Journal of The Ghana Institution of Engineers, Vol. 2, No 1, 2004, pp 57 – 61

COMPARATIVE PERFORMANCE EVALUATION OF RICE TRANSPLANTERS

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ABSTRACT

Agricultural machinery testing and evaluation is important in the development of mechanised farming of a country. Field tests were conducted according to Japanese national standards to determine the performance of riding- and walking-type rice transplanters. The parameters evaluated were planting accuracy, field capacity, field efficiency and economic analysis. The results from this study show that farmers can make useful investment decisions on the selection of farm machinery for profitable mechanisation operations.

Keywords: Mechanisation of farm operations, Rice Transplanter, Japanese National Standards, Evaluation, Testing, Selection.

1. INTRODUCTION

Mechanisation is a key input in any improved farming system, therefore a strategy for testing, evaluation and selection of agricultural machinery is important for mechanisation (Bishop and Morris, 1992).

The term "testing" is used in connection with the analysis of the behaviour of a machine compared with well defined standards under ideal and repeatable conditions (Johnson, 1985). In contrast, "evaluation" involves the measurement of machine performance under real farm conditions (Smith *et al.*, 1994). "Selection" on the other hand is the final act of judgment which decides the machine to use from the range of those available. An informed judgment is assisted by a systematic review of machinery evaluations made formally or informally (Inns, 1995). Machinery evaluation and selection thus depends on collecting information on available machines and assembling them systematically to allow relevant comparison to be made easily by the potential user (Inns, 1995).

The policy of many governments in developing countries, especially in Africa, to modernise agricultural operations implies that imported machinery and equipment will still dominate the market in the absence of local ones. Therefore, field evaluation of machinery and equipment is an important decision tool for profitable machanisation operations.

The objectives of this study were: (a) to determine the planting accuracies of riding and walking type rice transplanters; (b) to estimate the field capacities and field efficiencies of the rice transplanters; and (c) to perform economic analysis of the transplanters, according Japanese national standards.

2. MATERIALS AND METHODS

2.1 Rice Variety and Seedling Condition

This study was conducted at the farms of Tsukuba International Training Centre, Japan according to the Japanese national standards for rice transplanters. A mixture of soil and fetilizer (Kumiai Ryujo Kasei) was used to fill nursery boxes with dimensions of 58 x 28 x 2.5 cm. 'Hatsuboshi' variety of paddy rice was sown at 1.23 kg/m^2 (200 g/box) in the seedling boxes. The nursery boxes were kept in an incubator at 25-30°C for 3 days for germination. The seedlings were later transferred to a greenhouse to control the growing environment. Transplanting of the seedlings was done after 22 days when the average leafage was 2.21 leaves.

2.2 Field Condition

Two plots measuring 100 m x 17 m and 100 m x 8.5 m were puddled with a tractor mounted rotary tiller and drained to maintain the desired water level for transplanting. The water depth was measured with a meter rule and the hardpan depth was measured with a rod from the soil surface. The puddled soil hardness was measured with a cone-plumb penetrometer dropped from a height of 1 m, and the soil hardness was measured with a cone-penetrometer with a 6 cm^2 cross-sectional area.

2.3 Planting Accuracy

A 6-row riding type (ISEKI 600) and a 6-row walking type (KUBOTA S600) rice transplanters were used to transplant rice seedlings on plots measuring 100 m x 17 m and 100 m x 8.5 m respectively. A 4-row walking type transplanter was used in the second half of the plot used for the 6-row walking transplanter. For comparison purposes, only data for the 6-row transplanters are reported in this study. The row space was measured for a row distance of 10 m and the readings averaged. The average hill space was measured for 100 consecutive hills within a row. The planting depth was measured for 20 hills as well as the number of plants per hill were also counted.

2.4 Total Missing Hills

Missing hills were checked for 100 hills in a row on each field. Buried hills were determined as for missing hills. A seedling was considered buried if the planting depth was about ½(plant height) + 2 cm and over (JICA, 1982). Seedlings with roots visible were considered as floating hills. Total missing hills was calculated as the sum of missing hills, buried hills and floating hills.

2.5 Machine Performance

Working speed was determined by recording the travelling time for a measured distance of 20 m. Slippage was calculated from the distances travelled for 6 different travelling times for 10 revolutions of the transplanter on a farm road and in a paddy field. The field capacity was determined as the transplanted area by machine per total time of work. The total time was the sum of actual transplanting time, feeding time, turning time, adjustment time and travelling time. The field efficiency was calculated as actual transplanting time per total time.

2.6 Economic Analysis

The following expressions by Tsujimoto (1990) were used for economic analysis of the transplanters:

$$OC_{hr} = \frac{FC_{yr}}{T} + VC_{hr} \quad (1)$$

$$OC_{ha} = \frac{FC_{yr}}{T} + \frac{VC_{hr}}{A} \quad (2)$$

Where, OC_{hr} and OC_{ha} are the operating cost per hour, and per hectare, respectively

VC_{hr} - Total variable cost per hour,

FC_{YR} - Yearly fixed cost,

T– Total operating hours, and

A - Field capacity

3.0 RESULTS AND DISCUSSIONS

3.1 Seedling Condition

The height of seedlings in the standards ranges from 10-15 cm whereas the experimental values ranged from 12–20.4 cm (Table 1). The corresponding leafages were 2.0–2.5 leaves and 2.0–2.2 leaves for the standards and experiment respectively. The dry weight of seedlings varied from 0.0107–0.0115 g, which was within the standard range of 0.0107–0.0115 g. The raising period during the experiment was 2 d more than stated in the standards. The conditions of seedlings are important because they have a great influence on the performance of the machine. For example, if very short seedlings and a field with very soft soil surface are used, transplanting accuracy will decrease because of the increased number of burried hills (JICA, 1982).

Item	Standards	Experiment			
	Range	Range	Mean	Standard Deviation	Coefficient of Variation
Plant height (cm)	10.0-15.0	12.0-20.4	20.43	2.28	11.16
Leafage (leaves)	2.0-2.5	2.0-2.2	2.21	0.25	11.31
Dry weight of seedling (mg)	10.0-15.0	10.7-11.5	11.08	0.36	3.25
Raising period (days)	15-20	22	-	-	-

3.2 Field Condition

Table 2 shows the results of field conditions compared with standard conditions. The range of depth of water in the fields for the riding- and walking-type transplanters were 0.4–2.5 cm and 1.2–4.5 cm respectively. The suitable water level for optimum performance for transplanting varies from 2 to 3 cm according to the Japanese national standards. Water level more than 3 cm usually results in strong waves while transplanting and can damage newly transplanted seedlings. Moreover, the marker for direction indication may be difficult for the operator to use, resulting in wider and narrower inter-row spacings. In terms of physical condition of soil, less water causes the soil to stick to the wheels of the transplanter during operation making depressions in which seedlings may be transplanted. Also, soil thrown out by the wheels damage already transplanted seedlings.

The lower values of the coneplumb penetration depths were within the range of values in the national standards but the higher values from the experiment were far greater than the upper value of 12 cm in the national standards. This implies that the puddled soils were softer than stated in the national standards. Such a condition can cause burial of transplanted seedlings. The hardpan depth in the field used for the riding-type transplanter was within the range of the national standards but the upper value for the field in which the walking type was use was higher than 15 cm. Such a condition can cause seedlings to be buried during transplanting. The respective hardpan hardness values were 325 and 278 kPa at 20 cm depth in the fields in which the riding and walking type transplanters were tested.

3.3 Planting accuracy

Table 3 shows the results of planting accuracy. Planting accuracy of a rice transplanter is judged by percentage of missing hills, variations in the number of plants per hill, planting depth, variation of space between rows and variation of distance between hills. The experimental results show that the percentage of total missing hills were 3 and 2% for the riding and walking-type respectively. Since these values were less than the 5% in the standards, it implies that both machines performed well.

The range of number of plants per hill is 3–5 in the standards, whereas the corresponding ranges for the riding and walking transplanters were 2–8 and 2–11 plants per hill respectively. This implies that adjusting transplanters during operation is important. Alternatively, thining of hills with more seedling can be carried out. The average planting depths of the riding- and walking-type transplanters were 3 cm (range of 2–4 cm) and 2.9 cm (range of 1.9 – 3.9 cm) respectively. The upper values for both ranges were about 1 cm more than the standard values. This could be due to the density of the seedlings in the seedling mat.

The row space values for the riding type ranged from 24 to 42 cm whereas the corresponding range for the walking type was 24–47 cm. The variations from 30 cm in the standards were due to slippage and the difficulty of identifying the lines made by the marker. The ranges of hill space were 12–30 cm and 14–32 cm for both riding and walking types respectively, as against 15 cm from the standards. Slippage was responsible for the 12 and 14 cm hill spacings instead of 15 cm designed spacings of the machines. The slippage of the riding- and walking-type transplanters in the respective fields were 8.72 and 8.08%. The hill spacings of 30 and 32 cm for riding- and walking-type transplanter respectively were due to missing hills.

3.4 Machine Performance

From Table 4, the results from the experiment shows that the average working speeds were 1.25 and 0.45 m/s for the riding and walking-type transplanters respectively. The corresponding field efficiencies were 47 and 48% for the riding and walking types respectively.

The field capacity value of 0.42 ha/h was higher in the case of the riding type as against 0.25 ha/h for the walking type. This implies that the riding type transplanter may be useful for large-scale farms in areas where labour shortage is a problem during the transplanting period. The fuel consumption of the riding type transplanter was 41.22% more than that obtained for the walking-type. The field capacity is needed for the execution of systematic transplanting operation and the determination of economic efficiency.

Figure 1 shows the various time for each machine activity. The planting time for riding- and walking-type transplanters were 46.9 and 47.8% respectively. The corresponding percentages for turning time for the transplanters were 12.6 and 13.1%. The feeding time of 23.4% for the riding-type was lower than 27.6% in the case of the walking-type. This was due to additional seedling mats loaded on trays mounted on the transplanter, to make it unnecessary for the operator to load the feeding unit without disembarking from the transplanter.

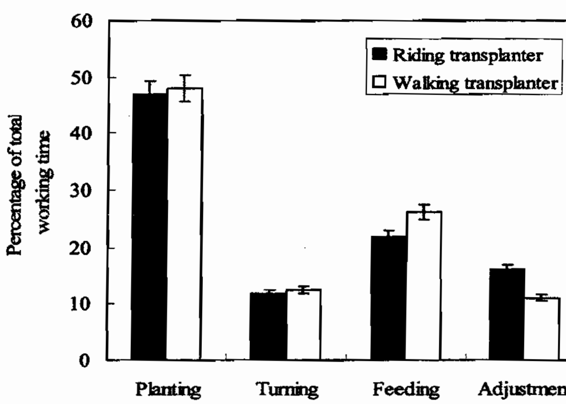

Fig. 1. Comparison of working time for transplanters.

For the walking-type, the operator had to move to the edge of the field to feed the transplanter. The adjustiment time was 17.1% for the riding-type transplanter compared with 13.9% for the walking-type. The field capacity and field efficiency of a transplanter can be improved if the feeding time of seedling mats can be reduced.

3.5 Economic Analysis

From Figure 2, the economic analysis show that as the yearly working hours increased the operating cost per hour decreased for both riding- and walking-type transplanters. The operating cost per hour was lower for the walking-type. Likewise, as the yearly working area increased the cost per hectare also decreased and, the values being lower for the walking-type (Figure 3). Figures 2 and 3 were found to be useful decision making tools in the selection and utilisation of transplanters.

Addo and Buhari (1994) reported in a study carried out on a commercial farm in Japan that the annual duration of use of a transplanter was 100 h compared to possible transplanting time of 80 h. Thus making the operating cost per hour lower than expected. Similarly, the cost per hectare for cultivating an area of 15.2 ha was more profitable than the calculated cost per hectare for a possible area of 12 ha.

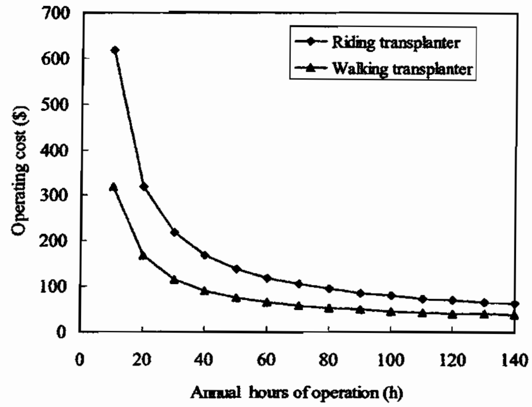

Figure 2. Cost per annual duration of operation.

4.0 CONCLUSIONS

The following conclusions were drawn from this study:

1. The depths of water from the standards is 2 to 3 cm whereas in the respective fields for the riding and walking transpanter, the values were 0.4 to 2.5 and 1.2–4.5.
2. The total missing hills were 3 and 2% for the riding and walking transplaters. These values were less than 5% in the standards.
3. The range of plants per hill in the stanards was 3–5, whereas the corresponding ranges for the riding and walking transplanters were 2–8 and 2 –11 respectively.
4. The range of planting depths of the riding and walking transplanters was 2 –4 cm and 1.9 – 3.9 cm respectively. The upper values of both ranges were about 1 cm more than the values in the standards.
5. The row space values for rising and riding transplanters ranged from 24 to 42 cm whereas the corresponding range for walking type was 24–47 cm compared to 30 cm in the standards. The ranges of hill space were 12–30 cm and 14–32 cm for riding and walking transplanters respectively, as against 15 cm recommended in the standards.
6. The riding transplanter was operated at average working speed of 1.25 m/s whereas the walking type was operated at 0.45 m/s. The field efficiencies were 47 and 48% for the riding and walking transplanters respectively. The respective riding and walking transplanters field capacity values were 0.42 ha/h and 0.25 ha/h.
7. The percentages for turning time for the riding and waliking transplanters were 12.6 and 13.1% respectively, whereas the feeding time of 23.4% for the riding-type was lower than 27.6% in the case of the walking-type. The adjustiment time was 17.1% for the riding-type transplanter compared with 13.9% for the walking-type.
8. The walking transplanter operated at lower costs per hour and per area than the riding type.

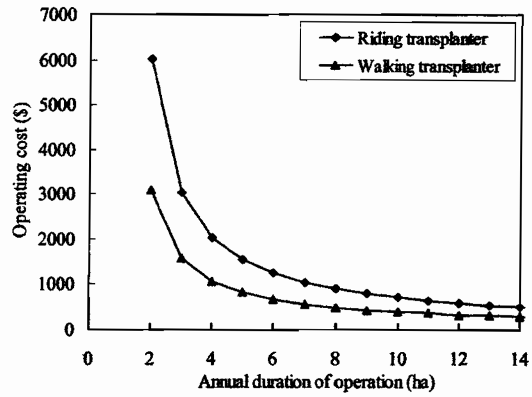

Figure 3. Cost per annual area of operation.

REFERENCES

Addo, A. and Buhari, I. O. (1994). Report on farm household practice in Ishikawa prefecture. In: *The Survey on Farm Household Practice in Japan.* Farm Mechanisation Section, Tsukuba International Agricultural Training Centre, Japan International Co-operation Agency.

Anonymous. 1982. Rice Transplanter. Field performance test manual no. 3. Rice Production Mechanisation Course, Tsukuba International Agricultural Training Centre, Japan International Co-operation Agency.

Bishop, C. and Morris, J. (1992). Agricultural mechanisation-strategy formulation. *Agricultural Engineer*, 124-127.

Inns, F. M. (1995). Selection, testing and evaluation of agricultural machiries and equipment. Theory. Agricultural Services Bulletin No. 115, FAO, Rome.

Johnson, I. M. (1985). Testing of farm machinery for agricultural development. Silso, UK. Overseas Division, National Institute of Agricultural Engineering. (Unpublished).

Smith, D. W., Sims, B. G. and O'Neill, D. H. (1994). Testing and evaluation of agricultural machinery and equipment: Principles and Practices. Agricultural Services Bulletin No. 110, FAO, Rome.

Tsujimoto, T. (1990). Farm mechanisation planning Vol. 1, 2 and 3. Farm Mechanisation Section, Tsukuba International Agricultural Training Centre, Japan International Co-operation Agency.

Table 2. Comparison of data for field conditions

Item	Standards	Riding Transplanter				Walking Transplanter			
	Range	Range	Mean	Standard Deviation	Coefficient of Variation (%)	Range	Mean	Standard Deviation	Coefficient of Variation (%)
Water depth (cm)	2.0-3.0	0.4-2.5	1.56	0.59	37.82	1.2-4.5	2.28	0.99	43.42
Coneplumb penetration depth (cm)	8.0-12.0	7.0-14.4	11.1	1.78	16.04	9.8-17.6	13.24	1.99	15.03
Hardpan depth (cm)	10.0-15.0	9.5-12.3	11.41	1.88	16.51	14.7-17.7	16.64	1.03	6.19
Hardpan hardness at 20cm (kPa)	-	334-360	352	64.73	19.9	268-288	278	68.75	24.73

Table 3. Comparison of data for planting accuracy

Item	Standards	Riding Transplanter				Walking Transplanter			
	Range	Range	Mean	Standard Deviation	Coefficient of Variation (%)	Range	Mean	Standard Deviation	Coefficient of Variation (%)
Missing hill (%)	<5	3	2.35	0.59	3	2	4.78	0.99	1.99
No. of plants per hill	3-5	2-8	4.82	1.78	32.57	2-11	5.25	2.13	40.57
Planting depth (cm)	2-3	2-4	2.89	1.88	20.76	1.0-3.9	2.68	0.47	17.53
Row space (cm)	30	24-42	29.67	64.73	8.17	24-47	30.25	3.94	13.03
Hill space (cm)	15	12.0-30.0	16.50	3.00	18.85	14-34	16.84	2.94	17.46