ESTABLISHMENT OF A POWER FARMING SYSTEM IN AN UPLAND FIELD CONVERTED FROM PADDY FIELD– GREEN SOYBEAN GROWTH AND YIELDS IN AN UPLAND FIELD DURING THE FIRST YEAR AFTER CONVERSION FROM PADDY FIELD CULTIVATION

M. Sato, D. Tanabe, M. Katahira, M. Natsuga

Yamagata University, 1-23, Wakabamachi, Tsuruoka , Yamagata, 998-8555, Japan

Abstract

This study assessed power farming and a new cropping system for vegetable cultivation in an upland field converted from a paddy field with improved drainage. We investigated green soybean cultivation and examined soil physical properties, work capabilities of rotary tilling and ridge-making implements, and green soybean growth and yield. Field experiments were conducted at two small paddy fields: Blocks A (2.0 a) and B (2.0 a) at the Yamagata Field Science Center Takasaka Farm, Faculty of Agriculture, Yamagata University. Block A had an outer open ditch only. Block B had an outer open ditch with a mole drain. The green soybean cultivar "Yuagari-musume" was seeded on May 14, 2015. We investigated soil physical properties (saturated hydraulic conductivity, plastic limit, pF1.8 water content, and upland index), work accuracy (theoretical work rate, pulverization rate, and ridge shape), and green soybean growth and yield. The open ditch and mole drain in gray lowland soil improved soil physical properties somewhat. Both fields had high pulverization rates and good soil water contents at the plastic limit with up-cut rotary tilling. However, the mole drain might have adverse effects during low rain fall years because water from the converted rice fields might drain out.

Key words: paddy-upland rotation, open field vegetable, green soybean, soil physical properties, power farming system.

INTRODUCTION

Yamagata Prefecture in Japan is famous as a paddy rice production area. Furthermore, that paddy field area on the Sea of Japan side of the country has many fields that have heavy clay soil with poor drainage. Nevertheless, Yamagata Prefecture has cultivated upland field crops positively to make effective use of paddy fields. Upland fields converted from paddy fields of Yamagata Prefecture usually grow soybeans. However, many area farmers have demanded introduction of garden crop cultivation, which is highly profitable, to improve land productivity. Garden crop cultivation on upland fields converted from paddy fields should introduce a work system to improve soil physical properties including drainage, air conductivity, and the pulverization rate. A work system of paddy fields with poor drainage in Japan has usually made open ditches and under-drains. Recently, soy bean cultivation in Japan has been introducing rotary tilling and ridge-making work systems (HOSOKAWA, 2004) to mitigate wet injury. Efforts to promote garden crop cultivation on upland fields converted from paddy fields should consider adoption of cropping systems that are suited to rural areas (HOSOKAWA, 2002). This study was undertaken to assess a power farming and new cropping system for cultivating vegetables in an upland field converted from a paddy field with improved drainage. We used green soybean as the first year crop of an upland field converted from a paddy field. We investigated soil physical properties, work capabilities of rotary tilling, ridge-making implements, and green soybean growth and yields.

MATERIALS AND METHODS

Test fields and test blocks

Field experiments were conducted in two small paddy fields, Block A (2.0 a) and B (2.0 a), at Yamagata Field Science Center Takasaka Farm, Faculty of Agriculture, Yamagata University. Block A had an outer open ditch only. Block B had an outer open ditch with a mole drain (Fig. 1).

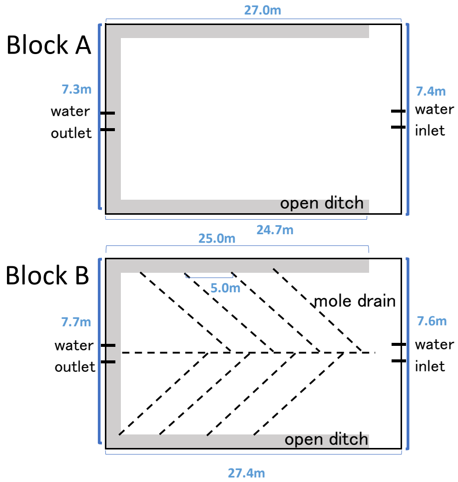

Fig. 1. – Open ditch and mole drain placement in test fields

Machine components

We made an open ditch using a tractor (AT-410, 30.9 kW; Iseki Co. Ltd.) with an attached screw auger type ditcher (OM-310; Matsuyama Co. Ltd.) on October 27, 2014. We made a mole drain at block B using a tractor (AT-410, 30.9 kW; Iseki Co. Ltd.) with an attached mole drainer (PD-110; Iseki Co. Ltd.) on November 8, 2014. Open ditches were set with ditch bottom width of 15–19 cm (S. D.:1.0 cm), ditch top width of 30–35 cm (S. D.:2.0 cm), and ditch depth of 26–38 cm (S. D.:3.5 cm). We constructed eight mole drains, four mole drains at one side, which were made for a 5 m interval from the drain side to the spout side. Each mole drain was connected to the open ditch. We sowed green soybeans using a rotary tilling and a ridge-making work system that comprised a tractor (KL31ZC, 22.8 kW; Kubota Corp.), up-cut rotary (APU1610H; Matsuyama Co. Ltd.), and sowing machine (AFRG-2S; Yazaki Co. Ltd.) (Fig. 2).

Fig. 2. – Schematic diagram of the rotary tilling and ridge-making work system

Cultivation outline

We used the medium-harvest-type green soybean cultivar "Yuagari-musume". Seed preparation was done using insecticide (Cruiser-MAXX; Syngenta). Basal fertilizing was 2 t/ 10 a for manure and 4 kg-N/ 10 a for chemical fertilizer (N-P_2O_5:K_2O=12:16:14) before sowing on all field areas. The sowing machine setting was 75 cm for inter-row space and 20 cm for hill space, sown in 6 rows with 2 seeds per hill on May 14, 2015.

Investigation contents

We investigated soil physical properties before drainage and before sowing, in addition to sowing work accuracy, growth, and yield of green soybeans. The investigated soil physical properties were saturated hydraulic conductivity ($cm.s^{-1}$), plastic limit water content, and the pF1.8 water content. These were investigated using the cylinder core (50 mm diameter, 51 mm height, 100 mL volume), which were extracted from soil (0–5 cm area) after removal of soil surface and organic matter. We obtained these data from three sampling points which had diagonal lines of a field, and equalized each datum. Therefore, we calculated the upland index according to the following formula (1).

Upland index = Plastic limit water content / pF1.8 water content (1)

The theoretical work rate was calculated using advanced work time for an average of three times. Sowing work accuracy was affected by the pulverization rate and ridge shape, which included the ridge bottom width, ridge top width, and ridge height. We investigated the germination rate to measure hill space on 4 rows, which were except outside rows each test blocks at 13 days after sowing. To assess the growth of green soybeans, we investigated the plant height, the number of nodes and branches, and the leaf color measured by SPAD 502 at three times, for four test points of 2.4 m length in each test block. We investigated yields for green soybeans at each test point.

RESULTS AND DISCUSSION

Soil physical properties of upland fields converted from paddy fields

Soil physical property of upland fields converted from paddy fields are presented in Tab. 1. Plastic limit water contents were 27.4% before drainage in October, 2014 and 30.6% after drainage in April, 2015 at test block A, and 28.8–30.8% at test block B. PF1.8 water contents were 0.38–0.41 in test block A, and 0.38–0.38 at test block B. Saturated hydraulic conductivity was -6, which was a multiplier only, after drainage for each test block. However, before sowing, they were -6 ‐ -7 in test block A and -4 ‐ -7 in test block B, which had little difference from test block A. Upland indexes were 0.71–0.74 in test block A, and 0.77–0.81 at test block B. These values were not significantly different for the respective test blocks and sampling times. An upland field converted from paddy fields was reported for the plastic limit water contents, non-plastic deformation of soil aggregate, with few deviations to improve drainage as the pF1.8 water content decreased. The paddy field of Takasaka, which was classified on gray lowland soil, had better drainage than the heavy clay paddy field. Therefore, that field had 0.71–0.77 at the upland indexes before drainage. The mole drain had little effect of decreasing the pF1.8 moisture contents.

Tab. 1. – Soil physical properties of the respective test blocks

Test blocks	Sampling season	Plastic limit water contents (%)	PF1.8 water contents	Saturated hydraulic conductivity (cm sec^{-1})	Upland indexes
A	2014/10	27.4	0.38	-6	0.71
	2015/4	30.6	0.41	-6～-7	0.74
B	2014/10	28.8	0.38	-6	0.77
	2015/4	30.8	0.38	-4～-7	0.81

Theoretical work rate and work accuracy

Theoretical work rates of tilling and ridging were, respectively, 0.70 h/ 10 a in test block A and 0.75 h/ 10 a in test block B. These values were not significantly different. Pulverization rates were 88.0% in test block A and 82.7% in test block B. These values were not significantly different (Tab. 2). Using up-cut rotary showed 80% over the pulverization rate at each test block of converted first year. Upland field of tilling and ridging showed ready pulverization such that it had about 0.3 at moisture content, which was near the plastic limit water content value at each test block.

Tab. 2. – Theoretical work rate and pulverization rate of tilling and ridging

Test blocks	Theoretical work rates (h 10a^{-1})	Pulverization rates (%)	Moisture content
A	0.70	88.0	0.30
B	0.75	82.7	0.29

Ridge shapes of test block A were 64.4 cm at the ridge bottom width, 33.7 cm at the ridge top width, and 18.5 cm at ridge height. Ridge shapes of test block B were 64.9 cm at the ridge bottom width, 36.0 cm at the ridge top width, and 17.8 cm at ridge height (Figs. 3 and 4). The ridge exhibited the same shape at each test; it was not significantly different. In addition, Hosokawa reported that up-cut rotary tilling and ridge-making work was 30–35 cm at the ridge top width and 15–20 cm at the ridge height (HOSOKAWA, 2004). Results showed good tilling and ridge-making work accuracy such that our study has the same ridge top width and height as those of Hosokawa's results.

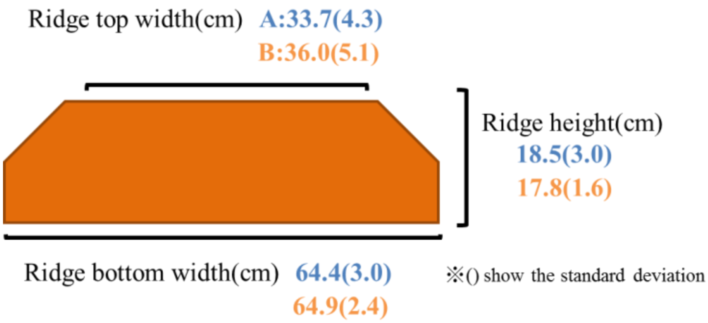

Fig. 3. – Schematic diagram showing ridge shapes

Fig. 4. – Field conditions after tilling and ridge-making work

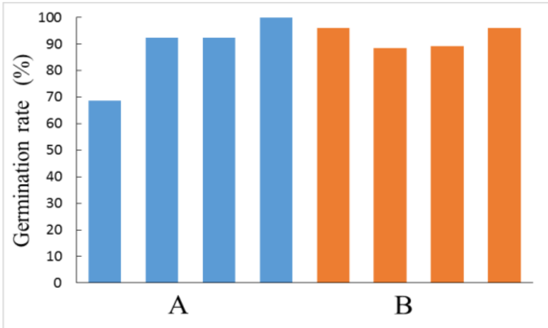

Fig. 5. – Germination rates of respective test blocks

Germination rate and growth of green soybean

The germination rates are shown in Fig. 5. Germination rates were 69–100% in test block A and 88–96% at test block B. Germination rates were 88% over at average values of each test block to attain a high pulverization rate and good water contents for green soy beans. Although test blocks A and B were found to have no significant difference, test block A might have some effect on the germination rate because of the difference of drainage to decrease the germination rate in a part of test block A.

Growth from the first stage to the flowering stage of green soybean is shown on Tab. 3. Plant heights were 10.9–26.8 cm in test block A and 11.9–29.6 cm in test block B. Numbers of nodes were 5.1–10.6 in test block A and 5.3–10.2 in test block B. Numbers of branches were 0–2.5 in test block A and 0.3–2.3 in test block B. Leaf colors were 30.0–31.7 in test block A and 31.7–32.9 in test block B. Growth of green soybean was not so much different for test fields, as shown in Fig. 6. However, test block B, which had the same plant height and number of nodes as test block A, had a longer interval length of nodes than test block A as well as increased plant density with much more leaf growth in the field. Consequently, test block B, which had a mole drain, supported better growth at the first stage than test block B.

Tab. 3. – Green soybean growth at respective test blocks

Day after seeding	Test blocks	Plant height (cm)	Number of nodes	Number of branches	Leaf color (SPAD)
33	A	10.9	5.1	0.0	30.0
	B	11.9	5.3	0.3	28.9
42	A	15.8	8.0	0.8	35.6
	B	16.7	7.9	1.2	36.8
53	A	26.8	10.6	2.5	31.7
	B	29.6	10.2	2.3	32.9

Green soybean yield

Yields of green soybean were 1173 kg/ 10 a in test block A and 747 kg/ 10 a in test block B (Tab. 4). Results demonstrated that drainage had no effect in this year that constituted a significant difference in any test block. This year had slight annual rainfall of 194 mm. Therefore, because of the low amount of rainfall, conditions of green soybean cultivation of this year were insufficient to test mitigation of wet damage introduced by tilling and ridge-making work system. To improve drainage, we reduced the amount of field water capacity, which decreased the green soybean yield in test block B, making it unable to accumulate the necessary water for vegetables.

Fig. 6. – Field conditions of harvest time (August 5, 2015: 80 days after sowing)

Tab. 4. – Yield and yield components

Test blocks	Planting density per square meter	Number of petiole per one	Number of pods per petiole	Pod weight per pod (g)	Rate of number of effective pods (%)	Yields (kg 10a^{-1})
A	13.3	23.4	2.8	2	68.2	1173.3
B	14.3	23.3	2.1	1.8	59.7	747.8

CONCLUSIONS

Although the upland field converted to a paddy field in its first year was able to show slightly decrease pF1.8 water content, that field showed small effects by which the upland index was over 0.8, with an increased range of saturated hydraulic conductivity. The tilling and ridge-making work system achieved good work accuracy with high pulverizing capability by up-cut rotary and good water contents at tilling time. In years with slight rainfall, the introduced mole drain and tilling and ride-making work system might induce water shortages at the flowering stage because of the decreased field water capacity amount.

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Corresponding author:

Mai Sato, Yamagata University, 1-23, Wakabamachi, Tsuruok , Yamagata, 998-8555, Japan