POWER FARMING SYSTEMS FOR WELSH ONION CULTIVATION

T. Otake[1], M. Sato[2], H. Shindo[3], M. Honjo[3], M. Saito[3], M. Katahira[2], S. Koide[4], M. Natsuga[2]

[1]*Fukushima Agricultural Technology Center, 116, Hiwada, Koriyama, Fukushima, Japan*
[2]*Yamagata University, 1-23, Wakabamachi, Tsuruoka, Yamagata, Japan*
[3] *Akita Agricultural Experiment Station, Yuwa, Akita, Japan*
[4]*Iwate University, 18-8, Ueda, Morioka, Iwate, Japan*

Abstract
Welsh onion cultivation places many demands on labor-saving technologies, which include low-cost cultivation by fertilizer reduction. We developed a chisel and two fertilizing openers for a fertilizer-applicator ditcher to improve the work rate and nitrogen absorption. This study investigated the influence of a softened ditch bottom and drill fertilizing positions on Welsh onion root growth when using drill fertilizing cultivation systems with a prototype fertilizer-applicator ditcher. Results show that prototype fertilizer-applicator ditcher increased root length and root length density and decreased soil hardness on the ditch bottom of the soil because of its chisel action. The drill-fertilized block showed a lower rate of root distribution to reach the fertilizer position quickly. Each test block processed with a chisel showed a higher rate of root distribution in deep locations in the ditch. However, in non-fertilized areas left by a fertilizer-opener, gas phase was present in large quantities in soil buried by a fertilizer-applicator ditcher.

Key words: welsh onion, fertilizer-applicator ditcher, root, drill fertilizing.

INTRODUCTION

Welsh onion cultivation places many demands on the labor-saving technologies of Japanese farmers, which include low-cost cultivation by fertilizer reduction. A fertilizer-applicator ditcher that can achieve low-cost cultivation is reported to have coverage that is 3.8–5.3 times greater than normal cultivation, achieving yields equal to those of normal cultivation by drill fertilizing. We developed a chisel and two fertilizing openers in a fertilizer-applicator ditcher to improve the work rate and nitrogen absorption. Fertilizing positions were 5 cm from the center horizontally of the seedling and 7 cm from the bottom of the ditch vertically. The total root length in 35% decreased fertilizing was longer than that of normal fertilizing in the germination experiment using no root seedlings. Nitrogen content in the territorial part for the drill fertilizing had lower reduction rate after transplanting and maintained higher until the middle growth stage than usual fertilizing. The plant height, branch height, stem diameter and dry matter mass were greater for the drill fertilizing than for the normal fertilizing through the middle growth stage. The drill fertilizing produced greater total mass and thicker stem diameter (before processing) than normal fertilizing. After processing, the drill fertilizing with 17–20% decreased fertilizing by had thicker stem diameter and higher total yields by 7–13% than the normal fertilizing (Shindo et al., 2015; Honjo et al., 2015). However, a new type of Welsh onion cultivation system that uses a prototype fertilizer-applicator ditcher did not take into account the influence of chisel and drill fertilizing positions by fertilizing openers on Welsh onion growth and yields. To improve Welsh onion root growth, this study therefore investigated the influence of a softened ditch bottom and drill fertilizing positions for producing Welsh onion drill fertilizing cultivation systems with a prototype fertilizer-applicator ditcher.

MATERIALS AND METHODS

1) Test location

We conducted tests in horticulture fields of the Akita Agricultural Experiment Station in Akita, Japan, and the Yamagata Field Science Center in Faculty of Agriculture, Yamagata University in Takasaka, Yamagata, Japan during 2014–2015. At the Akita field, we cultivated summer harvesting type one time and autumn–winter cultivation type two times. At the Takasaka fields, summer harvesting type was cultivated one time.

2) Machine components

This study examined open ditching and fertilizing using a tractor (Akita field: 25 kW, KL3450; Kubota Corp. / Takasaka field: 25 kW, KL34R; Kubota Corp.)

and a rotary machine with two fertilizer-applicator ditchers (prototype, R-47) set to 100 cm for the ditch space. The fertilizer-applicator ditcher included a chisel and two fertilizer openers in the body (Fig. 1). We transplanted Welsh onion seedlings to open ditches using a paper pot transplanter (HP-6; Nippon Beet Sugar Mfg. Co. Ltd.)(OTAKE ET AL., 2015).

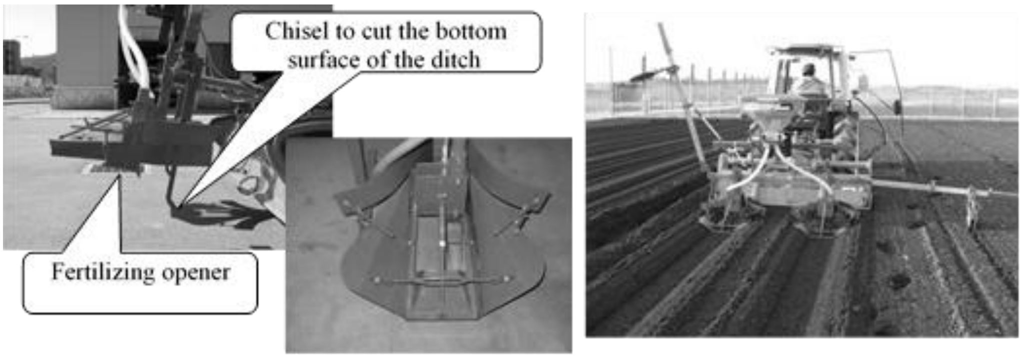

Fig. 1. – Outline of fertilizer-applicator ditcher

3) Cultivation outline

We used the Welsh onion cultivar "Natsu-Ougi Power" (Sakata Seed Co., Japan). The drill fertilizing of the summer harvest type was 75 kg/ 10 a, set 9.0 kg-N/ 10 a for nitrogen content, for the amount of basal fertilizer. Furthermore, topdressing was done four times with 125 kg / 10 a. Total amounts of fertilizer of these types were 200 kg / 10 a. Broadcast fertilizing of the summer harvesting type was 125 kg/10 a, set 15.0 kg-N/ 10 a for nitrogen content, for the amount of basal fertilizer. Topdressing was done four times with 125 kg / 10 a. The total amount of fertilizer of type was 250 kg /10 a. All fertilizing for autumn–winter harvesting types were 92 kg/10 a, set 23 kg-N/10 a for nitrogen content used controlled-release fertilizer, for the amount of basal fertilizer. Fertilizing positions were 5 cm from the seedling center horizontally and 3 cm from the ditch bottom vertically. The chisel was 15 cm from the ditch bottom vertically and seedling center. Test blocks of "Ar block were the following: One fertilizer opener, chisel, drill-fertilized type," "Br block: One fertilizer opener, no chisel, drill-fertilized type," "Cr block: Two fertilizer openers, chisel, drill-fertilized type," "Normally fertilized block: Two fertilizer openers, chisel, broadcast fertilized type" and "Non-fertilized block: Two fertilizer openers, chisel, non-fertilized type."

4) Test contents

Sampling times of Welsh onion roots were 21 days after transplanting for the 2014 summer harvest type, 17 days after transplanting for the 2014 autumn–winter harvest type, 30 days after transplanting at 2015 summer harvest type and 21 days after transplanting at 2015 autumn–winter harvest. We obtained Welsh onion roots and soil from each sampling block. The sampling areas that contained six seedlings were 21 cm wide, 15 cm long, and 14 cm deep. Therefore, we divided the sampling area to six sampling blocks that were 7 cm wide, 15 cm long, and 7 cm deep. They were three divisions for sampling area width and two divisions for the sampling area depth. We investigated the root length using a root scanner (Root Length Scanner; Comair). We calculated the root length density (mm/cm^3) and the rate of root length distribution (%) from those data. The following formulas were used to calculate the rate of root length distribution.

Rate of root length distribution (%) = (Total root length (mm) for a sampling block / Total root length (mm) for sampling area) × 100.

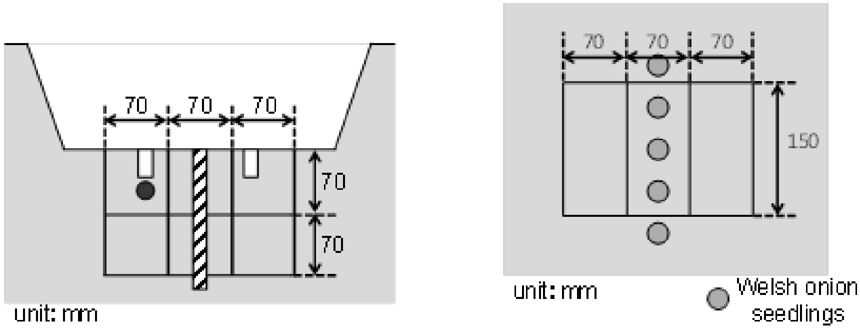

Fig. 2. – Sampling positions of Welsh onion root (left: sectional view; right, bird's-eye view)

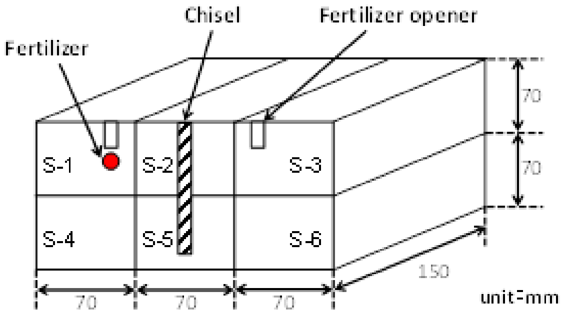

Fig. 3. – Sampling blocks

RESULTS AND DISCUSSION

(1) Root length and root length density.

The influence of total root length and root length density to be composed by cultivation and fertilizing types are shown in Fig. 4 and Fig. 5.

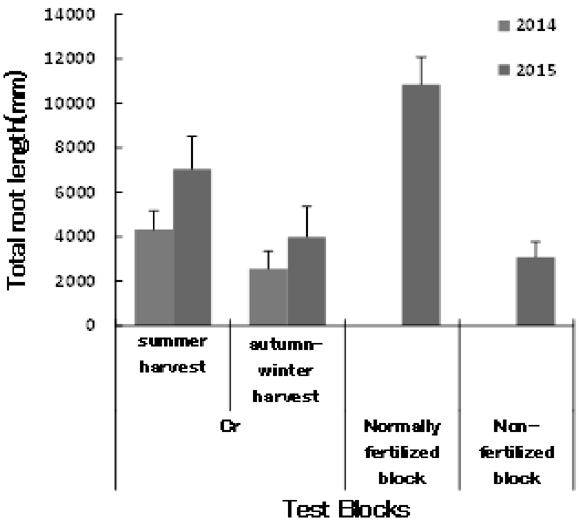

Fig. 4. – Influence of total root length by fertilizing and cultivation type

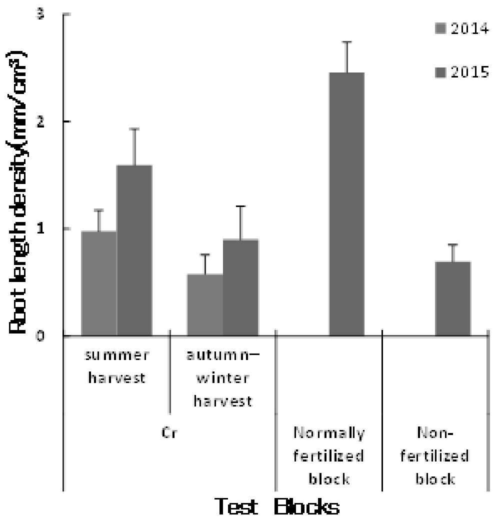

Fig. 5. – Influence of root length density by fertilization and cultivation type

Normally fertilized blocks exhibited the longest root length compared to Cr and non-fertilized blocks. Normally fertilized blocks displayed about 10,800 mm root length. That value was about twice that of other test blocks. Normally fertilized blocks exhibited the highest root length density compared to Cr and non-fertilized blocks. Test blocks that had greater distributions of fertilizer showed longer root length and higher root length density.

The influence of total root length and root length density to be composed by fertilizer openers and chisel is shown in Fig. 6 and Fig. 7.

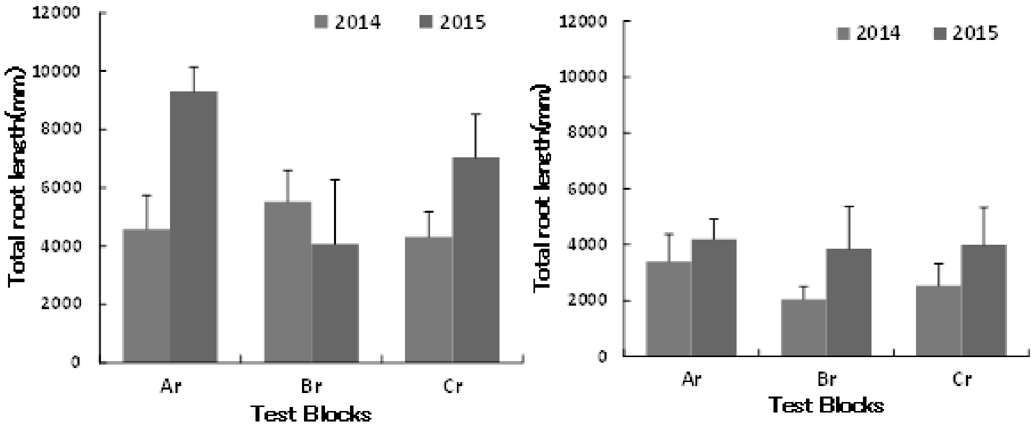

Fig. 6. – Fertilizer openers and chisel influence on total root length (left, summer harvest; right, autumn–winter harvest)

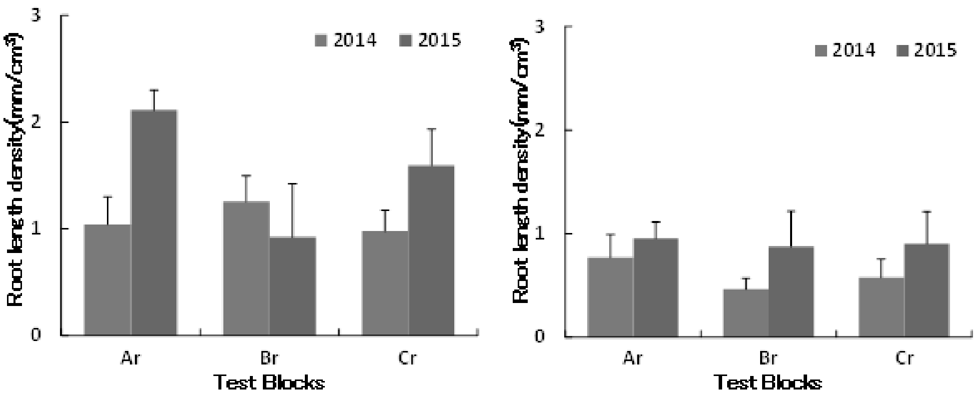

Fig. 7. – Fertilizer openers and chisel influence on root length density (left, summer harvest; right, autumn–winter harvest)

The Ar block showed greater total root length and root length density values than the Cr block did. The Br block showed the shortest total root length compared to the other blocks. The Br block exhibited the longest total root length compared to the other blocks for the summer harvest in 2014.

(2) Rate of root length distribution.

The cultivation and fertilization influence on the rate of root length distribution is shown in Fig. 8.

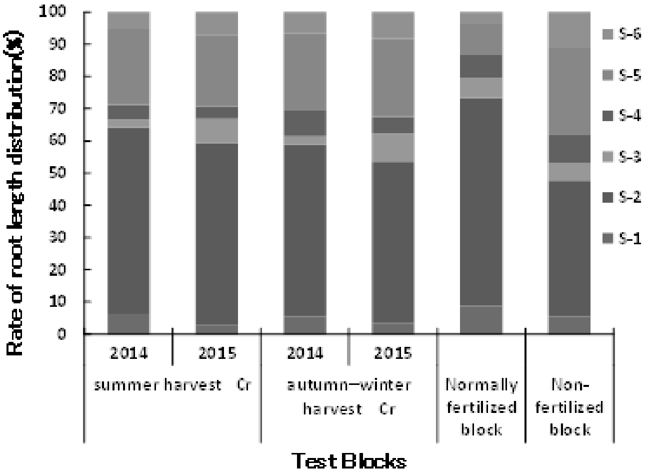

Fig. 8. – Influence of rate of root length distribution by cultivation and fertilization type

Sampling block S-2 of the transplant position exhibited the highest rate of root length distribution among all sampling blocks. The Cr block, which was drill-fertilized, had much higher rates of root distribution in sampling blocks S-5 and S-2, for which a chisel was used. Furthermore, other sampling blocks had high rates of root distribution in S-1 at 2014 and S-3 at 2015. In addition, drill-fertilized types had a two times higher rate of root distribution in sampling block S-5 than normally fertilized type. The normally fertilized type showed differences of root distribution for drill-fertilized and non-fertilized types to distribute in sampling blocks equally, except S-2. The non-fertilized type showed lower rates of root distribution in sampling blocks S-1 to S-3, which were shallow places of ditches, than those of other fertilizing types. That type showed higher rates of root distribution in sampling blocks S-4 to S-6, which were deep places of ditches, than those of other fertilizing types. However, that type showed a similar root distribution tendency for drill-fertilized type because the drill-fertilized type which had fertilizer in sampling block S-1 had short roots that quickly reached the fertilizer position. However, the drill-fertilized type grew roots into a non-fertilized area. Sampling block S-5 of drill-fertilized type had numerous growing roots in the chisel-softened soil. Normally fertilized types showed few if any roots for deep places of ditches to have fertilizer for a shallow place of the ditch.

Results showed the influence of the rate of root distribution to be composed by fertilizing openers and chisels, as presented in Fig. 9 and Fig. 10.

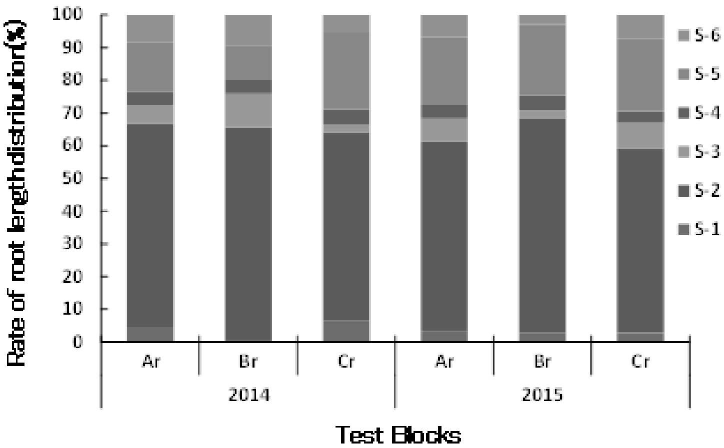

Fig. 9. – Fertilizer opener and chisel effects on the rate of root length distribution (summer harvest type)

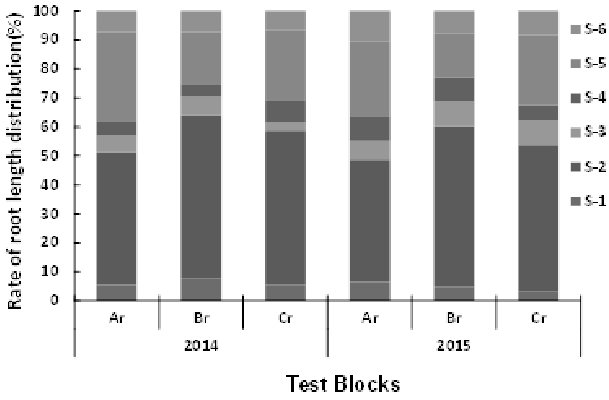

Fig. 10. – Fertilizer opener and chisel effects on the rate of root length distribution (autumn–winter harvest type)

Sampling block S-2 exhibited the highest rate of root distribution at all test blocks. Sampling block S-5 was the next highest. Sampling block S-5 of Ar and Cr blocks showed a higher rate of root distribution than Br block, except for the summer harvesting type in 2015. That difference was greater for the autumn–winter harvesting type. Sampling blocks S-1, S-2, and S-5 of shallow places in ditches made by fertilizer openers and chisels were higher rates of root distributions. Especially, block S-1, to which a fertilizer was applied, had many short roots; S-3 of the non-fertilized block showed many long roots. Using a chisel in the ditch encouraged many long roots penetrating to deep places in ditches to soften soil in the ditch. Sampling block S-3 of the Cr block, in which a fertilizing opener was used, showed greater differences in the amounts of roots than sampling block S-1 because S-3 had great differences of gas phase in the soil to have no fertilizer area.

CONCLUSIONS

The fertilizer-applicator ditcher developed for this research increased root length and root length density and decreased soil hardness because of a chisel used in the soil. The drill-fertilized block of Welsh onion plants showed a lower rate of root distribution because roots reached the fertilizer quickly. Each test block that had been prepared using a chisel in the ditch exhibited an increased rate of root distribution in deep parts of the ditch. However, non-fertilized areas prepared using a fertilizer-opener showed great differences in the root amounts because those areas showed large differences of gas phase in the buried soil as a result of the plate arrangement in the fertilizer-applicator ditcher.

REFERENCES

1. HONJO, M., SHINDO, H., OTAKE, T., SAITO, M., KATAHIRA, M., NATSUGA, M., YOSHIDA, Y., KANETA, Y.: Studies of Power Farming Systems of Welsh Onion Cultivation (Part 2) —Field test of new cropping type of Welsh onion using chain paper pots—ASABE, Paper Number: 152188880, 2015.
2. OTAKE, T., SHINDO, H., HONJO, M., SAITO, M., KATAHIRA, M., NATSUGA, M.: Studies of Power Farming Systems of Welsh Onion Cultivation (Part 1) —Optimization of chain pot connection—.ASABE, Paper Number: 152180882, 2015.
3. SHINDO, H., OTAKE, T., HONJO, M., SAITO, M., KATAHIRA, M., NATSUGA, M.: Studies of Power Farming Systems of Welsh Onion Cultivation (Part 3) —Growth promotion effects and fertilizer amount reduction with drill fertilizing—ASABE, Paper Number: 152188876, 2015.

Corresponding author:
Mitsuhiko Katahira, *Yamagata University, 1-23, Wakabamachi, Tsuruoka, Yamagata, Japan*