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Study on the mechanization of sugarcane transplanting

H.A. Abd El Mawla, B. Hemida, W.A. Mahmoud

***Abstract*— Transplanting technique has been applied in several countries for reducing the duration of sugarcane production season. Sugarcane transplanting has been recommended as an alternative planting method for saving considerable part of irrigation water that determines the expansion of agricultural area in the country. The technique also achieves several advantages such as saving seed quantity, labor power and total costs of sugarcane production. Farmers have been facing problems concerning trans-plating cane seedlings in the main field. Manual transplanting of sugarcane seedlings in the dry soil of the field is slow, inaccurate, costly and tedious task. The current research devoted to study the application of transplanting cane seedlings including nursery growing and mechanical transplanting to facilitate easy application of the technique.**

To establish a nursery, cane seed nodes was chopped to separate single buds with root band. The short sets of single buds were treated and planted either in small plastic sacs or in the well prepared nursery soil. After full germination of the seedlings, the operation of transplanting in the main field was take place at seedlings age up to 8 weeks. A mechanical trans-planter that developed especially for sugarcane seedlings was used. Seedlings sizes, germination, missing hills and died seedlings were determined. Germination was completed within 3 weeks and seedling sizes were variable because of the variation of germination period

Missing hills largely affected by the machine kinematic factor λ and died hills largely affected by the seedling age. The mechanical transplanting of sugarcane represented applicable technique that facilitates replacing traditional planting method to save more than 1000 LE of production cost. The technique saves 2000 m^3 of irrigation water and up to two months of production season

***Index Terms*— Sugarcane transplanting, nursery growing, trans-planter design, trans-planter performance, cane seedlings, feasibility of cane transplanting.**

I. INTRODUCTION

The main objective of introducing transplanting technique is to reduce the duration of sugarcane production season and to save about 15% of irrigation water. The problems of sugarcane transplanting represented in the difficulty of transplanting the crop seedlings in the main field. Manual transplanting of sugarcane seedlings in the main field is exhaustible, slow and tedious operation. Consequently, the technique has not been applied at the farmers' fields. Actually, farmers accepted the technique because of its multiple advantages but they have been locking for suitable machine to facilitate easier application of sugarcane transplanting. According to ***Sudara, (1998)*** cane transplanting advantages may be: a) saving in the seed cost as the seed requirement is only about 2.3 ton/ha in this system as against 8-10 ton used in the normal planting, b) synchronous tilering, leading to uniformly matured stalk population, which usually gives, better sugar recovery, c) sufficient time availability to prepare the main field, d) saving of 2-3 irrigations, e) saving 40 to 60 days in the main field duration, f) possibility of increased cane yield, g) efficient fertilizer management and h) better weed management. ***Wang and chang (1998)*** observed that there is an urgent need to mechanically transplant of sugarcane in Bangaladish. **Islam et al (2009)** stated that cane transplanting has multiple advantages of low production costs, higher crop production, labor saving and growth duration reduction. ***Singh et al., (2000)*** reported that in India transplanted sugarcane gave more production. Sugarcane field established by transplanting of spindle 'bud cultured plantlets at the scheduled planting time or 1 month later, or by conventional planting of sets at the scheduled time. ***Yadav, (1984)*** described the recently-developed spaced-transplanting method single-bud sugarcane sets were planted vertically in nursery beds, covered with dry cane leaves and, after a month, transplanted into rows 90 cm apart with 60 cm between plants. ***Jakeway and Hewetson (1987)*** explained why sugarcane transplanting is being considered. The primary motivating factors for switching to transplanting to establish a sugarcane crop growing conditions can be summarized as follows; 1) return seed acreage to revenue producing crop cane, 2) reduce present material handling and planting costs, 3) maximize the planting opportunities offered by drip irrigation, 4) low plant population for sugarcane compared to other transplanted crops, and 5) favorable climate for establishing an outdoor nursery. ***Stolf and Tokeshi (1990)*** reported that a ratoon transplanting technique for sugarcane is described. The method was tested in a 4th ratoon crop of CV CB 47-89 and compared with conventional planting utilizing stalks from a nursery. The conventional and ratoon transplanted crops had fewer gaps larger than 0.5 m, 12.0 and 10.7%, respectively, compared with 24.4% in the control. ***Mcintyre, (1993)*** indicated that performance of transplants was competed with that of conventionally planted cane in eight trials, six of which were established in spring and the balance in autumn. The results are summarized as follows: 1) Spring establishment; yields of the plant crops from transplants were inferior to conventionally planted cone in four trials, equal in one trial and variable in the other. Transplanted cone yields improved in the ratoon crops and, although varietal differences were evident. The yield from both treatments, particularly cane

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H.A. Abd El Mawla, Prof., Ag. Eng. Dep., Fac. of Ag., Azhar U., Assiut.
B. Hemida, Senior Researcher, Ag. Eng. Res. Inst., ARC
W.A. Mahmoud, Asst. Lecturer, Ag. Eng. Dep., Fac. of Ag., Azhar U, Assiut.

under irrigated conditions, was comparable. 2) Autumn establishment; from a limited number of trials, indications are that yields of autumn planted transplants were equal to those of cone planted in the conventional manner. 3) Quality of transplants; there is evidence to suggest that immature transplant, with poor root development at the time of planting not only reduced plant crop yield but also adversely affected the first ratoon crop. ***Werken, (1991)*** stated that the transplanting of plants is one of the major operations carried out by growers. It is therefore very important to minimize the time and labor involved in this process. For the system to be attractive to the growers, it has to be simple in use, reliable, possess a high transplanting capacity with good quality of the transplanting work and must do ail this at reasonable cost. ***Verma, (1984)*** classified mechanical trans-planter into two groups, pot type (root washed) trans-planter and mat type trans-planter, depending upon the type of producing seedlings in the nursery pot type is used widely with big seedlings, which is suitable for vegetable crops such as tomato, cabbage and tobacco. **Ravindra [et al](2013)** studied the mechanization of planting of sugarcane bud chip seedlings raised in protrays. Sugarcane bud chip planting is the latest technique of sugarcane planting, wherein the bud along with a portion of the nodal region is chipped off and planted in protray with FYM soil and sand. A tractor mounted two row mechanical planter for settlings raised from sugarcane bud chips was developed. It consists of mainframe which can be attached to standard three-point hitch arrangement of a 35 hp tractor. The metering mechanism, operator's seat, furrow openers, soil openers and furrow closers are mounted on the main frame with necessary supports. The optimum speed of operation was standardized as 1.4 km/h by experimentation where the missing percentage was 2.33 %. The field capacity of the equipment was 0.15 ha/h. The biometric parameters viz., diameter of the cane, cane height, single cane weight, juice content and yield of the mechanically planted sugarcane settlings were on par with the manually planted sugarcane settlings. Abdel-Mawla [et al] (2011) reported a single row machine developed for mechanical transplanting of sugarcane. The machine consists of a transplanting mechanism, powered by a ground wheel. A large tray was used to hold the seedlings. A labor fed the seedlings to some funnels which place it in bottom of the furrow that opened by the furrow opener of the machine. Soil was compressed from both sides to cover the seedlings root.

II. MATERIALS AND METHODS

The application of sugarcane transplanting technique included two main activities. The first was to establish the nursery for seedling production and the second was to mechanically transplant the sugarcane seedlings in the permanent field. The activities may be described as follow:

I - The technique of nursery establishing included:

- Cane seed chopped into single bud sets.
- Treatment of single bud sets as recommended by the agronomists. Bud sets were treated sinking in hot-water (50^0 C) for two hours then dropped in fungicide solution before planted in the nursery.
- The sets were then were planted in the nursery area either in small (6×12) cm plastic bags or in the nursery field plot of very well prepared soil (Figs 1, 2).

Planting the bud sets in plastic bags included filling the plastic bags (having punched holes for aeration) with homogeneous mixture of equal quantities of soil, sand and good rotten compost. The bud sets placed in plastic bags with the bud facing upwards and cover with soil/compost mixture.

- Nursery irrigation and fertilizer application was done as recommended by the agronomists.

Fig (1) Sets of single buds prepared to be planted in the nursery

Fig (2) Nursery of sugarcane seedlings showing directly planted and plastic bag seedlings after germination

II – Mechanical transplanting of sugarcane seedlings:

A machine (Fig 3) was developed by Abdel-Mawla (2010) was used for transplanting sugarcane seedlings in the main field during the cane production season of 2013. The functional components of the trans-planter prototype are:

a. The seedling metering device:

The seedling metering mechanism (Fig 4) consists of four funnels. Each funnel attached to dual displaced arm system that keeps the funnel perpendicular while rotation. The diameter of seedling metering mechanism is 70 cm. The mechanism is assembled to the main frame using ball bearing and powered by the ground wheel.

b- The funnel consists of two halves hinged together by two pins at the top side of the funnel. Springs are used to keep the lower end of the funnel always closed.

c- Especially cam arrangement (Fig 5) used to open the funnels at the proper position of dropping the seedling to be placed inside the open furrow.

d- Furrow opener of suitable design and power transmission system that all assembled to a frame of suitable design. Fig (6) shows the machine in operation.

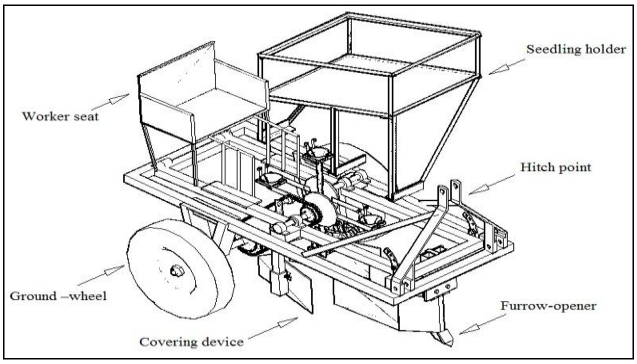

Fig. (3) Isometric of the machine prototype developed for sugar cane transplanting.

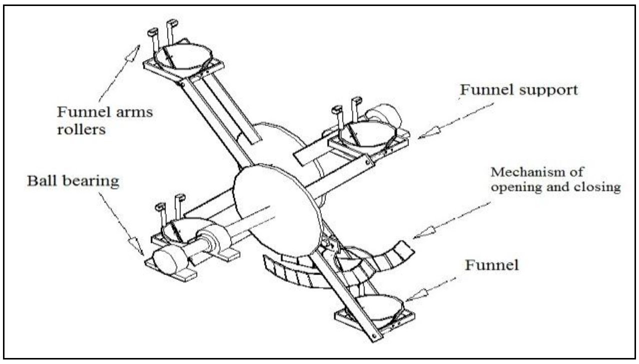

Fig. 4**:** Isometric of seedling transplanting mechanism.

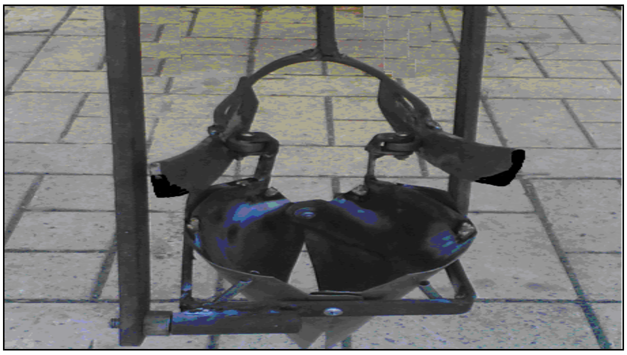

Fig. (5) Cam arrangement for funnel opening.

Fig (6) Sugarcane trans-planter in operation

Based on Klenin (1985), the kinematic index λ of the planter is the ratio of the linear velocity *u* of the extreme point of the clamping of the seedling and the speed *v* of the machine that is:

$$\lambda = u/v$$

The speed of the bucket is therefore governed by the average number of seedlings that can be deposited by the planter. The time interval T between the depositions is:

$$T = 2\pi R / z u$$

Where *R* is the radius of the bucket motion and *z* is the number of such holders. If spacing between the plants in the rows is assumed to be *a*, the kinematic index interrelation is:

$$\lambda = 2\pi R / z a_s$$

Therefore;

$$a_s = 2\pi R / z \lambda$$

The existing inter-furrow spacing of sugarcane ranged from 80 to 100 cm and the hill spacing along the furrow may also exists within the range from 30 to 40 cm.

For our current trans-planter, *R = the length of the funnel arm = 70 cm and z = the number of holders = 4 funnels*.

The variation of kinematic index λ was set within the existing range of hill spaces a_s. Performance parameters supposed to be estimated within the current research are:

- Germination percent of the single bud sets planted in the nursery.
- Seedlings characteristics at the time of transplanting.
- Actual average seedling spaces as affected by the kinematic index λ
- Missing hills as affected by the kinematic index λ
- The percent of died seedlings as affected by seedling age.
- Comparison of cane transplanting to traditional cane planting by cane seed stalks or sets. The comparison include;

a- Irrigation water consumption
b- Cane seed consumption
c- Production cost
d- Crop duration and cane production.

III. Results and Discussion

The bud chips or short sets that include one bud used to establish the sugarcane seedlings nursery were prepared where each set include healthy bud and root band. The cane material chopped for the purpose of nursery establishing was treated then planted as described previously. Seedlings germination was inspected every five days. Figure (7) show the percent of seedling as related to the period of seed planting. As indicated by the Figure, germination may start almost one week after planting. The percent of germinated seedlings increased directly with the period from planting for up to 4 weeks. Based on the activity of inspecting and selecting healthy buds before planted in the nursery, the percent of germination may reach very close to 100% after 4 weeks from planting. Actually some buds may need longer time for germination and arise over the soil.

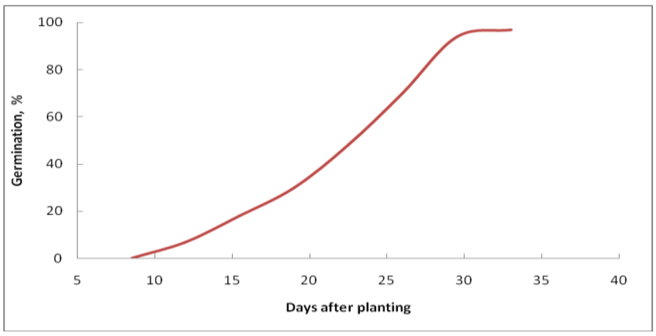

Fig (7) Seed germination in the nursery

Seedling size development parameters were also measured each five days after the full germination of the nursery. Consequently the measurements of seedling size were started 30 days after planting in the nursery. Figure (8) show two parameters used to describe seedling sizes represented in the full length of the seedling and the length of seedling stem. As shown in the Figure, the seedling size developed rapidly after germination. The average seedling full length may reach more than 50 cm within less than 45 days from planting. Actually, when planting several nurseries, considerable variation in seedling sizes may be easily seen. The variation may refer to the cane seed variety or to the nursery soil. The activities of seedlings treatment, planting at precise depth and nursery care may also be effective factors not only on germination but also on seedling size. Larger seedlings may cause difficulties in case of mechanical transplanting and longer seedling leafs may be rapidly dehydrated.

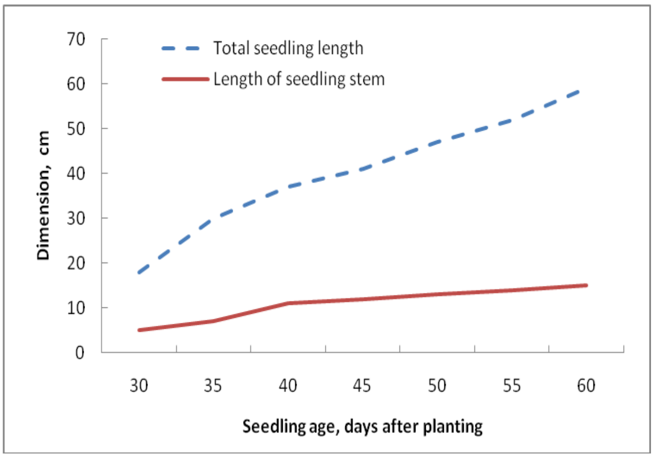

Fig (8) seedling size as related to nursery age

Based on Klenine (1985), the uniformity of seedlings placement of the planting unit is largely depend on the kinematics of the trans-planter mechanism. The kinematic coefficient λ was computed as previously described. Theoretical spaces in between seedlings were computed at variable values of λ. The machine was operated at the same values of λ, where the actual average seedlings spaces were measured in the field. Figure (9) show the average actual seedling spaces in comparison to the theoretical seedling spaces. Average spaces between seedlings were close to the theoretically computed spaces at the lower values of λ. The higher values of λ were set by changing the ratio of the funnel linear speed *u* to the machine forward speed *v* by replacing the sprockets on both shafts of the ground wheel of and the shaft that rotates the metering system shaft. The higher value of λ, the larger the variation between theoretically computed and actually measured spaces between seedlings. The variation of the transplanted seedlings spaces may refer to one or both of the following reasons: 1) Variation of slip ratio of the machine ground speed as affected by the change of forward speed. 2) The ability of the labor to feed funnels (that represent the metering system) at variable machine speed. At lower forward speeds, lower wheel slip ratio occurred and smooth current funnels to be fed with seedlings pass in front of the labor that explains the close values of the two curves of Figure (9) at lower values of λ.

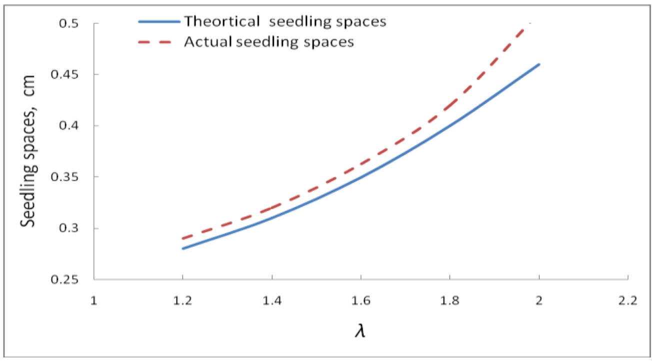

Fig (9) Seedling spaces as affected by the machine kinematic factor (λ).

The percent of missing hills (Fig 10) was determined after transplanting the full field. The missed hills detected in the trans-planted field represent the miss-feeding of some funnels due to the limited ability of the labor to handle seedlings from the tray and feed them in the funnels. At higher values of λ, the interval of feeding seedlings is shorter and the probability of miss-feeding becomes greater. When inspecting the transplanted furrow, the missed hills appear as gaps of distances between the adjacent seedlings that duplicate the proper spaces. In case of sugarcane fields established by transplanting, the problem of missing hills would be manageable since the farmer can easily transplant the missed hills by hand in the same day directly before irrigation. In contrast, missed hills represent a complex problem in case of traditional sugarcane planting method because the farmer will not be sure about missing hills before one and half month from planting. Therefore, replanting these gaps may be useless because the seeds replanted in such gaps will be weak and the cane of replanted hills will be immature at the time of harvesting.

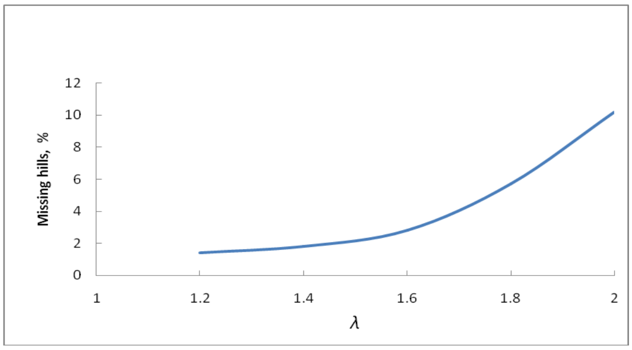

Fig (10) Missing hills as affected by the machine kinematic factor (λ).

Some transplanted seedlings may become died after transplanting. The field should be daily inspected for one week after transplanting to localize the dead hills. The drought seedlings should be removed and a healthy seedling transplanted by hand to eliminate the gap. Therefore, some extra seedlings should be left in the nursery to compensate both missing and died hills immediately after transplanting. Figure (11) show the percent of dead seedlings in relation to seedling age. Seedlings of 7 weeks age may of the optimum size for transplanting. Higher percent of dead seedlings may be occurred in case of small weak seedlings of 5 weeks age. The percent of dead seedlings may show rapidly increase in case of nursery older than 8 weeks. It may be reasonable to transplant sugarcane seedlings of nurseries up to 8 weeks age.

This may achieve the principle goals of applying sugarcane transplanting technique represented in saving irrigation water and field period.

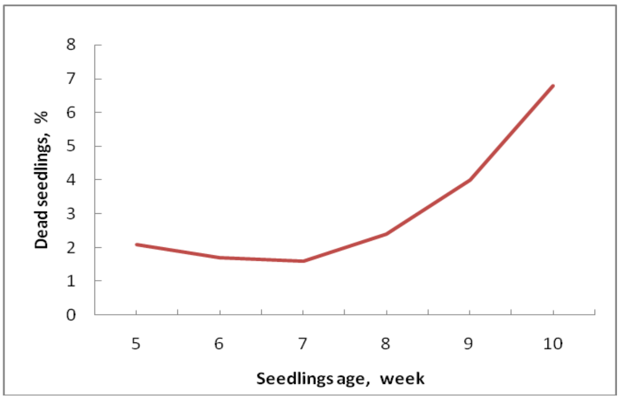

Fig (11) Dead seedlings as affected by the machine seedlings age

Table (1) present the most important advantages achieved by applying sugarcane transplanting technique in comparison to traditional planting. Applying sugarcane planting technique saves up to two months of the period required for sugarcane production. This is important advantage that permits the chance to harvest the previous crop and well preparation of field soil. Saving 7 to 8 weeks from sugarcane production duration reduces the production season from 12 to 10 months that eliminates three irrigations (about 2000 m^3/acre) and eliminate 2 cultivations by hand hoe.

Several references as well as the current research show that the production of the transplanted sugarcane field is equal or higher than that planted with traditional method. In Table (1) the parameter of cane production was eliminated because production may depend on several other factors such as seed variety, soil fertility and climatic conditions which are not considered in this research. The Table shows the production cost saved due to applying sugarcane transplanting technique compared to traditional. According to the data presented in Table (1), applying sugarcane transplanting technique may saves more than LE 1000 in addition to 2000 m^3 of irrigation water per acre and two months of the production season.

Table (1) Production costs saved when applying sugarcane transplanting

Item	Cane traditional planting	Cane transplanting	Save	Cost value LE/acre
Crop duration in the main field, (month)	12	10	2	NI*
Number of irrigations	18	15	3	300**
Irrigation water, (m^3)	13000	11000	2000	NI*
Seed consumption (ton)	3	1.5	1.5	550
Number of soil cultivations required	3	1	2	300
Total saved cost				1150

* NI: Not identified
**Cost of operating irrigation pump and one labor only (the money value of irrigation water not included)

IV. Conclusion

Sugarcane transplanting technique has been recommended to achieve advantages which are necessary for Egyptian agriculture. The application of transplanting technique to replace traditional planting of sugarcane saves up two months of the crop production season. Consequently, transplanting sugarcane saves considerable amount of irrigation water determined as 2000 m^3/acre. The quantity of seed consumed when applying transplanting technique is largely less than that of traditional method. The application of transplanting technique also eliminates the need for two cultivations. In addition to the reduction of production season and saving three full irrigations, the application of sugarcane transplanting technique may save more the 1000 LE/acre.

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