SEMI-CRAWLER TRACTOR EFFECTIVENESS FOR LASER LEVELING

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Abstract
Field leveling of paddy fields in Japan is worsening because of the introduction of large block fields and paddy-upland rotation. Field leveling is increasing in importance to support crop cultivation. Therefore, we investigated the influence of fuel consumption and the effectiveness of laser leveling work in large paddy fields comparing full-crawler tractors and semi-crawlers. Laser leveling work conducted by a laser leveler mounted on a semi-crawler tractor can shorten the total work time by decreasing the amount of reverse work and reverse distance compared to a full-crawler tractor. In addition, a semi-crawler tractor can decrease fuel consumption by decreasing the reverse distance. To decrease the fuel consumption and working time, field conditions should be examined before leveling. Work plans must be made to take a short working distance.

Key words: semi-crawler tractor, laser leveling, work time, work distance, fuel consumption, paddy field.

INTRODUCTION

Field leveling of paddy fields in Japan is becoming worse because of the introduction of large block fields and paddy-upland rotation. Therefore, the importance of field leveling has been growing considering its influence on crop cultivation (SHINDO ET AL., 2014). Laser leveling machines attached to tractors have been introduced for field leveling in Japan (KIMURA ET AL., 1999). This work is usually done by a full-crawler type tractor with low ground pressure because it requires strong traction force. Although full-crawler type tractors have high engine power, their work accuracy of turning movement presents a few difficulties. In recent years, semi-crawler tractors with both good steering performance and traction force have been introduced to paddy fields in Japan. Therefore, we investigated the influence of fuel consumption and the effectiveness of laser leveling in large paddy fields to compare full-crawler tractors and semi-crawler tractors.

MATERIALS AND METHODS

1) Test location

We conducted tests at a farmer's paddy field of Akita city in Japan (No. 1 field), at a paddy field at the Akita Agricultural Experiment Station (No. 2 field), and at a farmer's paddy field of Daisen city in Japan (No. 3 field) during 2012–2013. Field profiles were 1 ha (200×50 m) at Akita city fields (Nos. 1, 2), 76 a (152×50 m), and 70 a (140×50 m) at Daisen city field (No. 3).

2) Machine components

We used semi-crawler tractor (HMT transmission, EG105, 77.2 kW; Yanmar Co. Ltd.). Additionally, we used a full-crawler tractor (HST transmission, CT1010, 74.2 kW; Yanmar Co. Ltd.), which had same engine as the semi-crawler tractor and a full-crawler tractor (HST transmission, MK-140S, 103 kW; Morooka Co. Ltd.). Furthermore, we used direct mount type laser levelers of two types (LL4000 – 4 m work width, LL5000 – 5 m work width; Sugano Farm Machinery Mfg. Co. Ltd.) (Fig. 1).

3) Work system of laser leveling

We ploughed the fields using a laser plough (12 inch, 8 bottoms LCPQY128H; Sugano Farm Machinery Mfg. Co. Ltd.) to a set depth of 11–13 cm before laser leveling. Then we performed leveling using a direct mount type laser leveler. The aiming difference of elevation was set to ± 2.5 cm.

Fig. 1. – Test tractors (Left: Semi-crawler Tractor (EG105), Center: Full-crawler Tractor A (CT1010), Right: Full-crawler Tractor B (MK-140))

Test and investigation contents

1) Test blocks

We had laser leveling work at each field at test area Nos. 1–3 using a semi-crawler tractor and a full-crawler tractor to obtain each work rate and field properties by tractors of different types. We designate the Semi-crawler tractor Block as the Sc block and the Full-crawler tractor block as the Fc block. Tab. 1 shows the settings of test blocks and field properties, tractor types, and work width of the laser leveler.

Tab. 1. – Test block components

Test area Nos.	Test Blocks	Tractor Types	Tractor Power kW	Work width of leveler m	Field profiles Long side m	Field profiles Short side m	Field profiles Area ha	Investigation day d-m-y
No.1	Sc	Semi-crawler	77.2	4	200	50	1	21-Apr-12
	Fc	Full-crawler B	103.0	5	200	50	1	20-Apr-12
No.2	Sc	Semi-crawler	77.2	4	200	50	1	24-Apr-13
	Fc	Full-crawler A	74.2	4	200	50	1	23-Apr-13
No.3	Sc	Semi-crawler	77.2	4	152	50	0.76	08-Oct-13
	Fc	Full-crawler A	74.2	4	140	50	0.70	07-Oct-13

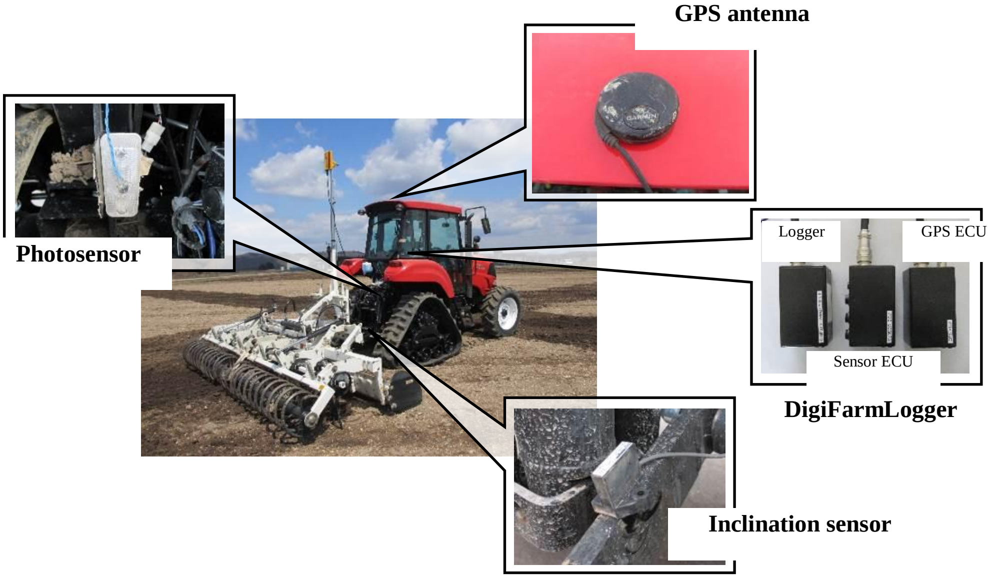

Fig. 2. – Semi-crawler tractor and DigiFarmLogger

2) Investigation contents

Working information of laser leveling was obtained using a farm work information data logger (DFL, DigiFarmLogger (OOMINE ET AL., 2011); Kimura kouyou kougei) attached on a tractor (Fig. 2). That data logger, which comprises a GPS antenna, an inclination sensor attached on a lower link and a photosensor attached on the back lamp, can record the work speed, coordinates, and up-down of the working device continuously. Therefore, we analyzed the work speed, forward-reverse operations and work performance using the data logger system. The tractor fuel consumption was measured using a fuel flow meter (DE-FL; Banzai Racing) attached on the tractor for each test field. We measured the degree of land leveling to divide 40 meshes (250 m^2 (25×10 m)) at No. 1–2 fields of 1 ha area, 30 meshes (253 m^2 (25.3×10 m) at Sc block, and 233 m^2 (23.3×10 m) at Fc block) at No. 3 test field. The paddy field level was measured using a laser surveying machine (LaserEye; Laserplane) at five points per mesh. The measuring points were 200 points at No. 1-2 fields, and were 150 points at the No. 3 field.

RESULTS AND DISCUSSION

(1) Degree of field leveling

Tab. 2 presents paddy field levels before and after leveling. The paddy field levels before leveling on No. 1 field were max 73.8 mm - min - 48.2 mm (σ=21.0) at the Sc block, and max 51.9 mm -- min -84.1 mm (σ=23.9) at the Fc block. Each test block had the same levels to have about 78% of ± 25 mm points. The paddy field levels after leveling on No. 1 field were max 16.4 mm -- min -18.6 mm (σ=6.6) at the Sc block, and max 13.4 -- min -20.7 mm (σ=6.9) at the Sc block. All measured points of both test blocks were less than ±25 mm. The paddy field level before leveling work on No. 2 field was max 31.2 - min -65.8 mm (σ=21.0) at the Sc block, and max 35.0 mm -- min -78.0 mm (σ=17.4) at the Fc block. Each test block had the same level to have about 85% of ± 25 mm points. The paddy field level after leveling work on the No. 2 field was max 24.5 mm -- min -44.5 mm (σ=13.2) at the Sc block, and max 23.2 mm -- min -39.8 mm (σ=12.6) at the Fc block. Both test blocks had more than 96% of ± 25 mm points. The paddy field level after leveling work on the No. 3 field was σ=10.4 at the Sc block, and σ=10.4 at the Fc block. The rate of ± 25 mm points was 84% at the Sc block, and 99% at the Fc block. Consequently, these test results show that No. 1 and 2 fields reached same degree of laser leveling.

Tab. 2. – Paddy field levels before and after laser leveling work

Test area Nos.	Test Blocks	Laser leveling	Measuring points	Max mm	Min mm	Median mm	σ	Level mm	Rate of point (%) > 25mm	< −25mm	−25～ 25mm
No.1	Sc	Before	200	73.8	−48.2	−0.7	21.0	122.0	11.5	10	78.5
		After	200	16.4	−18.6	−0.6	6.6	35.0	0	0	100
	Fc	Before	200	51.9	−84.1	4.4	23.9	136.0	8	14	78
		After	200	13.4	−20.7	−0.1	6.9	34.0	0	0	100
No.2	Sc	Before	200	31.2	−65.8	4.2	18.3	48.5	4.0	11.5	84.5
		After	200	24.5	−44.5	1.0	13.2	34.5	0.0	3.5	96.5
	Fc	Before	200	35.0	−78.0	2.0	17.4	56.5	4.5	8.5	87.0
		After	200	23.2	−39.8	1.7	12.6	31.5	0.0	4.0	96.0
No.3	Sc	Before	150	33.3	−70.7	1.3	19.0	52.0	6.7	8.7	84.7
		After	150	30.1	−37.9	0.1	17.1	34.0	6.0	10.0	84.0
	Fc	Before	150	48.1	−49.9	2.1	16.3	49.0	2.7	10.0	87.3
		After	150	23.2	−28.8	0.2	10.4	26.0	0.0	1.3	98.7

Paddy field levels was calculated an average value of measuring points as 0 level.
Laser leveling at No. 3: The Sc block of Daisen field could not be finished because of rain.

(2) Work time and work components

The work time and components of laser leveling are presented in Tab. 3 and Fig. 3. Work times were, respectively, 6.54 and 6.83 h/ha at the Sc block and Fc block on the No. 1 field. The semi-crawler tractor had shorter work time, in spite of the small work width of laser leveler and also lower engine power than the full-crawler tractor. Regarding work components, each tractor had the same total work time for advance work. However, the amount of reverse work of the Sc block was 194 times, which were much fewer than that of the Fc block. The amount of reverse work per total work time was also much less than that of the Fc block. The respective work times of the Sc and Fc blocks in No. 2 test field were 5.51 and 6.87 h/ha. The Sc block was shorter than the other blocks. Total work time of the advance work was equivalent at the Sc and Fc blocks, but the amount of reverse work of the Sc block was 189 times, which was much smaller than that of the Fc block. The amount of reverse work per total work time was also smaller than that of the Fc block. The amount of reverse work of Sc block in the No. 3 test field was also smaller than that of the Fc block, as well as other test fields. Amounts of reverse work per total work time were also small compared to the Fc block. Laser leveling of paddy field which had long side ridge over 200 m was showed that full-crawler tractor decreased work rate to increase rate of reverse and advance turn (TAKEUCHI ET AL., 2002). So, we got same results, too. These results demonstrate that a semi-crawler tractor has shorter work time by decreasing the amount of reverse work because of better steering performance than that of the full-crawler tractor.

Tab. 3. – Work time and work components

Test area Nos.	Test Blocks	Area	Total work time	Work components				Amount of reverse		Work speed		
				Advance work	Advance turn	Reverse	Stop and others			Ave.	Advance	Reverse
		ha	h	h	h	h	h	Times	Times/h	m/s	m/s	m/s
No.1	Sc	1	6.54	3.89	0.37	1.90	0.38	194	29.7	2.1	2.0	2.1
	Fc	1	6.83	3.95	0.34	2.02	0.52	296	43.3	2.0	1.9	2.4
No.2	Sc	1	5.51	3.05	0.21	1.21	1.03	189	34.3	1.2	1.3	0.9
	Fc	1	6.87	3.78	0.36	1.68	1.06	292	42.5	1.3	1.3	1.5
No.3	Sc	0.76	2.05	1.54	0.12	0.20	0.19	60	29.3	2.0	2.1	1.3
	Fc	0.70	6.36	3.34	0.35	2.03	0.64	304	47.8	1.6	1.5	1.7
	Fc*	0.70	2.05	1.22	0.12	0.56	0.16	95	46.4	1.6	1.5	1.7

Fc* indicates the data for only 2.05 hours from work start at test area NO.3.

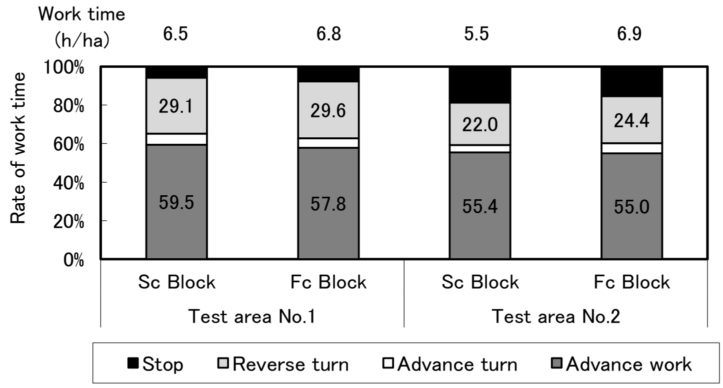

Fig. 3. – Work time components

(3) Total work distance and fuel consumption

The total work distance and components, and fuel consumption of laser leveling are presented in Tab. 4 and Fig. 4. Total work distances of Sc blocks in No. 1 and 2 test fields were, respectively, 45.5 and 19.0 km/ha, which were shorter than that of the Fc block. Each reverse work distance was shorter in these test fields and the amount of reverse work was smaller. Therefore, the rate of reverse work distance per total work distance was also smaller, which suggests that the semi-crawler tractor has shorter reverse distance when turning because it has a smaller turning radius. To increase work rate of laser leveling was shown that full-crawler tractor should have shorten reverse and advance turn time increase work speed to get in next operation, quickly (ONODERA ET AL., 2002). However, semi-crawler tractor could improve work rate to decrease reverse distance.

The fuel consumption of the Sc block in No. 1 and No. 2 test fields were 70.9 and 52.3 l/ha. These were smaller at 26% and 34% than in the Fc block. The fuel consumption per total work distance of No. 2 and No. 3 test fields in which full-crawler tractor and semi-crawler tractor with same type of engine were compared showed equivalent values. That is true because the semi-crawler tractor decreased fuel consumption by its shorter total work distance. To reduce the fuel consumption with laser leveling work, a semi-crawler tractor with a small turning radius can be useful to take short work distances. Setting a working plan for shorter total working distances is also effective.

Tab. 4. - Total working distance and fuel consumption

Test area Nos.	Test Blocks	Area	Work distances		Distance components Advance	Reverse		Fuel consumption			
		ha	km	km/ha	km	km	m/times	L	L/ha	L/h	L/km
No.1	Sc	1	45.5	45.5	30.8	14.7	75.8	70.9	70.9	10.9	1.6
	Fc	1	46.4	46.4	28.9	17.5	59.0	95.4	95.4	14.0	2.1
No.2	Sc	1	19.0	19.0	15.1	3.9	20.6	52.3	52.3	9.3	2.7
	Fc	1	27.8	27.8	19.0	8.8	30.2	79.6	79.6	11.1	2.9
No.3	Sc	0.76	13.6	17.9	12.7	0.9	15.5	24.8	32.6	12.1	1.8
	Fc	0.70	32.9	47.0	20.5	12.4	40.9	62.1	88.6	9.8	1.9
	Fc*	0.70	10.6	15.1	7.1	3.4	36.0	–	–	–	–

Fc* indicates the data for only 2.05 hours from work start at test area NO.3.

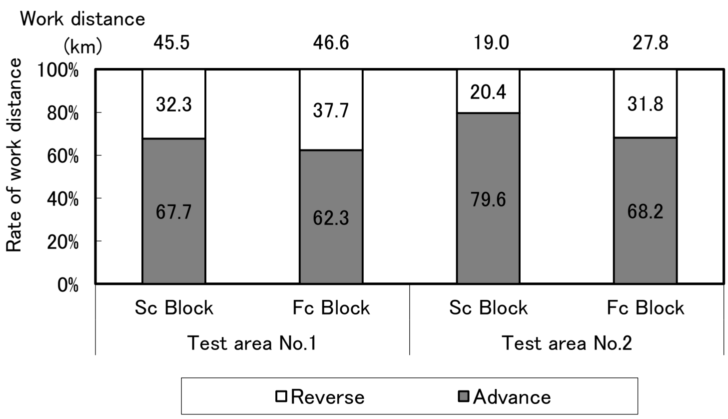

Fig. 4 – Rate of total working distance

CONCLUSIONS

Laser leveling using a laser leveler mounted on a semi-crawler tractor can reduce the total work time by decreasing the amount of reverse work and reverse distance compared to those of a full-crawler tractor. In addition, a semi-crawler tractor can decrease fuel consumption by decreasing the reverse distance. To decrease fuel consumption and the working time, field conditions should be examined before leveling. Working plans should be made to reduce working distances.

REFERENCES

1. KIMURA, S., IMAZONO, S., YAJI, Y.: Development of Labor Saving Operation Technique by Making Large Scale Paddy Field and Direct Seeding Cultivation of Rice in Tohoku District (Part 2). －Development of Technique for Automatic precision Laser-Levelling System－. , Japanese Journal of Farm Work Research 34(2), 1999: 113-121.
2. OOMINE, M., SUGIURA, R.: Development of Farm Working Data Recording System “Digi Farm Logger”. , Farming Mechanization 3116, 2011: 23-27.
3. SHINDO, H., SAITO, M., SASAKI, K.: Effect of Unevenness in a Paddy Field on the Plant Growth in Direct Seeding Cultivation of Rice., Tohoku Branch Report of The Japanese Society of Agricultural Machinery and Food Engineers 61, 2014: 11-14.
4. TAKEUSHI, H., SEKIGUCHI, K., KITAGAWA, I., TAKENAKA, H.: Repuirement for Field Leveling Using Lazer Leveler Machine on Direct Seeding Culture of Paddy Rice. , Bulletin of Hokkaido Pref. Agri. Exp. Stn. 83, 2002: 55-58.
5. ONODERA, T., TSURUTA, M., OSARI, H.: Leveling Rice Paddies Using a Laser Land Leveler When Tilling. , Trans of JAIDRE 219, 2002: 1-8.

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