ORIGINAL ARTICLE

Quality Assessment of Mechanized Rice Transplantation in Cuba

Evaluación de la calidad del trasplante mecanizado de arroz en Cuba

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Alexander Miranda-Caballero[I*], Guillermo S. Díaz-López[II], Michel Ruiz-Sánchez[I], Calixto Domínguez-Vento[III], Pedro Paneque-Rondón[IV]

[I]Instituto Nacional de Ciencias Agrícolas (INCA), San José de las Lajas, Mayabeque, Cuba.
[II]INCA, Unidad Científico Tecnológica de Base Los Palacios, Los Palacios, Pinar del Río, Cuba.
[III]Instituto de Investigaciones de Ingeniería Agrícola, UCTB Pinar del Río, Cuba.
[IV]Universidad Agraria de La Habana, Centro de Mecanización Agropecuaria, San José de las Lajas, Mayabeque, Cuba.

ABSTRACT: Mechanized transplantation of rice is being imposed worldwide and it requires certain conditions to develop the process efficiently like the production of seedlings in trays. In Cuba, transplanting machines with the system to the filling of the trays are being acquired, so it is necessary to establish a technology that allows the transplanting machines to be put into operation. The objective of this research was to evaluate the quality of rice seedlings to be used in mechanized transplantation under sowing conditions, in Pinar del Río Province, Cuba, with the use of the ERP-60 transplanter. Among the main results obtained in the tray seedbed technology at the time of transplantation, an interaction was found between the factors under study. When the component elements of the substrate were mixed and left at rest, the plants found the appropriate conditions for growth, in the four-element substrate (ST + MOT + FCSM + CAC), with 30 or more days of rest. This made possible to achieve seedlings of 15.37 cm high and 2.19 mm thick, 19 days after the seed germinated, complying with the requirements for transplantation with the ERP-60 machine.

Keywords: Seedbed, Seedling, Tray, Substrate, Technology.

RESUMEN: En el mundo se va imponiendo la operación del trasplante mecanizado del arroz lo que requieren ciertos y de determinados requisitos para desarrollar el proceso con eficiencia y entre ellos está la producción de las posturas en bandejas, en Cuba se están adquiriendo máquinas trasplantadoras con el sistema para el llenado de las bandejas, por lo que se hace necesario establecer una tecnología que permita la puesta en explotación de las máquinas trasplantadoras. La presente investigación tiene como objetivo evaluar la calidad de las posturas de arroz a utilizar en el trasplante mecanizado en las condiciones de siembra en la provincia de Pinar del Río, Cuba con la utilización de la trasplantadora ERP-60. Entre los principales resultados obtenidos en la tecnología de semillero en bandeja al momento del trasplante se encontró interacción entre los factores en estudio, cuando se mezclaron los elementos componente del sustrato y se dejaron en reposo, las plantas encuentran las condiciones adecuadas para el crecimiento, en el sustrato de cuatro elementos (ST+MOT+FCSM+CAC), con 30 o más días de reposo; lo que permite lograr plántulas de 15,37 cm de altura y 2,19 mm de grosor, a los 19 días de germinada la semilla, cumpliendo con las exigencias para el trasplante con la máquina ERP-60.

Palabras clave: semillero, postura, bandeja, sustrato, tecnología.

*Author for correspondence: Alexander Miranda-Caballero, e-mail: alex@inca.edu.cu

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INTRODUCTION

Cuba needs to import more than 400,000 tons of rice per year, so a strong investment program is carried out with the purpose of substituting imports and guaranteeing, before 2030, a national production of at least 85% of the 700,000 tons of rice the country consumes annually (Reyes, 2019).

However, the average yields obtained in the last 25 years do not exceed 3.75 t/ha and the traditional production system predominates in most areas where rice is grown (Miranda, 2020), which requires a high degree of mechanization (specialized cultivation), conditioned by the different sowing technologies that are used and the land extensions that are destined for its exploitation. There is a novel experience in the introduction of mechanized rice transplantation technology with a self-propelled transplanter to guarantee the production of seeds of new rice cultivars. This technology does not prevail yet, although it has a series of advantages, such as: cost reduction (better weed control, mainly red rice; and reduction in the amount of seed/ha). In addition, it generates better health of the rice plants, due to the low sowing density, better root development, which allows better absorption of nutrients and greater resistance to overturning. It also increases the vigor of plant stems, as there is less competition for nutrients, water and light. The technology of sowing by transplantation allows the control of contaminating rice, since the cultivation has a certain advantage over weedy rice, at the time of transplantation, in addition to the management of the water layer, which allows obtaining a culture free of contaminating rice (Miranda *et al.*, 2019; Miranda, 2020; Domínguez *et al.*, 2021b).

In Cuba, producers associated or not in cooperative farms, outside the lands of state companies, use manual transplantation as the fundamental way for sowing, where the producer, supported by his family, faces this great task that involves physical effort and direct exposure to the polluting medium of the rice plantation (Hernández *et al.*, 2016). In the world, the mechanized transplantation of rice is being imposed, which requires certain requirements to develop the process efficiently and among them is the production of the seedlings in trays, which implies a system of equipment that grinds and sifts the soil, fill the trays, fertilize, water and sow the pre-germinated seed (Domínguez *et al.*, 2021a). One hectare of soil for transplantation requires 400 trays of 0.30 x 0.60 cm (ERP-60, 2000).

MATERIALS AND METHODS

The experimental investigations were carried out in the experimental areas of Los Palacios Base Scientific and Technological Unit in Pinar del Río Province and had the objective of evaluating the quality of rice planting by mechanized transplantation with the use of the DAEDONG ERP-60 transplanter model. Figure 1 and Table 1 show some of its technical characteristics (Miranda *et al.*, 2021; ERP-60, 2000).

FIGURE 1. ERP-60 transplanter machine.

General Methodology for the Elaboration of the Seedbeds

As established by Minh (2012); Guerra *et al.* (2013); Hernández *et al.* (2016), the fundamental variants that affect the quality of seedlings in trays are: substrate composition, percentage of seed germination, seed selection, cultural care and plant vigor.

The methodology used for the preparation of the tray seedling consists of the following steps:

1. Sifting the soil and other components of the substrate

TABLE 1. Technical characteristics of the ERP 60 transplanter machine

Total length, mm	3,100
Overall width, mm	2,095
Total height, mm	1,880
Clearance, mm	405
Weight, kg	662
Model	FD620D
Kind	Two-cylinder, water-cooled gasoline engine
Power / Revolutions (max) (kW/rpm)	11.4 / 3,600 (14.7)
Displacement (cc)	617

2. Mixng all the components of the substrate relationship
3. Chemical analysis of the substrate relationship
4. Depositing the substrate up to two centimeters high in the tray
5. Moistening the substrate at the rate of two liters of water per tray
6. 130 g of seed are deposited per tray, at an average rate of 2.4 seed / cm2
7. The remaining space of the tray is covered with substrate and it is smoothed
8. The substrate is moistened again until it drains through the lower holes

The trays used have the following characteristics: length of 60 cm, width of 30 cm, depth of three centimeters, diameter of the holes of 0.3 cm; number of holes, 105 per tray.

To fill the trays, a semiautomatic seeder designed for "row by row" sowing is used, which allows using small quantities of seeds (naked or coated) with any type of tray. The change of the seeding bars and/or the nozzles is easy and fast; it allows the use of different types of trays with different varieties of seeds, Figure 2.

The rice tray seeder machine is pneumatically operated (it is connected to a compressor), it is manipulated by an operator in charge of assembling and disassembling the trays on the mobile support (2) and keeping the seed assortment in the head tank (3). The sowing is carried out in a synchronized way of four operations, the gauges make 20 traces on the moving tray, while the jars (4) suck the same amount of seed in the head deposit and release them into the conduits that deposit them on the trays of the tray. With this equipment a productivity of 30 trays sown per hour was achieved.

Methodology to Determine the Composition of the Substrate

According to studies of Hernández *et al.* (2016), in order to determine and adapt the components of the substrate for a carpet rice seedbed under conditions of the southern plain of Pinar del Rio, four variants were decided to prepare the substrate, taking into account the recommendations of the consulted bibliography in Philippine Rice Research Institute (2009) [10] , the substrates tested were:

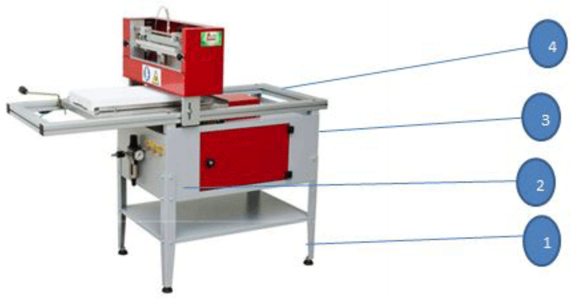

FIGURE 2. Tray seeding machine, 1- Support frame, 2- Movable tray support, 3- Seedling head, 4- Suction jar for seeds.

1. Sifted Dry Soil (ST).
2. Sifted Dry Soil + Sifted Organic Matter (ST + MOT).
3. Sifted Dry Soil + Sifted Organic Matter + Ground Cane Dry Fiber (ST + MOT + FCSM).
4. Sifted Dry Soil + Sifted Organic Matter + Ground Cane Dry Fiber + Carbonized Rice Husk (ST + MOT + FCSM + CAC).

The substrates, according to composition, remained at rest after mixing for: 40, 30, 20, 10, 0 days. For each substrate with its corresponding rest days, 4 trays (30 cm x 60 cm) were mounted, according to Table 2.

Methodology and Standards for Seed Selection

Selection of the seed. This is done by the seed selection method by specific gravity, for which they were immersed in a saline solution with a concentration of 1.13 g/cm^3, taking only the seeds submerged in the bottom of the container (Minh, 2012).

Determination of germination. The purpose of germination tests is to determine the maximum germination potential of a batch of seeds, to estimate its value for sowing in cultivation land and to provide results that allow comparing the different seed lots (Minh, 2012; NRAG/CTNR, 2012).

The actual seed mass (Mr) per tray varies depending on the percentage of germination of it (Expression 1).

$$\boldsymbol{Mr = \frac{Pr \cdot Mi}{Pi}, g} \quad (1)$$

Where:

TABLE 2. Location of the different substrates and resting time.

40 days	ST	ST + MOT	ST + MOT + FCSM	ST + MOT + FCSM + CAC
30 days	ST + MOT + FCSM + CAC	ST + MOT + FCSM	ST + MOT	ST
20 days	ST + MOT + FCSM	ST	ST + MOT + FCSM + CAC	ST + MOT
10 days	ST + MOT	ST + MOT + FCSM + CAC	ST	ST + MOT + FCSM
No rest	ST	ST + MOT + FCSM	ST + MOT + FCSM + CAC	ST + MOT

Pi - Percentage of germination of the ideal seed of 95… 98%;
Mi - Seed mass per ideal tray of 130, g;
Pr - Percentage of real germination of the seed, %.

Methodology to Analyze the Vigor of Plants

To measure the height and thickness of the seedlings, the method of the Standard for Rice according Graeguiles (2000) was used, supported by a tape measure and a caliper with accuracy ± 1 mm and 0.05 mm, respectively.

Methodology to Determine the Quality of the Transplantation Process

The following variables are to be evaluated in the experiment, assuming that the water sheet and the ground are parallel lines (r || p) and the plant (s) is perpendicular (Figure 3) (Menéndez *et al.*, 2012a; 2012b).

Inclination of the Plants when Transplanted

The angle of inclination of the seedling (∢BDL) after transplantation was calculated using the Pythagorean theorem and trigonometric identities (Figure 3).

Where,

1) The ∢ABC was calculated by the expression (2) determined by the inverse of sin∢ABC;

$$\sin\sphericalangle ABC = \frac{\overline{AC}}{\overline{BA}}, \text{grado} \quad (2)$$

2) The ∢ABC and ∢BDL are equal because they correspond between parallels (r‖p) and secant (s). The depth of transplantation (EF) perpendicular to the surface (p) was calculated by the following expressions.

Where:

1) The ∢EDF = ∢BDL for being opposite by the vertex;

2) Segment BD is determined by expression (3);

$$\overline{BD} = \frac{\overline{BL}}{\sin BDL}, \text{cm} \quad (3)$$

3) Sum of expression segments (4);

$$\overline{AF} = \overline{AB} + \overline{BD} + \overline{DF}, \text{cm} \quad (4)$$

4) Clearing expression (4);

$$\overline{DF} = \overline{AF} - \overline{AB} - \overline{BD}, \text{cm} \quad (5)$$

5) EF transplantation depth was calculated by expression (6).

$$\overline{EF} = \sphericalangle EDF \cdot \overline{DF}, \text{cm} \quad (6)$$

All measurements were carried out with 10 repetitions per plot randomly, with a tape measure with an accuracy of ± 1 mm.

Number of Seedlings per Transplanting Organ. Five plant counts were carried out at random in the three transplanting organs in each experimental plot.

Distance between Plants per Row. It was determined with a tape measure with an accuracy of ± 1mm, the distance between the base of the stems of the consecutive plant in a row, with at least 10 random repetitions and traversing the test plots along their diagonals. Subsequently, the mean value of such measurements was calculated.

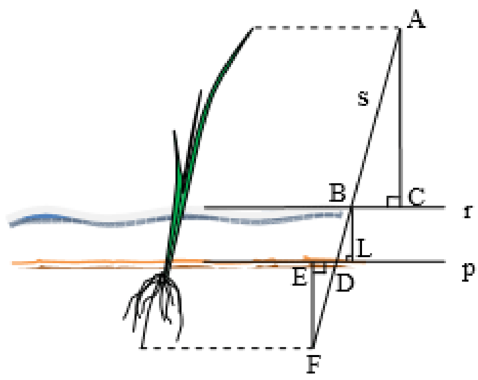

FIGURE 3. Seedling measurement scheme after transplantation.

Transplantation Effectiveness (Et). In order to know the effectiveness of the transplanter in the process of transplanting the rice crop, a count of the drives of the transplant organs was performed in a work pass, later the niches with transplanted seedlings were counted in the pass carried out and the per percent effectiveness was determined by expression (7).

$$Et = \frac{Tp \cdot 100}{Ca}, \% \quad (7)$$

Where:

Tp - Number of niches with transplanted seedlings, unit;
Ca - Number of drives of transplanting organs, unit.

Seedling Survival (Sp). Seedling survival one month after semi-mechanized transplantation was determined:

$$Sp = \frac{Ex \cdot 100}{Tp}, \% \quad (8)$$

Where:

Ex - Existence of niches with seedlings one month after transplantation, unit.

Number of Offsprings. The number of offsprings in 15 plants, taken at random in each experimental plot, which will be identified once the plants germinated from two months, and the evaluations were carried out every 15 days throughout the crop cycle.

DISCUSSION

Characterization of the Research Conditions

The experimental investigations were developed with six rice cultivars INCA-LP5, ROANA LP-15, GINES LP-18, GUILLEMAR LP-19 and JOSE

LP-20 by Colectivo de autores (2019) in the research areas of the Los Palacios Scientific Technological Unit (UCTB), of the National Institute of Agricultural Sciences (INCA), Los Palacios Municipality, Pinar del Río Province, during the 2019/2020 rice campaign.

Quality Parameters of the Seedlings Required by the ERP-60 Transplanter for Rice Cultivation

Analysis of Seed Gemination and Seedling Evolution

In studies carried out by Minh (2012); Guerra *et al.* (2013); Hernández *et al.* (2016), the best quality of the rice seedling is achieved when they are developed in the substrate made up of four parts of sieved soil, four parts of sieved organic matter, one part of dry cane fiber ground and a part of charred rice husk. With the aim of performing the investigations close to the real conditions of farms, these studies were mounted on the basis of the two main variants of substrates that can be obtained without difficulties on the farms themselves (Hernández *et al.*, 2016).

In the experimental tests, the results obtained in the two treatments carried out were analyzed (Table 3), for this, the size and thickness of the seedling was measured as a function of the substrate relationship, as well as the population per tray, at 19 days of germination of the seed, achieving in a shorter period of time that the seedlings reach the necessary height recommended 15… 20 cm, maintaining the quality required by the manufacturer for the transplanter (ERP-60, 2000).

Analysis of at the Time of Being Transplanted

Comparisons were made among the means (Figure 4) of treatments to know statistically how the relationships of substrates used influence each of the variables analyzed in the research. The analysis of the population per tray showed that the two treatments differ statistically, being the treatment with 50% of organic matter and sifted soil the one that presents the largest population with a coefficient of variation of 2,372, although the two treatments are within the necessary range for mechanized transplantation.

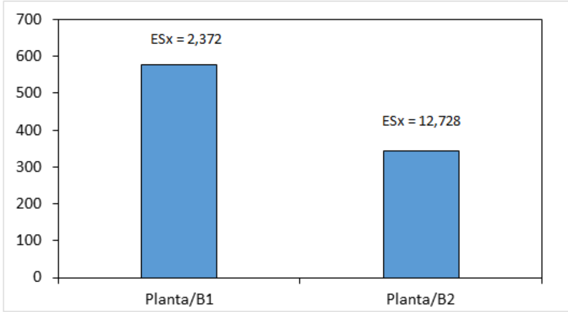

FIGURE 4. Result of the population count.

Quality Evaluation of Mechanized Transplantation

The production of seedbeds with the required quality is of vital importance, due to their direct dependence on the requirements of transplantation, to achieve a process of seedling sowing that allows a vigorous development in the environment in a satisfactory way (Minh, 2012; Guerra *et al.*, 2013; Hernández *et al.*, 2016).

Table 4 shows the statistical analysis carried out from the samples taken from the height of the water sheets and the thickness of the mud layer by plots at the time of rice transplantation, where the mean values, standard error, maximum and minimum coefficient of variation were determined.

TABLE 3. Result of the mean values of the measurements in seedbeds

Substratum	Rest time (days)	Result of mean values		
		Population per tray (un)	Seedling height (mm)	Diameter of the plants 24 mm from the base (mm)
100% sifted soil	30	342.71	14,782	2.22
50% sifted soil and 50% sifted organic matter	30	577,547	15,175	2.37

TABLE 4. Statistical analysis of the sampling to quality of soil preparation

	Sheet of water	Mud height
Average	7.66667	12,7083
Standard error	0.585658	0.508903
Coefficient of variation	37.42%	19.62%
Minimum	two	8
Maximum	12	16
Rank	10	8

Analysis of the Functioning of the Transplant Organs Carried Out at the Time of Transplantation

After the transplant activity, a count of the niches planted by the machine was made in two variants: 12 rows with the use of trays B1 and 12 rows with the use of trays B2, depending on the number of times the transplant organs were activated, according to the regulation of the machine, compared with those that had to be transplanted and verified a month later (Figure 5), to perform an analysis of the quality of the transplant and to measure technically the work of the transplanter.

As shown in Figure 5, it can be seen that there are no significant differences in terms of the counting of niches in different grooves when the trays B1 were used, compared to the operation of the working organs according to the machine regulation. With the use of tray B2, there are significant differences in four rows that put the quality of the transplant at risk, which shows that this result is a direct dependence of the population reached in the trays and not of the operation of the machine.

After performing the mechanized transplant, the number of niches (1 ... 3 seedlings) transplanted per square meter was counted at random by treatments carried out using trays B1 and B2. Significant differences were presented only in the areas planted with trays B2 (Figure 6), corroborating the result of the analysis (previous) of the row count. One of the indicators that is most required for mechanized transplantation is to achieve that the sedlings reach in 18 or 20 days of germination), heights that fluctuate between 15 and 20 cm (Washio, 2004), being the height of 15 cm the most suitable for the process of sowing with transplanting machines, since if the seedling exceeds these dimensions, it causes interruptions, once the transplant organ deposits it on the ground (Menéndez *et al.*, 2012a; 2012b; Minh, 2012).

CONCLUSIONS

In the tray seedbed technology at the time of transplantation, interaction was found between the factors under study, when the component elements of the substrate were mixed and left at rest, the plants found the appropriate conditions for growth, in the four-element substrate (ST + MOT + FCSM + CAC), with 30 or more days at rest. This makes possible to achieve seedlings of 15.37 cm high and 2.19 mm thick, 19 days after the seed germinated, complying with the requirements for transplantation with the ERP-60 machine.

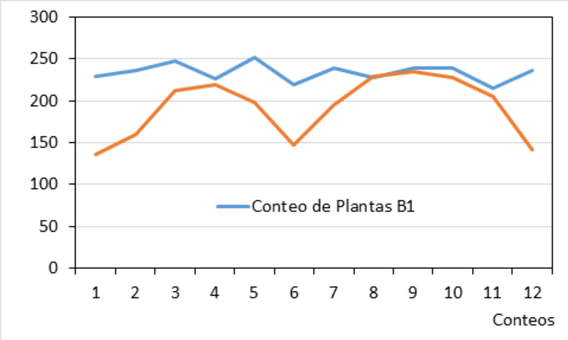

FIGURE 5. Behavior of the seedling count by rows.

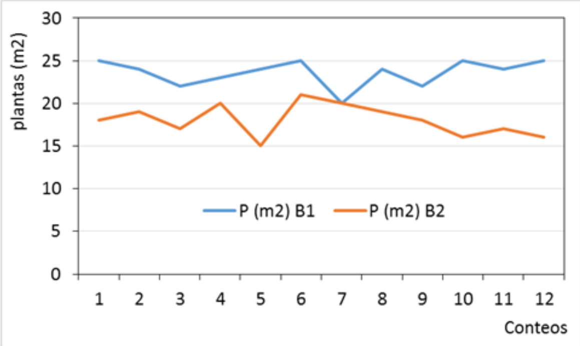

FIGURE 6. Behavior of the seedling count per square meter.

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Alexander Miranda-Caballero, Investigador y Profesor Titular. Director General Instituto Nacional de Ciencias Agrícolas, San José de las Lajas, Mayabeque, Cuba, e-mail: alex@inca.edu.cu.
Guillermo S. Díaz-López, Investigador Agregado. Unidad Científico Tecnológica de Base Los Palacios, perteneciente al Instituto Nacional de Ciencias Agrícolas, carretera La Francia km1½, Los Palacios, Pinar del Río, Cuba, e-mail: gdiaz@inca.edu.cu.
Michel Ruiz-Sánchez, Investigador y Profesor Titular Instituto Nacional de Ciencias Agrícolas, San José de las Lajas, Mayabeque, Cuba, e-mail: mich@inca.edu.cu.
Calixto Domínguez-Vento, Investigador Agregado, Instituto de Investigaciones de Ingeniería Agrícola, UCTB Pinar del Río, Cuba. e-mail: esp-iagric@dlg.pri.minag.gob.cu.
Pedro Paneque-Rondón , Investigador y Profesor Titular, Universidad Agraria de La Habana, Centro de Mecanización Agropecuaria, San José de las Lajas, Mayabeque, Cuba, e-mail: paneque@unah.edu.cu.

AUTHOR CONTRIBUTIONS: Conceptualization: A. Miranda. **Data curation**: A. Miranda; G. Díaz, M. Ruiz, P. Paneque. **Formal analysis**: A. Miranda; G. Díaz, M. Ruiz, P. Paneque. **Investigation**: A. Miranda; G. Díaz, M. Ruiz, P. Paneque. **Methodology**: A. Miranda, M. Ruiz, C. Domínguez. Supervision: A. Miranda; G. Díaz, C. Domínguez. **Roles/Writing, original draft**: A. Miranda; G. Díaz, P. Paneque. **Writing, review & editing**: G. Díaz, C. Domínguez, P. Paneque.