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DEVELOPING THE PLANTING UNIT MECHANISMS OF JAPANESE RICE TRANSPLANTER

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ABSTRACT

The planting unit mechanisms of a Japanese rice transplanter was developed to suit narrow row spacing (20 cm) and to agree with technical recommendations for rice cultivation in Egypt (RRTC, 2001). The development included proper modifications of fingers, and cross-feed stroke mechanisms, seedlings tray ,and the supporting floats. The developed transplanter was tested under different operating speeds (6.98, 7.85 and 8.96 m/s) to get different spaces under actual field conditions. The investigated machine was evaluated in terms of : the transplanting efficiency, the uniformity of hill distribution, and crop yield.

The results showed that:

- Lowest defective hills percentage (4.3 %) and the highest distribution uniformity of lateral space (99 %) was achieved as the developed machine at finger speed of 6.98 m/s. That may be compare to (3.9%) and (99.5%) for the transplanter before modifications.
- Average hill depositing index were (1.04, 1.07 and 1.09) versus finger speeds of 6.98, 7.85 and 8.96 m/s, compared to (1.03, 1.05 and 1.06) for the transplanter before modification,
- The actual hill space in row were varied from the adjusted one by an average decrement rate of 6.9 and 7.5 % for the machine before and after modification.
- Average row spaces after modification were (19.96, 20 and 20.1 cm) versus finger speeds of 6.98, 7.85 and 8.96 m/s, with standard deviation of (±0.61, ± .71 and ± 0.87) respectively.
- The grain yield and straw yields were almost more that before developing by 26 % .

Keywords: narrow rows spacing, rice transplanter, planting unit mechanisms, crop yield.

INTRODUCTION

The non uniform distribution, inadequate number of seedling per hill and number of hills per unit area transplanted manually was bushed the demand for developing of suitable equipment to mechanize the rice transplanting operation (Khan, 1979). El-Sahrigi (1983) reported that the mechanized transplanting is to ensure optimum numbers of plants per hill, numbers of hills per unit area and required planting depth for realizing high yields. El-Keredy et al. (1982) and El-Wehishy (1983), founded that, the mechanical transplanting gave a higher rice yield compare with the manual transplanting and broadcasting methods.

Abdel-Aal et al. (2002) indicated that, the total losses of seedlings (missed, floated and damaged) were resulted by increasing forward speed, while field efficiency and yield production were decreased. Soliman (2000) indicated that, the average row spacing for Japanese rice transplanter (JRT) crank type was 29.63 and 29.48 cm at forward speed of 0.38 and 0.59 m/s. Matouk et al. (1998) founded that, driving the JRT on a mudy clay soil which have been tilled by rotary plow twice gave the lowest wheel slip (9 %) and the least of fuel consumption (1.74 L/h); and energy requirements (6.49 kW/fed).

Abdou (1995) developed the transplanter to increase the plants density per unit area to suit the Egyptian agricultural requirements. It consisted of Kobuta 6 rows transplanting header attached behind the 6 rows Yanmar transplanting header in meddle position to give 15 cm inter row space. Kamel and ElKhateeb (2002) reported that, the highest number of hills per square meter (33 hills/m^2) and the best transplanting efficiency (84.5%) at forward speed of 2.8 km/h. The highest yields were 3.52 Mg/fed at 2.8 km/h. The lowest values of missing, damaged and floating hills were 1.8, 1.0 and 2.5 % with crank type transplanter.

Plant spacing is an important factor in transplanted rice production. Optimum spacing as recommended by the agronomists is essential to minimize weed infestation and obtain high yield. There is no single spacing practice best for all variety depends on soil fertility and season of planting (De Datta, 1981). Data indicated for rice varieties Sakha 101, 102, 104 and Giza 178 higher grain yield was obtained when plant spacing was either 20 x 15 or 20 x 20 cm. (row spacing x hill spacing). While, for Sakha 103 and Giza 177 the narrow spacing 20 x 15 or 15 x 15 produced higher grain yield (RRTC, 2001). Salem, A.K.M (2006), transplanting of the rice cultivar Sakha 101 at plant spacing of 20x15 cm can be recommended under Kafr El-Sheikh condition for higher grain yield. The existing transplanters should be improved so as to meet the needs of the specialized peasant households and a new type of transplanter for hybrid rice varieties should be developed (Qiang, 1985). All of the present rice transplanters rows spacing are fixed at 30 cm, while the distances between hills are adjustable from 13 to 21 cm. The present study objectives were:

1- To modify the planting unit mechanisms of Japanese rice transplanter to transplant at 20 cm row spacing instead of 30 cm.
2- To evaluate the effects of the proposed modifications on the transplanting efficiency, seedlings distribution uniformity and crop yield.

MATERIALS AND METHODS

1. Materials

Experiment work was carried out at rice mechanization center (RMC), Meet El-Dyba, Kafr El-Sheikh governorate.

1.1.The investigated transplanter

A Yanmar four wheel drive, and riding type transplanter (model YP-8000), was used for accomplishing the aim of the present work. The main technical specifications and the notifications of modified items of that transplanter are summarized in Table 1.

Table 1: Technical specifications and notifications of modified items of the investigated transplanter

	Item	Specifications
Engine	Type	Air-cooling , 4-cycle gasoline engine
	Power (kW/rpm)	6 / 1800
	No. of travel shifts	3 forward and 1 reveres (Only one for transplanting)
	Field capacity (hectare/h)	0.2 -0.3
	Planting finger type	Crank
	No. of planting rows (Modified)	8 (12)
	Rows spacing (Modified) (cm)	30 (20)
Planting	Operating width (cm)	240
unit	Planting finger cross cutting (mm)	10, 14
	Planting finger longitudinal cutting (mm)	12 , 14
	No. of seedlings / hill	3 - 8
	Planting fingers speed (m/s)	(6.98-7.85-8.96)
	Hills spacing / row (cm) No. of hills/m^2 – theoretically (Modified)- theoretically	18 , 16 , 14 18.52 – 20.83 – 23.81 (27.78– 31.25 –35.71)
	Nursery type	Mat seedlings
seedlings	Mat seedlings box , L X W X H (cm)	58 X 28 X 3
conditions	Seed density / tray (g)	125 - 280
	Range of seedlings height (cm)	10-25

1.2. Rice variety and preparing seedlings

The used rice variety was Giza 177, which is recommended to be transplanted at narrow spacing of (20 x 15) or (15 x 15) for higher grain yield. The sowing rate was 200 g/box**.** A three samples of 25 cm^2 were taken randomly from five seedlings boxes to check the seedlings characteristics after 25 days of sowing. The characteristics of seedlings are shown in Table 2.

Table (2) : The characteristics of the seedlings

Seedling height (cm)	Seedlings density (plant/cm^2)	Dry weight of seedling (g/plant)	Bed soil texture
15.6	3.9	0.015	clay

2.1.3. Field preparation and properties

The experimental field was prepared by using disc harrow two times followed by hydraulic scraper. Puddling was proceeded after irrigation by wooden puddler pulled by a horse. Table (3) shows the main experimental field properties.

Table (3) : The experimental field properties

Water depth (cm)	Hardpan depth (cm)	Cone plumb penetrating depth (cm)	Hardpan hardness (kg/cm^2)
2.7	15.6	10.3	5.4

1.4. Mechanisms modifications

The Planting unit of JRT is operated by the P.T.O. It has three operating speeds referred as N_1, N_2 and N_3 (6.98, 7.85 and 8.96 m/s). The Planting unit is divided into two feeding mechanisms (cross and longitudinal feeding) and planting fingers. The cross-feed mechanism moves the seedlings mats sideway by the reciprocation of the seedling tray to both ends of the cross-feed screw shaft and the longitudinal-feed mechanism slides down the seedling mats on the seedlings tray. The planting finger separates a small block from the seedlings mat and transplant it into the soil. The development of planting mechanisms were carried out in workshop in Desouk city, Kafr Elshiekh to transplant at 20cm inter row spacing. The modifications were included the following:

2.1.4.1. Planting fingers

The planting fingers are fixed at 30 cm inter rows spacing and arranged as a set of two fingers operated individually form a driven shaft. Planting fingers sets and it's power chain were rebuilt and rearranged to be operated at 20 cm apart. By changing the distance between the two fingers of each set to be 20 cm and also the distance of all fingers sets to be 20 cm. Meanwhile, the position of fingers driving chains and gears on the fingers power driving shaft also modified to match with the modified distance between fingers. The schematic of planting fingers before and after modifications is shown in Fig.(1).

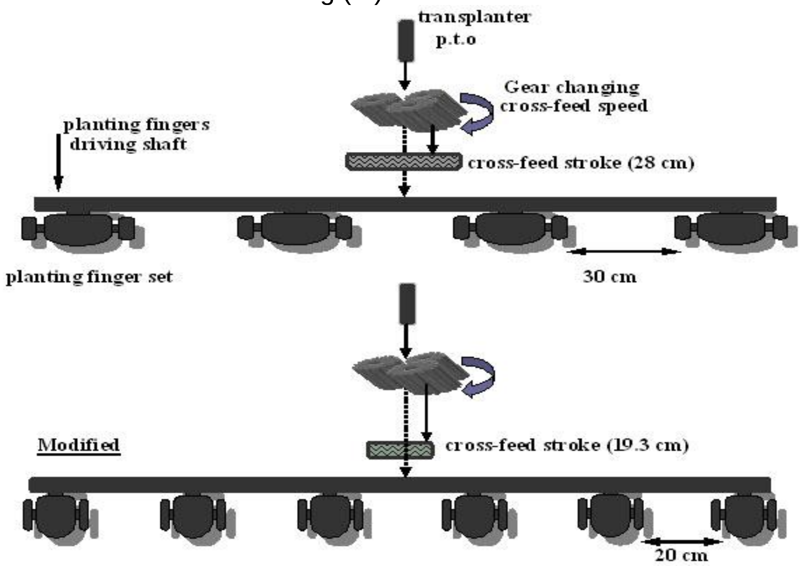

Fig. (1) : Schematic of planting fingers and cross-feed stroke before and after modifications

1.4.2. Cross-feed stroke

The cross-feed stroke of the seedling tray changed by adjusting the relation between the revolution of the cross-feed screw, the screw pitch and the revolution of the planting finger. The cross-feed screw pitch was modified to meet the new placing of the planting finger (20 cm) by changing the stroke length from 28 to 19.33 cm as shown in Fig. (1).

2.1.4.3. Seedlings tray

The seedlings mat box is dimensioned by W 28 X **L 58** X T 3 cm. The seedling tray of the 8 rows JRT are divided into 8 portions (W 28 X L 75 cm), each portion assigned for feeding one planting finger. The modified seedling tray are divided into 4 portions (**58** X 75 cm), each portion assigned for feeding three planting fingers in which the mat position was changed from the vertical to the horizontal position as shown in Fig. (2). This modification allows for using the seedling mat planting system without any modification and also same seedlings tray of the transplanter will be used.

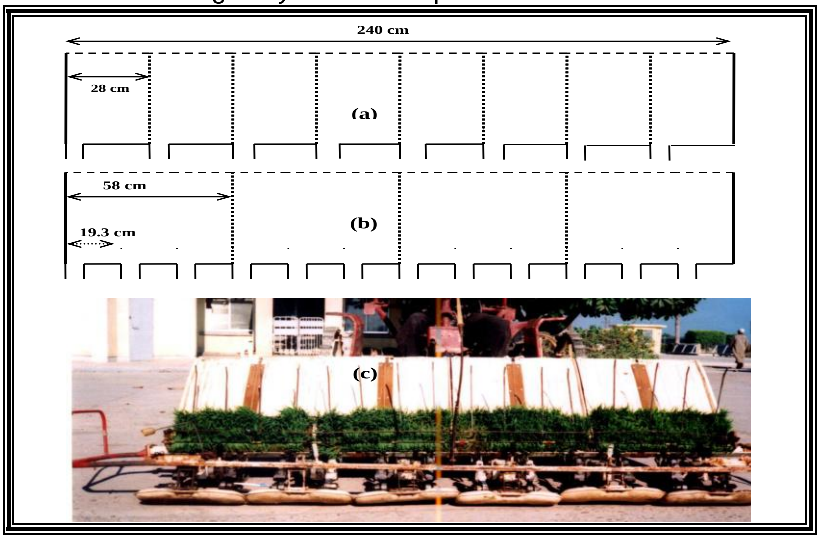

Fig. (2): Modified transplanter seedlings tray
(a) schematic of the original, 8 rows,
(b) modified 12 rows, (c) modified tray

1.4.4. Supporting floats

The weight of the JRT is supported by four wheels and floats. The floats location should be adjusted according to the planting fingers positions. Floats of the modified machine were sited close to each other to work as leveler and puddler as shown in Fig. (4).

2. Experimental Procedures

Transplanting was proceeded just after puddling. The machine performance of the modified planting unit mechanisms was evaluated according to the inter rows space and hills space to observe the effect of machine modification on both items. The data of 25 readings were collected by measuring the distance between adjacent rows and hills for 5 meter length. This procedure was repeated three times for different planting unit speed. Hills lateral dispersion, and hills defections (Missed, buried, damaged and floated hills) were also measured. At harvesting time a five samples of one square meter were taken randomly from each treatment in the field to estimate the grain yield.

3. Adjusting machine for operation

3.1. Within the row space

Hill within the row space is decided by the machine forward speed and planting finger speed. Increasing the planting finger speed relative to operating speed, hill space become narrow. On the contrary with lower finger speed the hill space becomes wide. Hill space is given by the following equation, (TIATC, 1984):

$$h_s = \frac{100.V}{N_F} \times 60 \qquad \text{..(1)}$$

Where,

h_s : hill space (cm) V : machine speed (m/sec)

N_F : planting finger speed (rpm)

The planting unit has three operating speeds gave a hill within the row space of 18, 16 and 14 cm

3.2. Transplanting depth

The planting depth was adjusted at 2 cm but under the field conditions the actual planting depth was ranged from 2.5 to 4 cm.

Transplanter forward speed

The transplanter model used in these study has only one operating speed for transplanting worked at full throttle. The change in operating speed (0.55 – 0.6 m/s) was due to the reaction between driving wheel and the soil surface.

4. Methods of Evaluation

The transplanting performances of the investigated machine before and after development were evaluated and compared in terms of transplanting efficiency, uniformity of seedling distribution, and crop yield. Figs. (3) and (4) illustrate the hills distribution and the field performance of modified the transplanter.

Fig. (3): Hills distribution

Fig.(4): Field performance of the developed transplanter

4.1. Transplanting efficiency,

The transplanting efficiency was estimated as a function of the percent of defective hill percentages. The percent of defective hills. later was determining by accounting the numbers of the total defective hills which was accounted manually after each transplanting treatments. The defective hills included : missed (M_h), buried (B_h), damaged (D_h), and floated (F_h) hills. Hence, the percent of defective hills for each investigated treatment was estimated as follows(TIATC, 1982):

$$H_T = \frac{M_h + B_h + D_h + F_h}{H_{th}} \times 100 \quad \text{..............................(2)}$$

where,

H_T : total defective hills percentage

H_{th} : theoretical number of hills / m^2

Consequently the transplanting efficiency was estimated as follows:

4.2. Seedling depositing index,

The seedling depositing index was introduced in the present work to evaluate the accuracy of depositing process of the investigated transplanter before and after modifications. The depositing index was determined as follows:

$$T_I = \frac{H_A}{H_{th}} \quad \text{..................................(3)}$$

where,

H_A : actual number of the transplanted hills / m2

H_{th} : theoretical number of the transplanted hills / m2

It should be denoted that if the index value is approached to unit(1), hence the accuracy of depositing process is maximum ,and Vic versa

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4.3. The uniformity of seedling distribution,

In the present work, the uniformity of seedling distribution was evaluated by determining, each of :dispersion of hill lateral space from the centerline of row, and the deviations in the distance between two adjacent rows.

The hills lateral dispersion was evaluated by determining of frequency percentages of four proposed lateral distance categories, that measured from the centerline of row. The normal distribution curves were used for plotting, the frequency percentages against each deduced lateral distance category. On the other hand the deviations in the distance between two adjacent rows was estimated by estimating the average and standard deviation of the measured distance between two adjacent rows.

4.4 Crop yield

The grain and straw yields were determined in both rice field plots that treated by the transplanter before modifications, and as affected by different planting finger speeds.

RESULTS AND DISCUSSION

The results of this study could be divided into three parts. The first is concerned with transplanting efficiency that considered the defective hills and hill depositing index. The second is concerned with the distribution uniformity of hills and evaluated in terms of hill lateral dispersion, hills space in row and the deviations of adjacent rows distance. The third is concerned with crop yield.

1- Transplanting efficiency

A- Defective hills

Figure (5) shows the effect of planting finger speed on the defective hills percentage before and after modification. It can be observed in general that, the defective hills increased by increasing the speed. The minimum defective hills percentage was 3.8 % at finger speed of 6.98 m/s (machine speed of 0.61 m/s). After modification while, the value was 4.7 % at the same speed by increment of 23.6 % from the before modification. The maximum defective hills percentage was 6.4 % at 0.61 and 8.96 m/s (machine and finger speeds),while, after modification the value was 7.25 % at the same speed by increment of 13.3 % before modification. Thus due to the increase of the number of planting fingers.

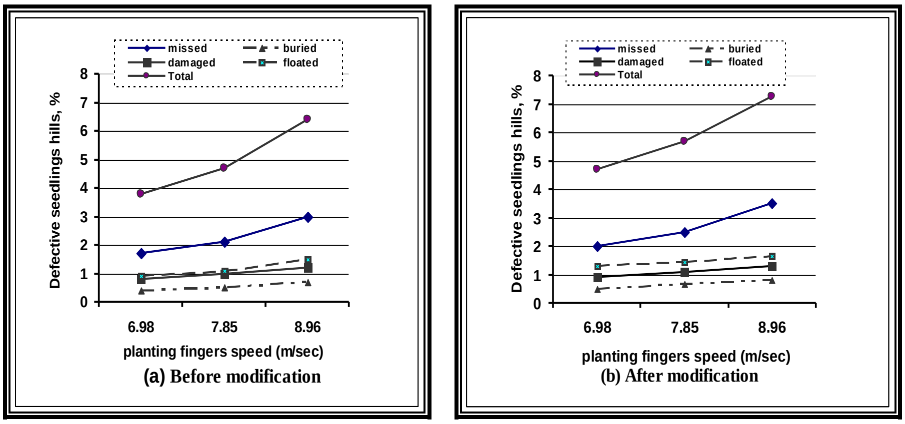

Fig. (5): Effect of fingers speed on the defective hills percentage (a) before, (b) after modification

It should be denoted that, the highest defective hills percentage is represented in the missing hill (2-3.5 %). The maximum missed hills percentage was 3 % at 0.61 and 8.96 m/s (machine and finger speeds),while, after modification the value was 3.5% at the same speed by increment of 16.7 % from the one before modification. Thus due to the increase of the number of planting fingers. The minimum percentage of missed hills was 1.7 % at 0.61 and 8.96 m/s (machine and finger speeds),while, after modification the value was 2 % at the same speed by increment of 15 % from the before modification .

B- Hills depositing index

The obtained results indicated that the average hills depositing index were (1.04, 1.07 and 1.09) versus finger speeds of 6.98, 7.85 and 8.96 m/s respectively and compared to (1.03, 1.05 and 1.06) for the transplanter before modification. The recorded index values was higher than 1 and that, may be due to the increase in the slippage and consequently which decrease in distance between hills within the row. That resulted in increase the number of hills per unit area than the adjusted one. It may be concluded the best depositing accuracy after developing is achieved at lower finger speed of 6.98 m/s.

Hills distribution Uniformity

A- Hills lateral dispersion

Figure (6) illustrates the effect of the investigated finger speeds on the hills lateral dispersion. It can be seen that, the lateral dispersion of hills is directly proportional to the planting speed. Increasing finger speed from 6.98 to 7.85 m/s, increased lateral dispersion percentage from 28 to 39 %. While increasing the finger speed to 8.96 m/s caused an increase of lateral dispersion from 28 to 53%.

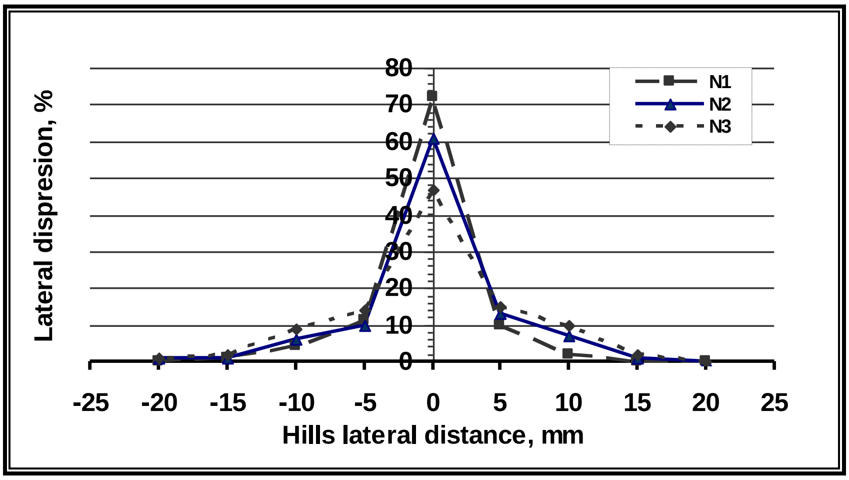

Fig. (6): Effect of fingers speed on lateral dispersion of seedlings hills

The frequency percentages of lateral distance category (± 5 mm), were 93, 84 and 76 % at finger speeds 6.98, 7.85 and 8.96 m/s respectively. While, frequency percentages of category (± 10 mm), were 99, 97 and 95 % at finger speeds 6.98, 7.85 and 8.96 m/s respectively. Similar hill lateral dispersion were accomplished the performance of the transplanter before modification.

It may be recommended to operate the developed transplanter at speed of 6.98 m/s to get a lower lateral dispersion.

B- Hills space

Before modification the finger speeds 6.98, 7.85 and 8.96 m/s gave a three theoretical hills spaces of 18, 16 and 14 cm within row. The average corresponding actual values of hills spaces under field condition were 16.8, 14.9 and 13.1 cm at 0.61 m/s forward speed. The decrement percentages between adjusted and actual hill spacing were 6.7, 6.9 and 7.1 %, respectively. While after development the actual values of hills spaces under field condition were 16.7, 14.7 and 12.9 cm at 0.61 m/s forward speed at the same adjusted hill spacing. The of decrement percentages of hill spacing were 7.2, 7.5 and 7.8 %, respectively. The difference in the hill spaces for the transplanter before and after modification is due to the increase of the number of rows (from 8 to 12). However increasing the finger speed increased the hill space differences and that is due machine slippage**.**

C- Deviations in the rows space

Fig. (7) illustrate the effect of finger speed on the average and standard deviation of obtaining row space. After modified the row space to 20 cm, the deviations in the distance between two adjacent rows were (± 0.62, ±0.71 and ±0.87 cm) versus finger speeds of 6.98, 7.85 and 8.96 m/s. It may be concluded that adjusting the developed machine at row space 20 cm resulted in row space average of 19.95 ± 0.62, 20± 0.71 and 20.1 ± 0.87 cm, at finger speed of 6.98, 7.85 and 8.96 m/s respectively.

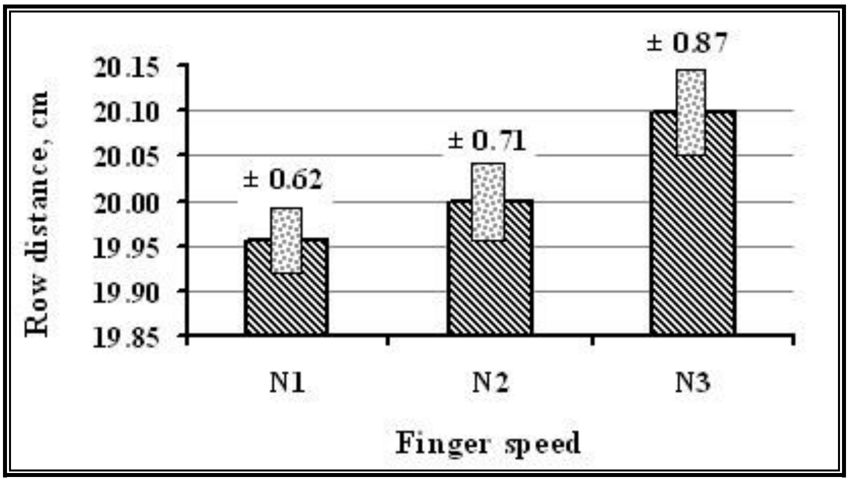

Fig. (7): Effect of finger speed on the distance between adjacent rows

3- Crop yield

The grain yield resulted from applying the before and after development as affected by finger speed is shown in Fig. (8). While the correspond straw yield is shown in Fig. (9). It can be seen that, developing the Japanese rice transplanter for narrow row space leads to increase the rice grain and straw yield by about 26 %.

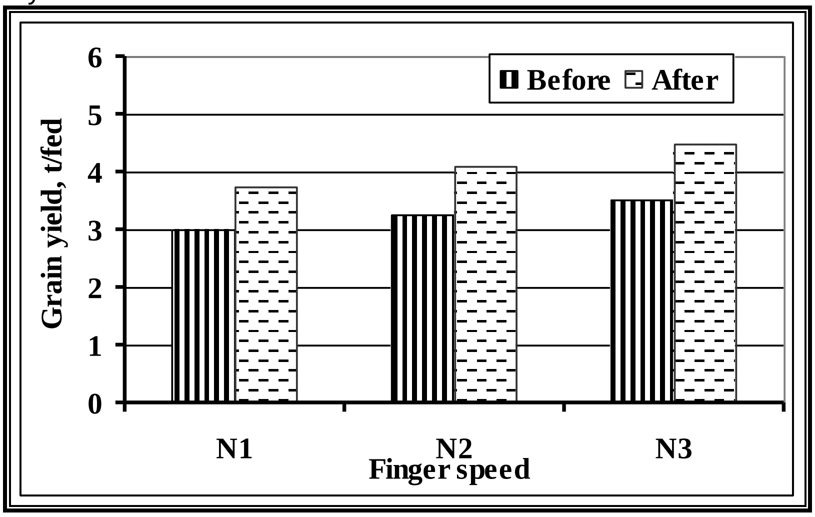

Fig. (8) : The grain yield

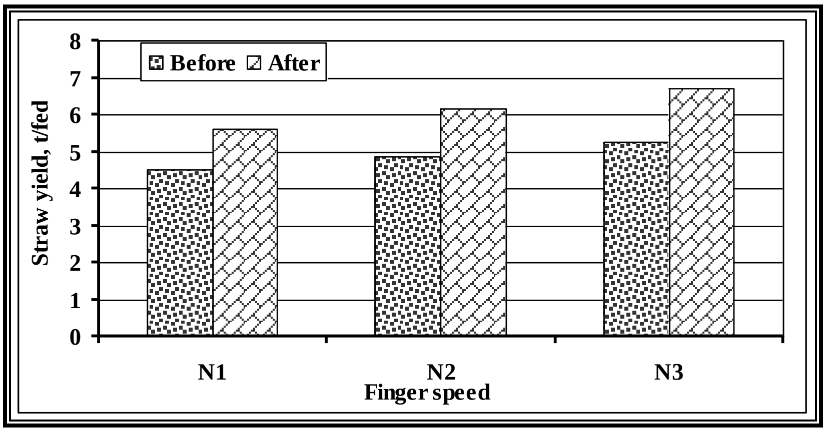

Fig. (9) : The straw yield

Conclusions

From the gained results, it could be concluded that:

The developed planting mechanisms is recommended to operate efficiently at finger speed of (6.89 m/s). In spite of, the comparison between performance of the machine before and after development showed similar or not significant difference in transplanting efficiency or distribution uniformity. But the grain yield and straw yields were almost more that before developing by about 26 % **.**

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تطوير التركيبات الآلية لوحدة الزراعة فى شتالة الأرز اليابانية

محسن إبراهيم عجيله

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تم تطوير التركيبات الآلية لوحدة الزراعة فى شتالة الأرز اليابانية لتناسب الزراعة فى خطوط ضيقة (٢٠سم) لتتوافق مع التوصيات الفنية لزراعة الأرز فى مصر (RRTC, 2001). وقد شمل التطوير إجراء التعديلات المناسبة على التركيبات الآلية لوحدة الزراعة والذى تضمن أصابع الشتل، مشوار التغذية الأفقية، حصيرة الصوانى وكذلك العوامات.

وتم إختبار الشتالة المطورة عند سرعات تشغيل مختلفة (٦,٩٨، ٧,٨٥ و ٨,٩٦ م/ث) للحصول على مسافات بينية مختلفة تحت ظروف التشغيل بالحقل. وعليه فقد تم تقييم أداء الشتل من حيث كفاءة الشتل ، إنتظام توزيع الكنون وانتاجية المحصول. وقد أظهرت النتائج:

- أقل نسبة للكنون التالفة كانت(٤,٣%) وأعلى أنتظامية لتوزيع الكنون للشتالة المطورة (٩٩%) تم الحصول عليها بالشتالة المطورة عند سرعة أصبع الشتل ٦,٩٨ م/ث مقارنة بـ (٣,٩%) و (٩٩,٥%) للشتالة قبل التعديل.
- متوسط مؤشر دقة غرس الكنون كان (١,٠٤، ١,٠٧ و ١,٠٩) عند سرعة أصابع الشتل ٦,٩٨، ٧,٨٥ و ٨,٩٦ م/ث مقارنة بـ (١,٠٣، ١,٠٥ و ١,٠٦) للشتالة قبل التعديل،
- كان متوسط نسبة التغير فى المسافة بين الكنون المضبوطة والفعلية (٦,٩ و ٧,٥%) للشتالة قبل و بعد التعديل على الترتيب.
- كان متوسط المسافة بين الخطوط بعد التعديل (١٩,٩٦، ٢٠ و ٢٠,١ سم /ث) عند سرعات تشغيل (٦,٩٨، ٧,٨٥ و ٨,٩٦ م/ث) بانحراف معيارى وقدره (٠,٦١، ٠,٧١ و ٠,٨٧) على الترتيب. لذا يوصى باستخدام السرعة ٦,٩٨ حيث أنها أعطت أفضل مسافة فعلية للمسافة المضبوطة بأقل إنحراف معيارى.
- حققت الشتالة بعد التعديل زيادة فى إنتاجية كل من محصولى الحبوب والقش بمتوسط ٢٦% مقارنة بالشتالة قبل التعديل.