, with very high correlation coefficients, can be established between the transplanter forward speed and the seedling resultant velocity at each seedling flow time (0.3, 0.4 and 0.5 s). By these simple equations we can calculate the seedling resultant velocity at coefficient of friction (μ = 0.5) and the flow time for the used equation, using only the transplanter forward speed.

Figure (4) shows that, there are simple linear equations, with very high correlation coefficients, can be established between the seedling flow time and the seedling resultant velocity at each transplanter forward speed (0.25, 0.4 and 0.55 m/s).

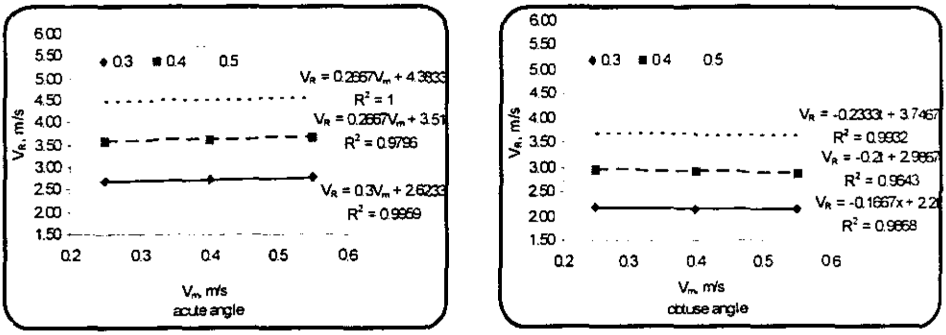


Figure (3): Effect of transplanter forward speed (V_m) on the resultant velocity (V_R), at different seedling flow time (t).

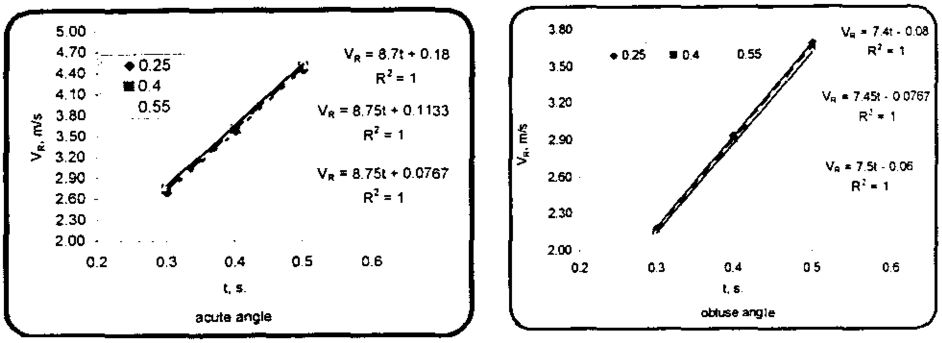


Figure (4): Effect of flow time (t) on the resultant velocity (V_R), at different transplanter forward speed (V_m).

The seedling flow time has a great effect on the seedling resultant velocity than the transplanter forward speed. This is clear from the inclination angles for the relationships in Figures (3 and 4). The relationships in Figure (4) were very close to each other for each of the acute and the obtuse angles. For each angle attempt has been done to establish a general simple equation between the seedling flow time and the seedling resultant velocity without any consideration for the transplanter forward speed (or in another word for the whole range of the transplanter forward speed 0.25 – 0.55 m/s). The attempts successive and general simple linear equations, with very high correlation coefficients, have been established as follows:-

For acute angle of 80°

$$V_R = 8.733\,t + 0.1233 \qquad (R^2 = 1)$$

For obtuse angle of 110°

$$V_R = 7.45\,t - 0.0722 \qquad (R^2 = 1)$$

The another two solutions when the seedling coefficient of friction were 0.4 and 0.6 show the same trend and behavior for both of the relationships between the transplanter forward speed and the seedling resultant velocity (as in Figure 3) and the relationships between the seedling flow time and the seedling resultant velocity (as in Figure 4). Also simple linear equations have been established for these relationships (not mentioned for avoiding the repetition).

Also, from these two solutions we can establish the multi equations, with very high correlation coefficients, between the seedling flow time and the seedling resultant velocity without any consideration for the transplanter forward speed. This means that we get three general simple equations, for each of the acute and obtuse angles, one for each of coefficients of friction. From these three general simple equations we established one absolute simple equation, with very high correlation coefficient, between the seedling flow time and the seedling resultant velocity, for each of the acute and the obtuse angle, without any consideration for both of forward speed and the coefficient of friction (in another word for the whole ranges of both the forward speed and the coefficient of friction). The multi equation may be as follows:-

$$V_R = 8.756\,t + 0.1159 \qquad \text{at acute angle} \qquad R^2 = 0.99$$

$$V_R = 7.456\,t - 0.0741 \qquad \text{at obtuse angle} \qquad R^2 = 0.97$$

Table (4) shows examples for the accuracy of the resultant velocity (the maximum and the minimum values of the whole three solutions) estimated using the absolute equations for the acute and obtuse angles comparing with its original values which calculated using equation (6).

Table (4): The estimated seedling resultant velocities using the absolute equations between the seedling flow time and seedling resultant velocity.

Inclination angle (α)	80°		110°	
Resultant velocity value	Maximum	Minimum	Maximum	Minimum
Recorded at	T 0.5, V_m 0.55 μ 0.4	T 0.3, V_m 0.25 μ 0.6	T 0.5, V_m 0.25 μ 0.4	T 0.3, V_m 0.55 μ 0.6
Original value	4.63	2.65	3.86	2.04
Estimated by absolute equation	4.49	2.74	3.65	2.16
Error %	-3.00	+3.4	-5.4	+ 5.9

3-2- The effect of the drop tube inclination angle on the seedling resultant velocity.

Figure (5) shows the relationships between the transplanter forward speed and the seedling resultant velocity for each value of the drop tube inclination angle. These relationships were positive linear relationships for the acute angles while they were negative linear relationships for the obtuse angles. These linear relationships for each of the acute and obtuse angles are far from each other which means that the drop tube inclination angles have great effect on the seedling resultant velocity (Figure 5). And the forward speeds have bigger effect on the seedling resultant velocity for the acute angles than the obtuse angles. Simple linear equations can be established between the transplanter forward speed and the seedling resultant velocity (Figure 5) at each drop tube inclination angle.

Figure (6) shows that, there are linear equations, with very high correlation coefficients, can be established between the drop tube inclination angle and the seedling resultant velocity at each of transplanter speed. These relationships were positive relationships for the acute angles and negative relationships for the obtuse angles. The drop tube inclination angles have great effect on the seedling resultant velocity for the acute angles than the obtuse angles.

The drop tube inclination angles have great effect on the seedling resultant velocity than the transplanter forward speeds. This is clear from the inclination angles for the linear relationships in Figures (5 and 6).

The relationships in Figure (6) were very close to each other for each of the acute and the obtuse angles. From the equations for these relationships general multi equations have been established between the drop tube inclination angle and the seedling resultant velocity for each of the acute and the obtuse angles.

The another two solutions when the seedling coefficient of frictions were 0.4 and 0.6 show the same trend and behavior for both of the relationships between the transplanter forward speed and the seedling resultant velocity (as in Figure 5) and the relationships between the drop tube inclination angle and the seedling resultant velocity (as in Figure 6).

Also, from these two solutions we established general simple equations, with very high correlation coefficients, between the drop tube inclination angle and the seedling resultant velocity without any consideration for the transplanter forward speed. From these general simple equations, for the three solutions, we established one absolute simple equation, with very high correlation coefficient, for each of the acute and the obtuse angles, without any consideration for both of transplanter forward speed and the seedling coefficient of friction. The multi equation for the above relationship may be as follows:-

$$V_R = 0.038\,\alpha + 0.542 \qquad \text{at acute angle} \qquad R^2 = 0.83$$

$$V_R = -0.062\,\alpha + 9.682 \qquad \text{at obtuse angle} \qquad R^2 = 0.83$$

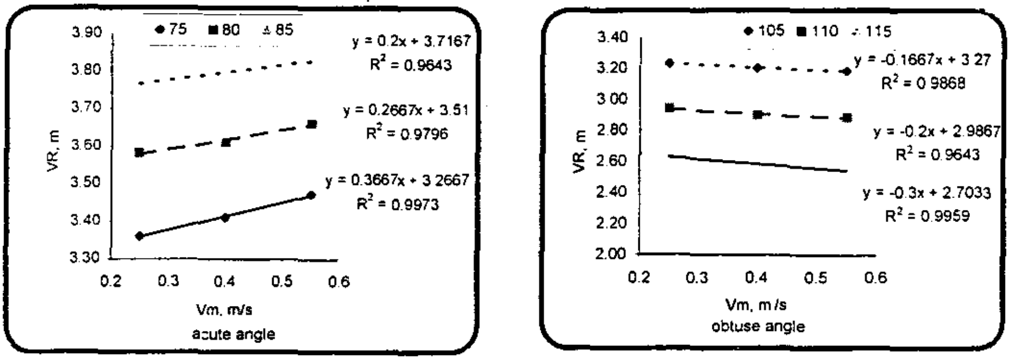


Figure (5): Effect of transplanter forward speed (V_m) on seedling resultant velocity (V_R) at different drop tube inclination angles (α).

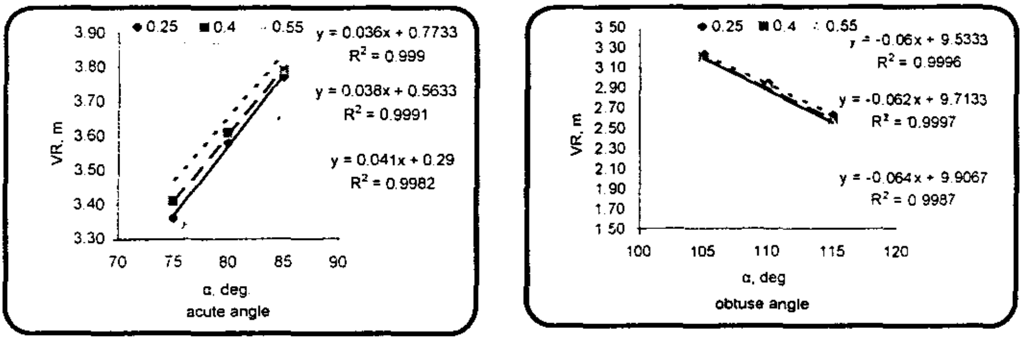


Figure (6). Effect of drop tube inclination angle (α) on seedling resultant velocity (V_R), at different transplanter forward speeds (V_m).

Table (5) shows examples for the resultant velocity (the maximum and the minimum values of the whole three solutions) estimated using the absolute equations for the acute and obtuse angles comparing with its original values calculated using equation(6).

Table (5): the estimated seedling resultant velocities using the absolute equations.

Inclination angle (α)	Acute angles		Obtuse angles	
Resultant velocity values	Maximum	Minimum	Maximum	Minimum
Recorded at	μ = 0.4 α= 85° V_m =0.55	μ =0.6 α= 75° V_m= 0.25	M=0.4 α= 105° V_m =0.25	μ =0.6 α= 115° V_m =0.55
Original value	3.86	3.25	3.33	2.38
Estimated by absolute equation	3.77	3.39	3.17	2.55
Error %	- 2.3	+ 4.3	- 4.8	- 7.1

3-3- The effect of the seedling coefficient of friction on the seedling resultant velocity.

For studying the effect of the seedling coefficient of friction on the seedling resultant velocity, equation (6) solved three times at three different values for the drop tube inclination angle as 75° (105°), 80° (110°) and 85° (115°) for the acute and the obtuse angles respectively. With each value of inclination angle the other variables in equation (6) have the values of 0.25, 0.4 and 0.55 m/s for the transplanter forward speed; 0.4m 0.5 and 0.6 for the seedling coefficient of friction and 0.4 s as an average value for the seedling flow time. Figures (7 and 8) show the solution of equation (6) when the drop tube inclination angle were 80° (110°), as an example of the three solutions.

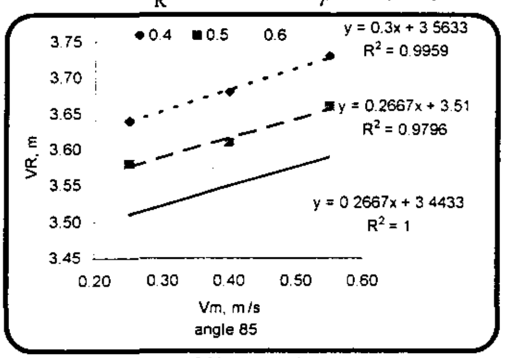
From figure (7), these relationships for both the acute and the obtuse angles are far from each other which means that the seedling coefficient of frictions have great effect on the seedling resultant velocity. In addition, the forward speeds have bigger effect on the seedling resultant velocity for the acute angle than the obtuse angle. Simple equations can be established between the transplanter forward speed and the seedling resultant velocity (Figure 7) at each drop tube inclination angle.

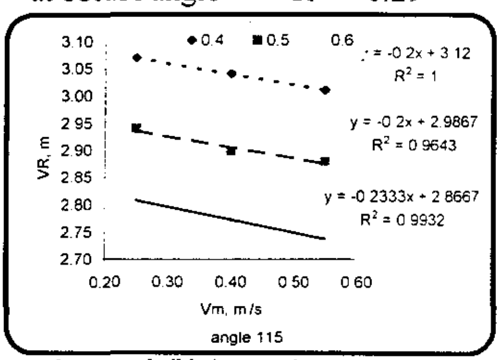
Figure (8) shows that, there are negative relationships between the seedling coefficient of friction and the seedling resultant velocity. And simple linear equations, with very high correlation coefficients, can be established between the seedling coefficient of friction and the seedling resultant velocity. General simple equations established for the acute and the obtuse angles, with moderate and high correlation coefficients respectively.

The another two solutions when the drop tube inclination angles were 75° (105°) and 85° (115°) show the same trend and behavior for both of the relationships between the transplanter speed and the seedling resultant velocity (as in Figure 7) and the relationships between the seedling coefficient of friction and the seedling resultant velocity (as in Figure 8). Also simple equations have been established for these relationships. The three solutions (by three different drop tube inclination angle) for both the acute and the obtuse angles had no good absolute simple equations between the seedling coefficient of friction and the seedling resultant velocity. The multi equation for the above relationship may be as follows:-

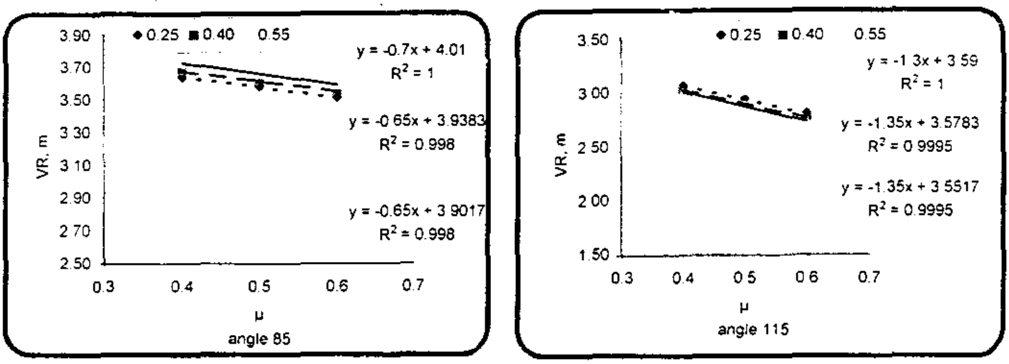
$$V_R = -0.678\,\mu + 3.879 \qquad \text{at acute angle} \qquad R^2 = 0.10$$

$$V_R = -1.167\,\mu + 3.638 \qquad \text{at obtuse angle} \qquad R^2 = 0.29$$





Figure(7): Effect of transplanter forward speed (V_m) on the resultant velocity (V_R), at different seedling coefficient of friction.



Figure(8): Effect of seedling coefficient of friction (μ) on the resultant velocity (V_R) at different transplanter forward speed (V_m).

3-4- The effect of the transplanter forward speed on the seedling resultant velocity.

For studying the effect of transplanter forward speed on the seedling resultant velocity, equation (6) solved several times in the previous three sections (3-1; 3-2 and 3-3) and the effect of the forward speed on the seedling resultant velocity have been shown through these solutions.

CONCLUSIONS

1- The suitable inclination angles for the seedling drop tube were in the range of 75° – 85° and 105° – 115° for the acute and obtuse angles respectively.
2- The bigger values for the acute inclination angles increase the values of seedling resultant velocity, while the bigger values for the obtuse angles decrease the values of this velocity.
3- Increasing the obtuse angles minimize greatly the seedling resultant velocity, while it increased greatly by increasing the acute angle.
4- With increasing the transplanting forward speed the seedling resultant velocity increased with the acute inclination angles, while it decreased with the obtuse inclination angles.
5- The seedling flow time, the drop tube inclination angle and the seedling coefficient of friction had great effect on the seedling resultant velocity than the transplanter forward speed.
6- The seedling flow time and the seedling coefficient of friction, separately, had the same effect on the seedling resultant velocity for both of the acute and obtuse inclination angles. This velocity increased greatly by increasing the seedling flow time, while it decreased by increasing the seedling coefficient of friction.
7- Simple linear equations have been achieved between some of the transplanting parameters, which could simplify the estimation for these parameters.

THE RECOMMENDATIONS

1- The drop tube inclination angles should be in the range of 75° – 85° and 105° – 115° for the acute and the obtuse angles respectively.
2- The smaller values for the acute angle and the bigger values for the obtuse angle were preferable.
3- The obtuse inclination angles were preferable than the acute angles.
4- Increasing the transplanter forward speed with the obtuse inclination angles is preferable than with the acute inclination angles.
5- For getting the suitable, certain drop tube inclination angle, when transplanting the seedlings for different crops, we may suggest that the drop tube designed to be hinged at the top and have juxtaposition at the bottom. Then the selecting of the right angle, in the field, will be according to the transplanting parameters and the real conditions for the seedling and the field.

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تحليل نظري لتقدير ودراسة العوامل التي تؤثر علي الشتل بالتغذية اليدوية

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مازال شتل شتلات معظم المحاصيل والخضر يتم بواسطة الشتلات ذات التغذية اليدوية. وذكرت مراجع كثيرة أن الشتل الجيد يمكن الحصول عليه عندما تشتل الشتلات بحيث تميل سيقانها بالنسبة للوضع الأساسي بزاوية من ٣٠ – ١٥° لذلك أجري تحليل نظري علي القوي المؤثرة علي الشتلة وسرعتها أثناء سقوطها خلال أنبوبة إسقاط الشتلات بغرض دراسة العوامل المؤثرة علي هذه السرعة من حيث قوتها وزاوية الميل لها. وكان الهدف من الدراسة الوصول بزاوية سرعة المحصلة للشتلة إلي الزاوية المطلوبة من ٣٠ – ١٥° من الرأسي ودراسة العوامل التي تقلل من قيمة هذه السرعة لتقليل قوة اصطدامها بالتربة ومحاولة تبسيط المعادلة التي يتم بواسطتها حساب بعض العوامل المؤثرة في سرعة المحصلة للشتلة.

ولإكساب الشتلات عند إسقاطها سرعة محصلة بالزاوية والمطلوبة تم التوصل إلي أن زاوية الميل المناسبة لأنبوبة إسقاط الشتلات هو ٧٥ – ٨٥° لزاوية الميل الحادة لهذه الأنبوبة ومن ١٠٥ – ١١٥° لزاوية ميل المنفرجة لهذه الأنبوبة كما وأن زاوية الميل المنفرجة لأنبوبة الإسقاط أفضل من الزاوية الحادة لأنها تقلل بدرجة كبيرة من قيمة سرعة المحصلة للشتلة مما يقلل من قوة اصطدامها بالتربة وأن السرعات الأمامية العالية للشتالة مفضلة مع زاوية الميل المنفرجة لأنبوبة الإسقاط عن الزاوية الحادة.

كما وأن من هذه الدراسة تم التوصل إلي اقتراح بعمل أنبوبة الإسقاط للشتلات مفصلية عند قمتها ولها أكثر من موقع عند قاعها وذلك بهدف ضبطها علي زاوية الميل المحددة المناسبة وذلك حسب سرعة آلة الشتل وحالة الشتلات نفسها وحالة التربة.