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Development, Fabrication and Evaluation of Semi-Automatic Field Crop Transplanter

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***Abstract:** Increase the area allocated for field crops cultivation requires moving from manual agriculture to mechanical farming. The aim of this study is development, fabrication and evaluation semi-automatic field crop transplanter. Performance evaluation of the transplanter was carried out for transplanting of 20-25, 25-30, and 30-35 cm corn seedlings at three forward speed levels of 0.3, 0.4 and 0.5 km h^{-1} under actual field conditions in terms of plant spacing, planting depth, and missing plant index. The transplanter precisely plants seedlings into ground. The effect of seedling height on the planting depth was found to be significant. In addition, plant missing percentage increased with increasing of forward speed.*

***Keywords:** transplanter, forward speed, semi-automatic, corn, plug seedlings.*

I. INTRODUCTION

Field crop is one of the most important food resources in the world. Field crops transplanting in the most of the countries still is done manually, as no machine is yet available for this work. Manual transplanting is very tiresome and labour consuming[1].

In semi-automatic machines, the transplants are fed by hand into the plant-placing device. several researchers have conducted countless experiments to increase the productivity and efficiency of mechanical transplanting [2, 3]. Different types of metering mechanisms were developed and evaluated to improve performance of semi-automatic vegetable transplanters such as a single row semiautomatic transplanter with cone type metering mechanism [4], a transplanter with finger type metering mechanism for holding and placing the seedling [5], a tractor mounted two row semi-automatic vegetable transplanter having a picker wheel type metering mechanism [6], and a two row vegetable transplanter with revolving magazine type metering mechanism [7].

Transplanting should be done using optimum seedling height and driving speed to have better machine performance. In an average 5.2, 3.6, 4 and 4.3 of missing plant percentage was noticed with 100-150,150-200, 200-250 and 250-300 mm length of seedlings respectively [8].

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For proper covering of seedlings, the average seedling height should be in the range of 150-200 mm [5, 9]. It was observed that planting depth increased with increase seedling age [5]. The smaller seedlings as well as larger seedlings showed relatively more difficulty in dropping properly than the medium length seedlings [8, 10].

The forward speed is a limiting factor on the performance of the semi-automatic transplanters. With the increase in speed, the operators tend to commit errors in feeding the seedlings in a repetitive loading operation increased in an exponential manner and even at very slow feeding rate [11]. The performance of a two row semi-automatic vegetable transplanter was evaluated for transplanting two vegetable crops; tomato and chilli at an average speed of 1.0 - 1.2 km h^{-1} with two operators feeding seedlings per row. Plant missing was within the acceptable limit of 3 - 4 per cent [5]. Semi-automatic vegetable transplanter with revolving magazine type metering mechanism was tested for transplanting brinjal, and the average plant missing was 2.22 to 4.44 [7]. The aim of this study is development, fabrication and evaluation of semi-automatic field crop transplanter.

II. MATERIALS AND METHODS

A. Design of main components

A prototype of semi-automatic one row field crop seedlings transplanter was designed and fabricated according to the biometric properties of field crop seedlings Table1. Auto CAD software 16 was used to prepare and design the drawings of different components of the transplanter as shown in Fig. 1. Computer numerical control (**CNC**) machine was used to fabricate the main components of the transplanter. The transplanter consist of main frame with three points hitching system, ground wheel, furrow opener, finger type metering mechanism, closing guide, transmission gears, seedlings box, press wheels, ridge shaper and operator's seat for two persons. The assembled prototype of the semi-automatic seedling transplanter is shown in Fig.2. The transplanter can be easily adjusted for transplanting a wide range of field crops that require different planting rate, width, and depth.

B. Performance evaluation of the prototype

The performance of the prototype was evaluated for corn transplanting. Corn can be transplanted at 15-40cm, 60-80cm and 10-12cm plant spacing, row to row distance and planting depth respectively. In this study, factorial experiment was conducted in one of the fields of the Diyala governorate, Iraq according to the two factor complete randomized block design (RCBD) with three replications.

Three levels of recommended corn seedling heights of 20-25, 25-30, and 30-35 cm were transplanted at three levels of forward speed of 0.2, 0.3 and 0.5 km h^{-1} with one worker feeding seedlings. The transplanter was calibrated to tranplant on planting depth of
10cm and plant to plant spacing of 15 cm as shown in Fig. 3. The forward speed of the tractor was controlled by adjusting the hand throttle and gear position, while seedling length was varied by sowing corn seeds in nursery at three different dates. The following parameters were recorded:

- **Planting depth**

The height of seedlings under the soil is planting depth. To measure planting depth, 10 seedlings were randomly uprooted in a row selected in each plot. The results of the planting depth were presented in cm.

- **Plant Spacing**

Plant spacing is the distance between each two adjacent seedlings in the same line. The Total number of plants is transplanted for 30 m distance was counted. The plant spacing was calculated by dividing the measured distance (30 m) by total number of seedlings transplanted in 30 m distance, the improperly transplanted plants slanted more than 30° to the vertical direction or completely lying down and the missing plants in the wide distance more than 1.5times the theoretical spacing between two adjacent seedlings were also counted.

- **Plant Missing**

The missing plant percentage was calculated by counting the number of plants is transplanted for 30 m distance. The expected number of seedlings for the same distance was counted for by dividing the length which the seedlings are counted by average plant spacing[8]. The missing plant percentage was calculated using the following formula [12, 13] :

$$\%MP = (n_2 - n_1)/n_2 \times 100 \quad (1)$$

Where, *% MP* = missing plant percentage, n_1 = actual number of plants transplanted for a distance of 30 m, n_2= expected number of plants for the same distance.

Table1: Specifications of a semi-automatic field crop transplanter

Particulars	Specifications
No. of rows	one
plant spacing	15 - 44cm, can be adjusted by changing sprockets or no. of fingers
Power source	35 hp tractor
Over all dimensions mm	2500× 900 × 1000 (L × W × H)
Type of metering mechanism	Finger type
Power transmission	From lugged ground wheel by chain and sprocket drive
No. of fingers	Max No.12 can be changed according to the required plant spacing
Furrow opener	Runner type with depth adjustments
Soil compacting unit	at 15º with vertical
Ridge shaper dimensions, cm	38 × 38 × 17 (L × W × H)
Ridge cross-section	Trapezoidal

1- main frame, 2-ground wheel 3- transmission gear 4-furrow opener 5-press wheels 6- ridge shaper 7- seedlings pocket 8-seedlings box 9- finger type metering mechanism, 10- closing guide 11-operator's seat 12- place for additional seedlings trays 13- three points hitching system

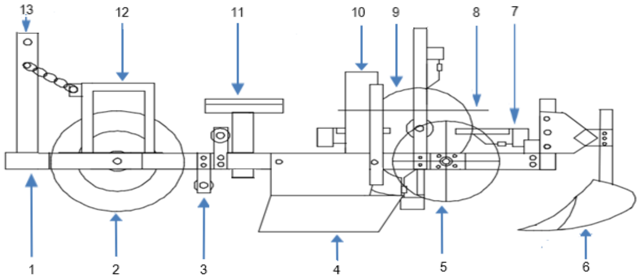

Fig.1: Schematic diagram of the main components of the semi-automatic field crop transplanter

Fig.2: The assembled prototype of the semi-automatic field crop transplanter

Fig.3: Field performance evaluation of the semi-automatic field crop transplanter

Statistical analysis of the data was done. The means were compared by calculating the least significant difference (LSD test) up to a 5% probability value using the SPSS 16 software package.

III. RESULTS AND DISCUSSION

A. Effect forward speed of tractor and seedling height on planting depth

The Effect forward speed of tractor on depth of planting was found non-significant at 5 % level. An increase seedling height affects significantly on the increase in the mean planting depth due to the very long seedlings caused by the blocking of the worker in determining the correct position of the seedlings within the picking fingers as shown in Table 2.

B. Effect forward speed and seedling height on plant spacing

Based on the results obtained in Table 3, the effect of forward speeds on plant spacing was found significant while there was no significant difference in plant spacing between seedling heights.

The practical results show that plant spacing varied from 15.31 cm to 16.50 cm. The average plant spacing observed in all methods of transplanting were comparable and close to the targeted plant spacing of 15 cm.

C. Effect forward speed and seedling height on missing plant

In Table 4, missing plant increased with the increase in the transplanter forward speed and the seedling height. The highest missing plant was noticed of 11.23% by transplanting corn seedlings with the height of 30-35 cm at forward speed of 0.5 km h^{-1} due to delay time while pulling the seedlings from seedlings box and the difficulty of feeding seedlings faced by the operator in putting seedlings while feeding in to the picking fingers.

Table 2: Effect forward speed and seedling height on planting depth

Forward speed (km h^{-1})	Plant height (cm)	Mean planting depth (cm)	Std. Deviation
0.3	20-25	9.23	0.251
	25-30	9.60	0.100
	30-35	10.51	0.101
0.4	20-25	9.40	0.050
	25-30	9.30	0.200
	30-35	10.75	0.050
0.5	20-25	9.23	0.115
	25-30	9.93	0.152
	30-35	9.93	0.057

L.S.D of forward speed is not significant at the .05 level
L.S.D of seedling height is significant at the .05 level

Table 3: Effect forward speed and seedling height on plant spacing

Forward Speed (kmh^{-1})	Plant height (cm)	Mean Plant Spacing (cm)	Std. Deviation
0.3	20-25	15.31	0.104
	25-30	15.50	0.100
	30-35	15.43	0.115
0.4	20-25	16.06	0.152
	25-30	16.00	0.100
	30-35	15.80	0.100
0.5	20-25	16.40	0.100
	25-30	16.40	0.100
	30-35	16.50	0.100

L.S.D of forward speed is significant at the .05 level
L.S.D of seedling height is not significant at the .05 level

Table 4: Effect forward speed and seedling height on missing plant percentage

Forward speed (km h^{-1})	Plant height (cm)	Mean missing plant (%)	Std. Deviation
0.3	20-25	2.06	0.667
	25-30	3.25	0.627
	30-35	3.53	0.369
0.4	20-25	6.24	0.585
	25-30	6.62	1.200
	30-35	6.05	1.243
0.5	20-25	9.13	0.225
	25-30	10.13	0.230
	30-35	11.23	0.208

L.S.D of forward speed is significant at the .05 level
L.S.D of seedling height is significant at the .05 level

IV. CONCLUSION

The semi-automatic one row field crop seedlings transplanter was developed, fabricated and evaluated for corn transplanting. Three seedling heights were transplanted at different forward speeds. Based on the field tests and statistical results, it was noticed that there was significant difference in plant spacing between forward speeds. In addition, there was significant difference in missing plant between forward speeds and seedling heights due to the operator tends to commit errors in feeding of seedlings. Forward speed of the tractor influences the time available for the feeding mechanism to plant, as the seedlings are fed to feeding mechanism manually, an increase in planting rate increased missed seedlings. The overall performance parameters of the transplanter are considered to be satisfactory. However the results can be improved further by reducing missing plant at higher speeds if two operators feed seedlings instead of one.

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