



DESIGN AND DEVELOPMENT OF HAND TRACTOR – ATTACHED TRANSPLANTER

¹Isidro D. Millo, ²Emerito V. Banal, ³Ronie S. Alamon,
⁴Raymond S. De Ocampo,
⁵Fei Xyza B. Asuncion and ⁶Denise Daryl A. Florante



ABSTRACT

The Metals Industry Research and Development Center (MIRDC) in collaboration with the Philippine Center for Postharvest Development and Mechanization (PHilMech) worked on a project entitled “Design and Development of Hand Tractor-Attached Transplanter.” This project generally aims to design and develop rice transplanter that can be readily mounted to and dismounted from a typical hand tractor. It specifically aims to evaluate the prototype through functional and measured testing based on the Philippine Agricultural Engineering Standards. After a comprehensive literature review, actual evaluation of existing designs of hand tractors and transplanters and thorough consideration of the different mechanisms that enable the equipment to function properly, the final design of the hand tractor-attached transplanter was created using the Computer-Aided Design (CAD) softwares Solidworks, NX8 and AutoCAD. The developed hand tractor-attached transplanter has a capacity of 1.68 ha/day, designed to cover six rows at 30-cm spacing, planting depth of three (3) to six (6) cm and power requirement of 7hp. Preliminary tests were performed in Amucao, Tarlac City, Tarlac; PHilMech - Muñoz, Nueva Ecija and Philippine Sino Center for Agricultural Technology (PHILSCAT)-Muñoz, Nueva Ecija to determine the functionality of the prototypes. Results were satisfactory and comparable to existing commercial transplanters.

INTRODUCTION

The Philippines is predominantly an agricultural country which is faced with the challenge of meeting the demands of its growing population. One of its major concerns is food-sufficiency through an agricultural production system that produces optimum yield at the minimum possible input.

Such challenge was further discussed by Elepaño *et al* on the 2009 country report entitled “Agricultural Mechanization Development in the Philippines.” The report cited two basic challenges being faced by the agricultural sector in the Philippines and Asia in general. First is meeting the growing demand for food, increasing agricultural production in the face of less labor, less land, less water and climate change consideration. Second is increasing the profitability of agricultural production system and competency in the global free trades. This requires the agricultural products to meet quality standards and cost of production to be significantly reduced.

Mechanization of farm operations is seen to aid in facing these challenges. Agricultural mechanization is basically the process of improving farm labor productivity through the use of agricultural machinery, implements and tools. It involves the provision

¹Supervising Science Research Specialist (SRS) and Chief, Equipment Prototyping Section (EPS), Prototyping Division (PD), Metals Industry Research and Development Center (MIRDC), Department of Science and Technology (DOST); ²Senior SRS, EPS, PD, MIRDC, DOST; ^{3,4}SRS II, EPS, PD, MIRDC, DOST; ^{5,6}SRS I, EPS, PD, MIRDC, DOST.

and use of all forms of power sources and mechanical assistance to agriculture, from simplehand tools, to animal draught power, and to mechanical power technologies (FAO, 2015). It plays an important role in helping farmers increase their crop production and income. It promotes timeliness of operation to take advantage of the potentials of modern crop varieties and crop intensification (IRRI, 1978).

However, the level of agricultural mechanization in the Philippines remains relatively low. Despite considerable advances in agriculture and agricultural technologies, most farmers are still using inefficient manual tools and farm operations are predominantly done manually. Land preparation of rice farms have higher level of mechanization while other farm operations remain manually performed.

The same report by Elepaño *et al* (2009), presented that as of 2005, the level of mechanization in transplanting rice was practically very low. There had been attempts to introduce mechanized rice transplanting in the past. A number of hand tractor powered-transplanters were imported from reputable international agricultural machinery manufacturers like Kubota and Yanmar. Others were introduced by research institutions like the Internatinal Rice Research Institute (IRRI) and Philippine Rice Research Institute (PhilRice). However, the level of adoption by rice farmers remained limited.

Concerned government research and development (R&D) agencies are collaborating to address these pressing issues. For instance, the Department of Agriculture has implemented the Mechanization Program which aims to achieve an industrialized country by year 2016. The partnership of DA-Philippine Center for Postharvest Development and Mechanization (PHilMech) with the Department of Science and Technology, in particular, has introduced useful technologies, low-cost and innovative machinery that makes farming more efficient and productive.

The hand tractor is considered as the basic workhorse of many small farms in many Asian countries, especially those in which lowland rice is a major crop like in the Philippines. During the Eighth Session of the Technical Committee of CSAM held on October 2012, at Sri Lanka, Dr. Delfin C. Suministrado of the Agricultural Machinery Testing and Evaluation Center (AMTEC-UPLB) reported that about 49% of the two million rice farmers in the country own or use multi-purpose hand tractor.

Transplanting is the most common method of crop establishment for rice in Asia. It is basically the method of moving rice seedlings from the nursery into puddled and leveled fields. This ensures a uniform plant stand and gives the rice crop a head start over emerging weeds. It may also allow crop intensification as the crop stays in the main field for less time. Commercially available rice transplanters are mostly self-propelled which are classified either as ride-on type or walk behind type. The hand tractor-based rice transplanters of which are generally dedicated machines in nature. This means that the transplanting mechanism is intimately integrated to the hand tractor unit and cannot be readily disassembled in order for the hand tractor to be usable for other farm operations.

This study will not only introduce a new concept in agricultural mechanization but will develop a new technology that will further increase the utilization of hand tractor in farm areas and potentially reduce the cost of farm mechanization.

OBJECTIVES OF THE STUDY

This project generally aims to design and develop a transplanter that can be readily mounted to and dismounted from typical hand tractor.

It specifically aims to;

1. To review and evaluate existing designs of hand tractors and rice transplanters;
2. To design and develop a hand tractor- attached transplanter prototype; and
3. To evaluate the performance and functionality of the prototype.

MATERIALS AND METHODS

Benchmark Activity

The design of commercially available Lakas Kuliglig hand tractor (SK 160 Model) and Kubota walk-behind type rice transplanter (SPW 480 Model) was evaluated and documented. Actual operations of these equipment were performed to observe their functionality. Furthermore, these units were disassembled and reassembled to identify the design features and further understand the involved mechanisms of operation. Figure 1 shows the ongoing documentation of some of the disassembled parts of the equipment.



Figure 1. Ongoing documentation of the disassembled parts of the hand tractor and transplanter.

Results of this activity identified certain design features to be incorporated to the hand tractor-attached transplanter prototype.

Conceptual Drawing

The design of the hand tractor-attached transplanter prototype was conceptualized after an intensive literature review and thorough consideration of the results of the benchmarking activity. The transplanting mechanism of the prototype was based from the documented Kubota walk-behind type rice transplanter SPW 480 Model. Additional features and attachment mechanisms were incorporated to effectively integrate the transplanting unit to the hand tractor unit. The final design of the hand tractor-attached transplanter, shown in Figure 2, was created using different Computer-Aided Design (CAD) softwares namely Solidworks, NX8 and AutoCAD.



Figure 2. Concept design of the hand tractor-attached transplanter as rendered from Solidworks.

Fabrication

The fabrication of the hand tractor-attached transplanter prototype was done mostly at the Metalworking Shop II (MWS II) of the Metals Industry Research and Development Center. On the other hand, the lead screw, which is the main metering device of the transplanter prototype, was fabricated in collaboration with E.R. Machine Shop, a local metalworking shop, due to its more complex specifications.

Features and mechanisms to avoid or minimize the effect of hand, arm and whole body vibration when using hand tractor, as well as the possibility of dampers, shock absorbers and rubberized hand grip were also considered.

Figure 3 shows the ongoing fabrication of some parts of the prototype.



Figure 3. Ongoing fabrication of the prototype.

Functional and Field Testing

The developed hand tractor-attached transplanter prototype was subjected to preliminary testing to determine its functionality, the possible problems to be encountered during operation and the adjustments deemed necessary. After which, a series of actual field testing was conducted to assess its performance. This shall be carried out following relevant Philippine Agricultural Engineering Standards (PAES). Figure 4 shows actual operation of the prototype during one of the field tests.



Figure 4. Field testing of the hand tractor-attached transplanter prototype in Amucao, Tarlac.

While there are existing standards that focus on the specifications and methods of test of mechanical rice transplanters (PAES 151:2010 and PAES 152:2010), these standards are limited to the self-propelled type. There are likewise PAES for the specifications (PAES 109:2000) and methods of test (PAES 111:2000) of walking-type agricultural tractor but there are no standards developed yet specific for a hand-tractor-attached type of transplanter. Hence, performance evaluation of the prototype was based on these four standards.

RESULTS AND DISCUSSION

The developed prototype, shown in Figure 5, has six main components. The engine of the hand tractor unit serves as the prime mover. The chassis assembly, which consist of series of pulleys, belts and pillow blocks, is connected to the speed reducer in order to transmit the power from the engine to the transplanter attachment. The speed reducer synchronizes the motion of the hand tractor with the planting mechanism. The seedling tray assembly, on the other hand, holds the rice seedling in position for planting. While the planting gearbox, which is composed of a series of spur gears, sprocket, cylindrical reversible cam and shifter assembly, facilitates the movement of the seedling tray, seedling descender, and the transplanter arm during planting operation. Lastly, the planting mechanism, which is composed of series of bearings, rocker arm with high tensile spring, a special rotary cam, sprockets and chains, is responsible for the movement of the picker arm as it injects the seedlings into the paddy.

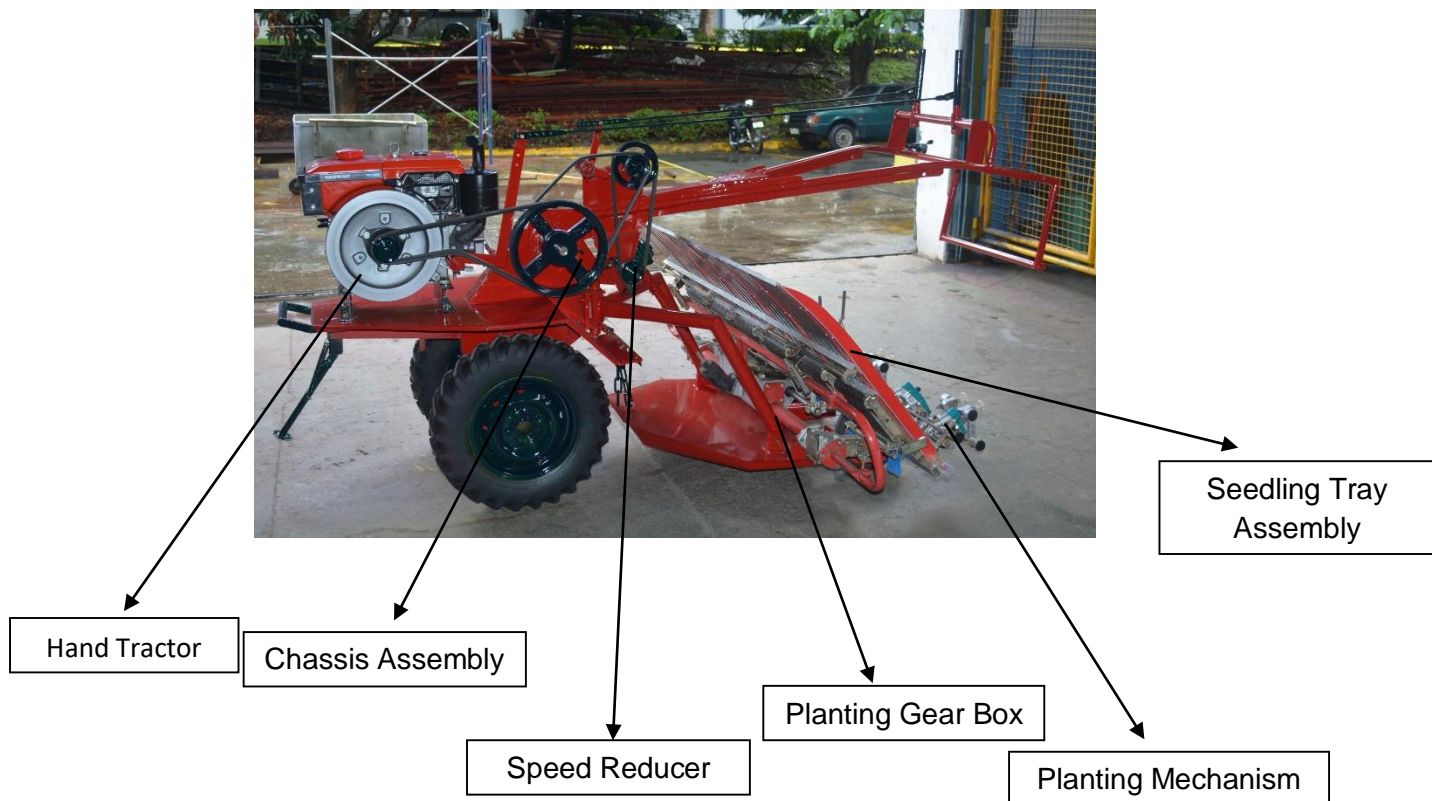


Figure 5: the developed hand tractor-attached transplanter

The prototype was first subjected to preliminary test at the MWS II, MIRDC compound to determine its functionality. This basically observed the movement of the transplanting mechanism. After the necessary adjustments, the prototype was brought to the field for actual testing and evaluation of its performance. Specifications of the prototype and results of field testing are summarized in Table 1 while the details of the series of field testing are presented in Table 2.

Table 1: Specifications of the hand tractor-attached transplanter prototype

Parameters	Measurements
Physical Characteristics	
Dimensions	2.90 X 1.45 X 1 m
Weight	40 kg.
Power	7 hp diesel engine
Field Testing Results	
Row Distance	300 mm
Hill Distance	200 mm
Speed	0.7 m/s
Field Capacity	0.2 – 0.3 ha/hr
Field Efficiency	50-75 %

Table 2: Performance evaluation of the hand tractor-attached transplanter

	1 st Field Testing	2 nd Field Testing	3 rd Field Testing
Site	PHILSCAT, Nueva Ecija	Amucao, Tarlac	PHILRICE, Nueva Ecija
Area	43 m x 30 m	23 m x 21 m	50 m x 21 m
Transplanting Depth	1 to 5 cm	4.8 cm	3 to 5 cm
Transplanting Speed	1.02 m/sec	0.7111 m/sec	0.71 m/sec
Field Capacity	0.258 ha/h	0.2892 ha/h	0.21 ha/h
Field Efficiency	46.84%	75.3 %	54.77%
Major Problem/s Encountered	<ul style="list-style-type: none"> -Turning radius was relatively wide -Mounting distance of the transplanter to the hand tractor was relatively long -Floater design cause “bulldozing” effect -Planting distance was longer than the 20 cm standard. -Loose vertical connection between the transplanter, hand tractor and joint for the turning. 	<ul style="list-style-type: none"> -The paddy wheel sunk in the very deep and very soft part of the field. Clay sticks on the wheel as well. The width of the paddy wheel was not suited for a clay-type / soft soil. -Some part of the field was over-filled with water and was too soft/deep thus, it destroys some of the nearby planted seedlings. 	No major problem encountered.

Table 2 cont'd: Performance evaluation of the hand tractor-attached transplanter

	1 st Field Testing	2 nd Field Testing	3 rd Field Testing
Solutions/ Recommendations	-Turning radius should be short -Shorter mounting distance of the transplanter to the hand tractor -Revision of Floater to minimize the accumulation of soil and “bulldozing” effect -Shorter planting distance of 20 cm should be the standard hill distance by changing the speed. -Fix vertical connection between the transplanter and hand tractor and joint for the turning.	-Driving the hand tractor to a shallower part of the field and making another design of the paddy wheel that can maneuver on a certain type of soil and its preparation. -Planting in a field with harder soil and with lesser water.	

SUMMARY AND CONCLUSION

In an effort to contribute to the improvement of the agricultural mechanization of the country, this study was implemented to introduce and develop a transplanter that can be readily mounted to and dismounted from a common hand tractor. It was able to develop a six-row hand tractor-attached transplanter prototype, determined the functionality of the prototype through preliminary testing, and evaluated the performance of the prototype through a series of field testing based on existing Philippine Agricultural Engineering Standards for mechanical rice transplanter and walking-type agricultural tractor. Results showed an average of 50-75% field efficiency which suggests that the performance of the prototype is comparable to the existing commercial transplanter. Furthermore, the obtained efficiency suggests that the prototype be improved to achieve a more efficient and consequently the optimum transplanting performance.

RECOMMENDATIONS

The following recommendations are hereby raised for the improvement of this study:

1. Determination of ergonomic considerations that will gauge the ease of operation, acceptability and overall performance of the prototype.
2. Development of a four-row hand tractor-attached transplanter applying the same mechanisms used in this study. Six-row transplanters are relatively heavy and are

more appropriate for ride-on type transplanter. Four-row transplanter, on the other hand, are more compact hence more suitable for walk-behind types.

3. Performance of endurance test to determine the durability of the machine parts and measures for repair and maintenance.
4. Performance of AMTEC Test once the standard for a hand tractor-attached transplanter is established.

ACKNOWLEDGEMENT

This project would not have been completed if not for the untiring cooperation of various government agencies and their dedicated experts. Utmost respect and gratitude are hereby extended to the MIRDC Project Staff headed by Engr. Isidro D. Millo; the funding agency - Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCAARD) headed by Dr. Reynaldo V. Eborá; the cooperating agency - Philippine Center for Postharvest Development and Mechanization (PhilMech) headed by Engr. Rex L. Bingabing; the Philippine Rice Research Institute (PhilRice) headed by Engr. Bernard D. Tadeo; the Project Management and Engineering Design Services Office (PMEDSO) and the Department of Science and Technology and its Management Committee.

LITERATURE CITED

DEPARTMENT OF AGRICULTURE. 2014. Future of Philippine Agriculture: DA's Farm Mechanization Program Gives Rise to Innovative Technologies. Retrieved from the world wide web at <http://www.da.gov.ph/index.php/2012-03-27-12-04-15/2012-04-17-09-30-59/5475-future-of-philippine-agriculture-da-s-farm-mechanization-program-gives-rise-to-innovative-technologies>

ELEPAÑO, ARNOLD R. et. al. 2009. Country Report: Agricultural Mechanization Development in the Philippines. A report presented to the UNAPCAEM's 5th Technical Committee Session and Expert Group Meeting on Application on Agricultural Machinery for Sustainable Agriculture in the Asia-Pacific Region. Los Baños, Laguna.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. 2015. Mechanization. Retrieved from the world wide web at <http://www.fao.org/tc/exact/sustainable-agriculture-platform-pilot-website/energy-management/mechanization/en/>

OFFICIAL GAZETTE FROM THE DEPARTMENT OF AGRICULTURE. 2014. DA: Mechanization to Reduce Rice Production Cost. Retrieved from the world wide web at <http://www.gov.ph/2014/04/11/da-mechanization-to-reduce-rice-production-cost/>

SUMINISTRADO, DELFIN C. 2013. Status of Agricultural Mechanization in the Philippines. A report presented during the 8th Session of the Technical Committee of CSAM on October 2012. Sri Lanka.