Performance of Rice-Transplanters as Evaluated by National Test

By Yoshiaki MORI

Testing Division, Institute of Agricultural Machinery

It is estimated that more than 700,000 rice-transplanters were on the farm at the end of 1974 in Japan. Reflecting such a rapid progress of mechanization, national test[1] of transplanters was initiated in early 1974. Performances[2] of rice-transplanters as evaluated by the national test are reported in this paper with some related discussions.

General description of structure

All the transplanters which have passed the national test are motor-driven machines of walking type to be used for so-called Tsuchi-tsuki-nae (seedlings with soil not washed away). They are classified as follows: Six of two-row transplanter, five of four-row transplanter, both to be used for seedling-mat, and two of two-row transplanter for special seedling-band, giving a total of 13.

Weight of these transplanters is 89–107 kg for two-row transplanters, and 154–179 kg for four-row transplanters, including weight of seedlings mounted on the machines.

Transplanters are consisted of engine, transmission, travelling device, feeding device for seedlings, planting device and operating device.

As the engine, four-cycle gasoline engines have been increasingly used, but two-cycle engines are still being used. Rated output is 1.6–2.5 PS for two-row type, and 2.0–2.5 PS for four-row type. Recoil-starting devices are used for both types as a starting system.

The transplanters are equipped with steel wheels and steel or plastic floats: most of the two-row transplanters have two wheels and one float, but one of them has one wheel and two floats, whereas all of the four-row type have two wheels and three floats. Floats, attached to the machine body by link mechanism, glide on soil surface, supporting a partial weight of the machine. Wheels are attached to the machine body by swing-arm which moves up and down, and carry the machine, supporting the rest of machine weight. According to the depth of hard pan the height of wheels can be adjusted. For this adjustment, a mechanical device was used, but recently hydraulic pump and hydraulic cylinder are mostly utilized, particularly with some of four-row transplanters automatic height control mechanism is adopted in order to increase adaptability to field conditions and to simplify operation.

For feeding seedling-mat, seedlings are placed in seedling-board made of plastic or aluminum plate. The board declines either forwards or rearwards, with an angle of 50°–60° at the lower end. Feeding of seedlings is made by lateral forwarding caused by reciprocating movement of the seedling-board itself (by use of solid cam), and downward or longitudinal forwarding by use of conveying claw or star-wheel equipped at the lower part of the seedling-board. Planting of seedlings is made by using planting fork which is operated by crank and link mechanism; the planting fork picks up a block of seedlings and plant it to field. Cam mechanism of different structures is used to grasp seedlings and release them in the soil.

For feeding seedling-band, an unique mechanism quite different from that of feeding seedling-mat is used: seedling-bands contained in nursery box (specially deviced for making seedling-bands) are conveyed in a longitudinal direction on seedling-board, and transferred on a conveyer belt for lateral feeding by use of a special device, and then cut into pieces and planted by planting forks.

Row spacing (spacing between planting forks) is 28, 30, 31, and 33 cm depending on different kinds of transplanter. Although the row spacing is not adjustable, distance between hills can generally be adjusted to 2–4 different levels. Nominal distance between hills ranges from 11 (minimum) to 20 cm (maximum). Theoretical planting density, calculated by taking these values of row spacing and hill spacing, is 16.3–27.9 hills/m^2.

Depth of planting is also adjustable to 3–4 levels. Number of plants per hill can be adjusted to 3–5, by changing the rate of seeding to the nursery box and size of seedling-band pieces picked up or cut by planting fork.

To protect planting device from overload, and to prevent the damage of planting fork, torque-limitter and ceiling device for planting fork are adopted respectively. Some of the transplanters are equipped with a marker to determine the row spacing between bouts, an indicator showing relative position of wheels and floats, device for lifting one wheel when planting alongside the dyke (two-row type), and spare seedling-board.

Walking speed is one forward speed for two-row type, and one forward and one reverse for four-row type.

Field performance

Major results of field test conducted on a 10 a (50×20 m) plot at normal field condition is shown in Table 1. Operation was started along a longer side of the plot and

Table 1. Results of field performance test

	2-row type	4-row type
Field condition	Soil type: Clay loam, Depth of water: 2.4 (1.9–3.9) cm, Penetration depth of dropped cone*1): 8.7 (7.9–9.3) cm, Vane torque*2): 2.2 (1.8–2.6) kg/cm, Depth of hard pan: 17.3 (16.4–18.2) cm	
Seedling condition	Variety used: Nihonbare, Plant height: 12–19 cm, Leaf number*3): 2.4–4.2 leaves	
Bout width (cm)	61.6 (58.8 –64.0)	122.3 (117.2 –132.3)
Forward speed (m/s)	0.63 (0.50– 0.70)	0.49 (0.43– 0.54)
Travel reduction (%)	10.8 (6.6 –14.1)	13.8 (11.4 – 15.7)
Time per 10 a (min/10a)	53.0 (44.0 –71.0)	36.7 (33.5 – 38.6)
Theoretical field capacity (a/h)	13.8 (10.8 –15.1)	21.7 (20.6 – 23.3)
Fffective field capacity (a/h)	11.4 (8.4 –13.1)	16.0 (15.2 – 17.7)
Field efficiency (%)	82.3 (77.8 –87.1)	73.8 (70.9 – 76.9)
Field machine index (%)	90.5 (87.5 –92.0)	88.1 (86.6 – 89.3)
Percentage of missing hills (%)	1.9 (0.7– 4.3)	
Percentage of missing two successive hills (%)	0.4 (0 – 1.5)	
Row spacing (cm)	30.2 (28.4–31.8)	
Coefficient of variation (%)	5.9 (3.5–10.0)	
Distance between hills (cm)	15.3 (13.2–17.2)	
Coefficient of variation (%)	16.5 (11.4–21.7)	
Depth of planting (cm)	2.6 (1.7– 3.6)	
Coefficient of variation (%)	28.2 (20.8–42.9)	

*1) The cone (base area: 10 cm^2, weight: 115 g) dropped from 100 cm height above field surface.

*2) The vane (1×6 cm) slowly turned at 6 cm depth in the soil.

*3) The primary incomplete leaf was not counted.

finalized with two bouts each on both headlands. Two persons were engaged: an operator and another one to take care of seedling feeding. Time used for distributing seedlings along the headlands was not included in time measurement.

Walking speed was 0.43–0.70 m/s: two-row transplanter run a little faster. Average time per turn was 8.7 sec for two-row type and 10.9 sec for four-row type: the latter required 1.25 times that of the former.

Travel reduction was calculated by using following formula:

$$S=\left(1-\frac{n_0 l}{l_0 n}\right)\times 100\ (\%) \cdots\cdots\cdots\cdots(1)$$

where

- l_0: Distance (m) of travel with n_0 revolution of wheel on the road.
- n: Number of revolution of wheel for a distance l (m) at the time of transplanting.

It was slightly higher with four-row type than two-row type, but as a whole lower than designed value (14–17%), and therefore distance between hills was apt to become wider.

Effective field capacity was 8.4 a/h (two-row type)–17.7 a/h (four-row type): in an average that of the latter was about 1.4 times that of the former.

Field efficiency (E_f), as defined by a formula (2)[3], was averaged to 82% with two-row type, and 74% with four-row type. Generally, reduction of the efficiency is associated with an increase of number of planting rows.

$$E_f=\frac{T_0}{T_0\left(\frac{100}{K}\right)+T_L}\ (\%) \cdots\cdots\cdots(2)$$

where

- T_0: Theoretical field time per 10 a (h/10 a) at theoretical field capacity.
- T_L: Non-productive time per 10 a (h/10 a).
- K: Percentage of bout width actually utilized=(actual bout width/theoretical bout width)×100(%).

T_L is a total of time required for turning, for feeding seedlings to transplanter, and for adjusting and other miscellaneous works, each occuping 9–13%, 4–12%, and 0–6% of total field time, respectively. Turning time showed highest percentage.

Generally, a tendency was observed that actual bout width became wider than theoretical value, with a few exceptions, and K value of formula (2) was 101 (96–107)%.

Filed machine index (F.M.I.) of formula (3)[4], that symbolizes influence of geometry of fields on capacitive performance of field machines is 91% with two-row type and 88% with four-row type. At a given area of field, the value is improved with longer rectangular field. Therefore, it is assumed that the value will be 95% and 94% respectively with a field plot of 100 × 10 m.

$$\text{F. M. I.}=\frac{T_p}{T_p+T_t}\times 100\ (\%)\cdots\cdots\cdots(3)$$

where

- T_p: Productive field time (min/10 a)
- T_t: Turning time (min/10 a)

Percentage of missing hills was 1.9 (0.7–4.3)%; lower than the standard (5%) allowed to pass the test. 54% of the missing hills were caused by mechanical disorder (planting fork worked without planting seedlings), 32% were due to floating hills, and 14% were due to buried hills (buried more than (plant height × 1/2 + 2) cm). Percentage of missing two successive hills was very low, only 0.4%.

Row spacing varies by movement of soil due to floats etc., with coefficient of variation of 3.5–10%. With two-row transplanter, one wheel and two floats type gave wider spacing than theoretical value, whereas two wheels and one float type gave narrower spacing. Deviation was very small with four-row type[2),5),6)]. As row spacing between bouts tends to become wider, being effected by the skill of operator, it gave a large coefficient of variation.

Distance between hills also varies due to travel reduction and movement of soil. Deviations from the designed value were rather great, being 104 (99–109)%, because travel reduction was smaller than designed value.

Coefficient of variation was 11.4–21.7%, i.e., about 2.5 times variation of row spacing.

Number of hills planted per m² was 21.5 (19.1–24.2). Deviation (D_N) to the designed value, calculated by using formula (4), was −4.1 (+1.4∼−13.9)%. Considerable decrease in number of hills from an expected value occurred with some transplanters, largely due to the travel reduction.

$$D_N=\left[\left(\frac{100-S_0}{100-S}\right)\left(\frac{100}{K}\right)-1\right]\times 100\ (\%) \quad \cdots(4)$$

where

S_0: Designed travel reduction (%)

S : Actual travel reduction (%)

Number of seedlings per hill was 5.0 (4.0–5.8), with coefficient of variation of 40 (32–51)%. Depth of planting was 2.6 (1.7–3.6) cm, with coefficient of variation of 28 (21–43)%.

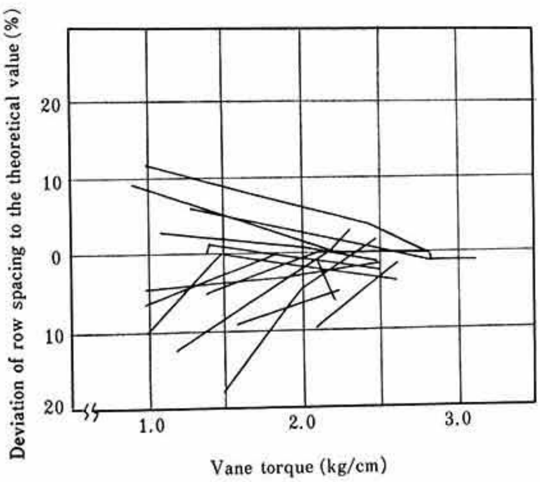

Fig. 1. Row spacing as effected by soil hardness (data of 20 machines)

In field with soft soil, planting depth apt to become too deep, resulting in an increased percentage of buried hills, and an increased variation of distance between hills. Deviation of row spacing to the designed value showed a tendency to converge to zero with an increase of soil hardness (Fig. 1). It was also observed that travel reduction increased with deeper hard pan and increasing soil hardness[2),5),6)].

Seedlings of 10–20 cm in height and 2.5–4 leaf stage can be used by these transplanters satisfactorily.

References

1) The national test code of the rice-transplanter to be used for seedlings with soil not washed away. Official Gazette issued on April 19 (1974) [In Japanese].

2) Institute of Agricultural Machinery: Test reports of rice-transplanters (13 machines) passed the national test. (1974) [In Japanese].

3) Bainer, R., Keppner, R. A. & Barger, E. L.: Principles of Farm Machinery. John Wiley and Sons, New York, 28 (1955).

4) Renoll, E. S.: A method for predicting field-machinery efficiency and capacity. *Transactions of the ASAE*, 13(14), 448–449 (1970).

5) Institute of Agricultural Machinery: Reports on test of rice-transplanters (7 machines). (1972) [In Japanese].

6) Institute of Agricultural Machinery: Reports on test of rice-transplanters (3 machines). (1973) [In Japanese].