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Original Paper

Biomass Production and Weed Control in Some Winter Cover Crops in Hokuriku District

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北陸地域における秋播きカバークロップのバイオマス生産と雑草抑制

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Introduction

Cover crops have some benefits in soil management. In physical soil properties, cover cropping increased water-stable aggregates and water infiltration capacity of the soil (McVay *et al*, 1989). Cover crop residue mulch reduced soil temperature in mid- summer (Teasdale and Mohler, 1993 ; Araki and Ito, 1999) and reduced soil erosion through diminished rain-drop impact and surface runoff (Frye *et al*, 1985). Cover crops can be managed to enhance weed control by mowing them and leaving their residues on the ground surface as mulch (Teasdale, 1993 ; Teasdale and Daughtry, 1993 ; Creamer *et al*, 1997). Legume cover crops provide a substantial amount of N for the succeeding crop, and lead to increasing the crop yield and reducing the amount of N fertilization required for succeeding crops (Sainju and Singh, 1997 ; Abdul-Baki *et al*, 1997).

Winter cover crops use NO_3^- remaining in the soil after the fall harvest, thereby reducing the amount available for leaching (Waggar *et al*, 1998). Grasses have been widely used as non-legume cover crop to control NO_3^- leaching from the soil (Shipley *et al*, 1992 ; Kuo *et al*, 1996 ; Sainju and Singh, 1997). Non-legume cover crops, especially rye and annual ryegrass, effectively remove NO_3^- from the soil and lower its concentration in the soil leachate compared to a control without a cover crop (Kessavalou and Walter, 1999).

It is necessary to produce a large amount of above-ground biomass in cover crops to provide such effects as mentioned above. The growth habits of cover crops were affected by climate. Promising cover crops were shown in each re-

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gion and state in the USA (Sustainable Agriculture Network, 1998). However, a database on the growth characteristics of cover crops has not yet been established in Japan. In the present paper, for the introduction of winter cover crops into summer crop production in Hokuriku district, biomass production in spring in some grass and legume cover crops was measured and weed control effects of their residue mulch was observed.

Materials and methods

The experiment was conducted at Muramatsu Station, Field Center for Sustainable Agriculture and Forestry, Faculty of Agriculture, Niigata University in 1999 and 2000. Muramatsu Station has volcanic ash soil (SiC) and is located in a snow cover region where fields are covered with snow for about 2 months in ordinary year, from January to February. Field operations were shown in Table 1.

1. Experiment in 1999

1) Sowing of cover crops

Four grasses (wheat, barley, rye and bristle oat) and 3 legumes (hairy vetch, HV ; common vetch, CV ; crimson clover, CC) shown in Table 3 were used in the present study. Before sowing of these cover crops, chemical fertilizer (N 8 kg/10 a, P_2O_5 8 kg/10 a, K_2O 8 kg/10 a) were supplied to the soil and test fields were rotary tilled. On October 28, 1998, seeds of cover crops were drill-sown in test fields, 20 cm distance between lines, and compacted by roller. The plot area was 6 m^2 (2 m×3 m) and the experiment was conducted with 2 replications. Chemical fertilizer was added to the bare fields same as cover crop field in 1998 and the bare fields were rotary-tilled in spring for control.

Table 1　Field operation in 1999 and 2000

Operation	1999	2000
Sowing cover crops	Oct. 28, 1998	Oct. 12, 1999
Top dressing of fertilizer to grass cover crops	—	Apr. 16
Measuring AGB	June 9	May 19
Mowing cover crops	June 9	May 21
Transplanting lettuce	June 10	May 25
Growth and DW of weed	every 2 weeks	June 20, July 23
Lettuce harvest	July 26	July 19

AGB : Above-ground biomass.

2) Above-ground biomass (AGB), N content and C/N ratio in cover crops

Cover crops and weeds were collected from 2 sites (0.25 m^2/site) in each plot on June 9, 1999. Collected cover crops and weeds were dried in an oven at 70℃ for 48 hours and measured as dry weight (DW) of the above-ground biomass (AGB). Dried cover crops were macerated and filtrated by stainless steel mesh with Φ0.25 mm grid. N content and C/N ratio in the filtrated sample were measured with CN corder (MT 700, Yanaco Co., Ltd).

3) Weed emergence and growth in cover crop residue mulch fields

On June 9, 1999, cover crops were mowed by bush cutter at the base of each plant and cover crop residues were spread for organic mulch. On the same day, the bare field was rotary-tilled for control. Weed emergence and weed growth were investigated in cover crop residue mulch field and bare field for 8 weeks after mowing the cover crops and rotary-tillage in a bare field.

Dry weight of weeds emerged during every two weeks were measured at a designated site (0.5 m^2 ; 1 m×0.5 m) in each plot for the investigation of weed emergence. On the other hand, the dry weight of emerged weeds was measured at 2 different sites (0.25 m^2/site, 0.5 m×0.5 m) in each plot for evaluating weed growth at 2 (June 24), 4 (July 8), 6 (July 24) and 8 (August 5) weeks after mowing of the cover crops and rotary-tillage in a bare field.

4) Growth of lettuce in cover crop residue mulch field

For the evaluation of crop growth in cover crop residue mulch field, lettuce (*Lactuca sativa* L. 'Okayama saradana') was grown in the test field because lettuce grows rapidly and can be harvest within 2 months after transplanting. Ten seedlings of 31-days-old lettuce grown in a plastic tray with 128 holes were transplanted by hand in the cover crop residue mulch field and bare field on June 10. The distance between lines and plants were 30 cm and 20 cm, respectively. Insecticide (o, s-dimethyl-N-acetylphosphor-amidothioate) was applied, 2 g/plant, on June 29, and no herbicide was applied during the examination. Lettuce was harvested on July 26. Five lettuce plants with average growth in each plot were collected, dried at 80℃ for 24 hours and measured their dry weight.

2. Experiment in 2000

1) Sowing of cover crops

The same four grasses (wheat, barley, rye, bristle oat) as in 1999, 3 legumes (hairy vetch, HV ; milk vetch, MV ; crimson clover, CC) and 1 Brassica (rape) were used as shown in Table 3. These cover crops were drill-sown in the same manner as in 1999, except for no chemical fertilizer application before sowing of cover crops.

The plot area was 6 m^2 (2 m×3 m) and 3 replications were conducted. In the bare field without cover crops, one half was no-tilled during the experiment and the other half was tilled just before the transplanting of lettuce.

2) AGB of cover crops, weed control and lettuce growth

AGB of cover crops and weeds was investigated on May 19. Cover crops were mowed on May 21, 2000, for subsequent production of summer crop and cover crop residue mulch was formed in the same manner as in 1999, and lettuce ('Okayama saradana') seedlings were transplanted in the cover crop residue mulch field on May 25. The ground-cover by the cover crop residues was evaluated by quadrate method, using 1 m^2 frame with 25 small cells (0.04 m^2 ; 0.2 m×0.2 m) in each plot. Covering ratio in each cell was classified into 5 levels (0, 25, 50, 75, 100%) by visual observation on June 29 and July 28. Average ratio of 25 small cells was calculated as covering ratio in each plot. DW of weed in the 2 site (0.25 m^2) in each plot was measured on June 20 and July 23, 2000. DW of lettuce was measured on July 19 by same manner as 1999.

3) Statistical analysis

Analysis of variance was performed for each factor, and Fisher's least significant difference (LSD) was used for mean separation.

Results

1. Air temperature and snow cover in winter, 1999 and 2000

Air temperature reduced below than 10℃ from late November (Table 2) and cover crops stopped growing. It began to increase from early March in 1999, however it did from late March in 2000.

The period of snow cover in 1999 examination was 2 months, January and February, and snow fallen in March was immediately melted. On the other hand, the period of snow cover in 2000 was longer than that in 1999. Snow cover was observed from middle December in 1999 and covered snow was melted in early January temporarily, however snow cover was formed again and continued from middle January to

Table 2 Air temperature, snow fall and snow cover from Novemver to April at Muramatsu Station, Niigata University, in 1999 and 2000

Month		1998-1999			1999-2000		
		Air temp. (℃)	Snow fall (cm)	Max snow cover (cm)	Air temp. (℃)	Snow fall (cm)	Max snow cover (cm)
November	Early	14.0	0	0	11.7	0	0
	Midle	10.5	0	0	10.6	0	0
	Late	6.7	0	0	8.6	0	0
December	Early	5.5	0	0	6.7	0	0
	Midle	6.9	0	0	2.0	30	18
	Late	4.9	1	1	2.4	34	40
January	Early	1.1	91	45	5.2	0	0
	Midle	2.5	8	31	4.0	1	1
	Late	3.0	71	28	0.0	44	24
February	Early	1.7	92	54	1.7	17	19
	Midle	2.5	34	36	0.7	21	11
	Late	2.6	42	36	−0.5	48	24
March	Early	5.4	0	0	2.5	22	14
	Midle	8.6	10	10	3.7	10	12
	Late	5.9	8	6	5.6	7	4
April	Early	8.5	0	0	9.5	0	0
	Midle	13.9	0	0	10.1	0	0
	Late	13.0	0	0	12.5	0	0

middle March. In 2000, air temperature was lower than 1999 and snow-melting delayed to March 25.

2. AGB of cover crops and weed emergence at mowing

At mowing of cover crops on June 7, 1999, heading had already occurred in all grass cover crops, and grains of barley and wheat matured. In all legume cover crops, flowering had occurred and seeds were formed. In 1999, larger AGB was recognized in rye and HV, 646 kg and 591 kg per 10 a, respectively, compared with other cover crops (Table 3). In other grasses, AGB was 495.9 kg and 481.4 kg per 10 a in wheat and bristle oat, respectively. In other legumes, AGB was 484.8 kg and 339.3 kg per 10 a in CV and CC respectively. Weed emergence was suppressed in HV and CC because their stems and leaves covered the ground surface effectively. A few weeds (49.9 kg/10 a) emerged in rye owing to its large AGB. DW of weeds was near or more than 100 kg/10 a in other cover crops.

The residue mulch was formed by mowing cover crops. However, mature seeds were spread on ground surface and new seedlings emerged in the CC field. Also, new seedlings were germinated from their panicles in barley and wheat, and new shoots (suckers) were elongated from stubbles in the rye mulch field.

In 2000, cover crops were mowed on May 19, 18 days earlier than in 1999 examination. In grass cover crops, heading occurred same as in 1999 ; however, seeds were not matured. AGB of rye and bristle oat showed a higher value compared to wheat and barley. In particular, AGB of rye was 1,151 kg/10 a and suppressed weed emergence. Legume cover crops did not reach the flowering stage at mowing. In MV field, because few plants survived after the snow melting in the field, and the AGB of MV was very small, 14 g/10 a, the tested fields were covered with weeds later and the examination could not be continued. In HV, the AGB was small, 167 kg/10 a, and weeds grew vigorously in 2000. In rape, flowering was already finished at mowing, and hard flower stalks remained in the tested field where they disturbed lettuce planting.

3. N content and C/N ratio of cover crops

There were differences in C/N ratio and N content between grass and legume cover crops (Table 4). C/N ratio of grasses was 23–27 and that of legumes was 11–12. N content showed 1.7–2.1% in grass and 4.1–4.3% in legume. N-biomass in dry matter was 6–12 kg/10 a in grass, against 14 kg/10 a in crimson clover, 20.7 kg/10 a in CV and 24.7 kg/10 a in HV.

4. Covering ratio of cover crop residue mulch on ground surface

Plant residue of all cover crops decomposed on the ground surface. A difference in the visual covering ratio was recognized among cover

Table 3　Above ground biomass (ABG) of grass and legume cover crops and weed DW in 1999 and 2000

Cover crops	Latin name	Cultivar[z]	Seeding density (kg/10 a)	June 9, 1999		May 19, 2000	
				Cover crop (kg/10 a)	Weed (kg/10 a)	Cover crop (kg/10 a)	Weed (kg/10 a)
Wheat	*Triticum aestivum* L.	mulchmugi	5	495.9 b[y]	139.8 ab	217.7 d	166.9 b
Barley	*Hordeum vulgare* L.	Nozomi nijo	5	348.3 c	112.4 ab	392.5 c	240.5 a
Rye	*Secale scereale* L.	Aogari rye	5	646.1 a	49.9 bc	1151.5 a	50.7 c
Bristle oat	*Avena strigosa* S.	New oats	5	481.4 b	101.5 ab	873.1 b	48.6 c
Hairy vetch (HV)	*Vicia villosa* R.		5	591.0 a	0 c	167.3 d	74.8 c
Common vetch (CV)	*Vicia sativa* L.		5	484.8 b	95.9 ab	—	—
Milk vetch (MV)	*Astragalus sinicus*		5	—	—	14.0 e	94.5 c
Crimson clover (CC)	*Trifolium incarnatum* L.		5	339.3 c	11.9 a	361.1 c	40.3 c
Rape	*Brassica napus* L.		3	—	—	356.8 c	61.0 c

[z] These species and cultivars were obtained from Kaneko Seeds Co. Ltd.
[y] Values within columns followed by same letter are not significantly different according to LSD (P＝0.05).

crop residue mulch fields on June 29, 40 days after mowing in 2000 (Table 5). On July 28, 70 days after mowing, covering ratio was significantly high in rye and bristle oat, 99% and 93%, respectively. It was reduced to 56.3% and 67.7% in wheat and barley residue mulch. In legume cover crops, it was shown 39.5% and 56.3% in HV and CC.

5. Emergence and growth of weed in cover crop residue mulch field

The main weeds that emerged in test fields were common chickweed (*Stellaria media* V.), southern crabgrass (*Digitaria cirialis* K.), common lambsquarters (*Chenopodium album* L.), tufted knotweed (*Persicaria longiseta* K.), and common purslane (*Potulaca oleracea* L.). Common chickweed emerged mainly until 4 weeks after mowing, and southern crabgrass continued to emerge until 8 weeks.

In 1999, weed emergence in the cover crop residue mulch fields was larger than in the tilled field until 4 weeks after mowing (Table 6). However, this tendency reversed after 4 weeks, and the weed emergence in the cover crop residue mulch fields became smaller than that in the tilled field. Weed emergence in HV residue mulch fields was lowest during the observation for 8 weeks and emerged weed DW was 0.2–1.6 kg/10 a every two weeks in 1999.

Weed growth in the tilled field was very small until 4 weeks, 0.8–1.2 kg/10 a, and increased after 4 weeks. Weed DW in cover crop residue mulch field also increased after 4 weeks, however, there was a difference in weed DW among the cover crops (Table 7). The largest DW of weed, 239.2 kg/10 a, was recognized in CV residue mulch 8 weeks after mowing. Weed DW in HV residue mulch was small until 6 weeks, 17.6 kg/10 a ; however, it increased to 104 kg/10 a at 8 weeks, larger than that in the tilled fields. Weed growth in the other cover crop residue mulch fields was statistically the same as in the tilled field at 8 weeks.

In 2000, large DW of weed was shown in legume mulch fields on July 23, about 8 weeks after mowing (338.1 kg/10 a in HV and 246.4 kg/10 a in CC), and these were larger than in bare (no till) fields (Table 8). Weed DW in grass resi-

Table 4 C/N ratio and N content in cover crops used in 1999

Cover crops	C/N	N Content	
		(%/DW)	(kg/10 a)
Wheat	27.1 a[z]	1.7 b	8.5 de
Barley	27.1 a	1.7 b	5.9 e
Rye	26.1 a	1.9 b	12.3 c
Bristle oat	23.3 b	2.1 b	10.1 cd
Hairy vetch (HV)	11.4 c	4.2 a	24.7 a
Common vetch (CV)	11.0 c	4.3 a	20.8 b
Crimson clover (CC)	11.8 c	4.1 a	13.9 c

[z] Values within columns followed by same letter are not significantly different according to LSD (P=0.05).

Table 5 Time course of change in covering ratio by cover crop residues from visual observation, 2000

Cover crops	Covering ratio (%)		
	June 2	June 29	July 28
Wheat	89.0 ab[z]	66.0 c	56.3 c
Barley	99.3 a	79.7 b	67.7 b
Rye	100.0 a	99.3 a	99.0 a
Bristle oat	99.3 a	98.7 a	93.0 a
Hairy vetch (HV)	96.0 a	65.0 c	39.5 d
Milk vetch (MV)	—	—	—
Crimson clover (CC)	93.7 a	73.0 b	56.3 c
Rape	83.0 b	61.3 c	45.7 d

[z] Values within columns followed by same letter are not significantly different according to LSD (P=0.05).

Table 6 Time course of change in weed emergence in cover crop residue mulch fields every 2 weeks after mowing, 1999

Cover crops	Dry weight of weeds emerged (kg/10 a)			
	Weeks after mowing			
	0–2 W	2–4 W	4–6 W	6–8 W
Wheat	9.2 ab[z]	1.2 ab	1.6 c	0.4 bc
Barley	12.4 a	1.4 a	2.8 ab	0.6 b
Rye	4.4 bc	0.6 b	1.4 c	0.4 bc
Bristle oat	8.4 ab	1.0 ab	3.2 a	0.6 b
Hairy vetch (HV)	1.2 c	0.2 b	1.6 bc	0.6 b
Common vetch (CV)	4.8 bc	0.4 b	4.2 a	0.4 bc
Crimson clover (CC)	7.2 ab	1.4 a	0.6 c	0.2 c
Bare (Till)	1.2 c	0.4 b	3.6 a	2.6 a

[z] Values within columns followed by same letter are not significantly different according to LSD (P=0.05).

Table 7　Weed growth in cover crop residue mulch fields in 1999

Cover crops	Dry weight of weeds emerged (kg/10 a)			
	Weeks after mowing (Date measured)			
	2 W (June 24)	4 W (July 8)	6 W (July 24)	8 W (Aug. 5)
Wheat	9.2 ab[z]	10.4 bc	22.4 cd	66.0 c
Barley	12.4 a	16.8 ab	38.8 b	85.6 c
Rye	4.4 bc	3.6 c	25.2 bc	53.6 c
Bristle oat	8.4 ab	16.4 ab	36.0 bc	58.8 c
Hairy vetch (HV)	1.2 c	20.4 ab	17.6 d	104.0 b
Common vetch (CV)	4.8 bc	27.2 a	86.8 a	239.2 a
Crimson clover (CC)	7.2 ab	10.4 bc	10.8 d	65.6 c
Bare (Till)	1.2 c	0.8 d	28.8 bc	77.2 c

[z] Values within columns followed by same letter are not significantly different according to LSD (P=0.05).

Table 8　Weed growth in cover crop residue mulch fields in 2000

Cover crops	Dry weight of weed (kg/10 a)	
	June 20	July 23
Wheat	3.5 cd[z]	104.7 cd
Barley	5.6 cd	135.0 cd
Rye	1.1 d	72.4 de
Bristle Oat	0.4 d	47.9 ef
Hairy vetch (HV)	11.8 b	338.1 a
Milk vetch (MV)	—	—
Crimson clover (CC)	12.1 b	246.4 b
Rape	8.6 bc	73.6 de
Bare (No-till)	33.1 a	137.7 c
Bare (Till)	0.4 d	34.7 f

[z] Values within columns followed by same letter are not significantly different according to LSD (P=0.05).

due mulch fields was the same or smaller than in bare (no till) fields.

6. Growth of lettuce

Percentage of dry matter in lettuce obtained in the present examination was 6.4% in average. Larger DW (5.5–5.6 g) of lettuce was significantly observed in HV and CV residue mulch fields in 1999 (Table 9). Lettuce grew with living mulch, seedlings in wheat, barley and CC on the ground surface, and with suckering plants from stubble in rye. Lettuce DW in these cover crop residue mulch (0.8–2.0 g) was smaller than that in tilled fields.

Table 9　Dry weight of lettuce produced in cover crop residue mulch fields, 1999 and 2000

Cover crops	Dry weight (g/plant)	
	1999	2000
Wheat	1.5 bc[z]	2.2 cd
Barley	1.8 bc	1.6 cd
Rye	1.2 bc	2.4 bc
Bristle oat	2.0 bc	5.0 a
Hairy vetch (HV)	5.5 a	4.5 a
Common vetch (CV)	5.6 a	—
Crimson clover (CC)	0.8 c	3.0 bc
Rape	—	0.5 d
Bare (No-till)	—	0.6 d
Bare (Till)	2.7 b	3.8 ab

[z] Values within columns followed by same letter are not significantly different according to LSD (P=0.05).

In 2000, large DW of lettuce plant was shown in bristle oat (5.0 g) and HV (4.5 g). DW of lettuce in other cover crop residue mulch fields was larger than that in no-till+bare field (0.6 g), but smaller than till+bare field (3.8 g).

Discussion

1. Growth of cover crop and residue mulch formation

AGB is important for showing benefits in crop production in cover cropping. Large biomass of grass cover crops are contributed weed control and straw mulch effect. AGB for cover crop-use were reported, 330–1100 kg/10 a in grasses and 250–600 kg/10 a in legumes, (Sustainable Agriculture Network, 2001). In Japan, AGB was measured for whole crop silage production in barley, rye and bristle oat. Dry matter yield of barley and rye for forage crop (harvest in next June) was 1,200–1,300 kg/10 a in barley and about 1,000 kg/10 a in rye in snowy district, Hokuriku, when sown from late September and early October and these were reduced when sown in middle and late in October (Kobayashi *et al.*, 1989). In the present examination, a large amount of AGB was shown in rye, however AGB of other grasses was lower than previous reports as a whole. Lower AGB was caused by late sowing and no top-dressing in spring in 1999 examination and early mowing in 2000 examination. Though cover crops are generally cultivated in extensive, it is important to sow appropriate time and secure the growing period for obtaining a large amount of AGB.

As to AGB production in Genus *Avena,* DW more than 1000 kg/10 a was obtained in middle and late maturity varieties of *A. sativum* sown in November in Chiba prefecture, no snow region (Hosoya *et al*., 1998). However, Survival rate was less than 5% after snow melting in northern part of Hyogo Prefecture where snow cover continues more than 60 days (Noda *et al*., 1986). Bristle oat, *A. strigosa* S., used in the present examination was wild species in Genus *Avena,* and was recognized as antagonistic green manure plant for the control root-knot nematodes (Shiraishi *et al*., 1998 ; Yamada *et al*., 2000). This species is able to overwinter in autumn-sowing and is a promising species for obtaining a certain degree of AGB in spring in Genus *Avena*.

The nitrogen content of HV reached 24 kg/10 a and its supply of much N to soil is expected as legume winter cover crops provide substantial amounts of nitrogen to succeeding crops (Peoples *et al*, 1995 ; Sainju and Singh, 1997 ; Kuo *et al*, 1996 ; Vigil and Kissel, 1991). Probably 150–200 kg-N/ha will be supplied to the soil in HV judging from previous reports (Decker et al, 1994 ; Ranells and Wagger, 1996). A low C/N ratio, near 11, was recognized in all legume cover crops used in the present examination. Wagger (1989) reported that 50% of nitrogen of HV was mineralized in the incubation at 30℃ for 16 weeks. The role of rapidly avaibale N fertilizer was expected in HV according to a previous report (Smith and Sharpley, 1993). CV also showed a large AGB (484.8 kg/10 a) in 1999. Though HV residue covered the ground surface completely, non-covered areas remained in the CV residue mulch field. AGB in CC was smaller than those of HV and CV in 1999 ; however, similar AGB was obtained between 1999 and 2000 in CC.

HV is supposed to be a promising legume cover crop from large amount of AGB in 1999, however, it has serious problem in overwinter ability. Vetch snow blight was reported (Iida, 1964) and Tsuji (2002) pointed out that HV did not suit in snow cover region. Differences in the growth of HV were recognized between 1999 and 2000. The experimental location, Muramatsu Station at Niigata University, is a snow cover region, and the field was covered with snow from January to February in ordinary year. Survival of HV plants under snow cover is not stable. Snow cover in 2000 began earlier and the period of snow cover was longer than ordinary year. Such snow cover condition caused to reduce HV-survival in spring. The establishment of a cultivation technique for a higher survival ratio of HV sown in autumn under snow cover is needed for the cover cropping system.

Mowing time is very important for cover crop residue mulch formation. There is a difference in maturing time between HV and grasses. HV planted in autumn begins to grow from April again, flowering occurs in mid and late May and vigorous growth stops after flowering. Mowing of HV should be performed in mid-May for summer crop production. Rye matures early in July, and wheat and barley do late in June in the Hokuriku district. If rye and HV are mix-planted and mowed in mid-May, the suckering problem will occur in rye, as observed in the present study. It is necessary to suppress the suckering of rye by herbicide treatment and so on when it has been mix-planted. A mix-planting of wheat or barley and HV, can be mowed late in May for summer crop production. Living mulch was formed by seed germination on the ground surface after mowing wheat, barley and crimson clover, and they should be mowed earlier for dead mulch formation.

2. Weed control and lettuce growth

In general, weed control effect is closely concerned with the maintenance of plant residues on the ground surface. For 2 weeks after mowing, weed emergence in cover crop residue mulch field was larger than in the tilled field even with plant residue. This phenomenon is caused by holding soil water near the ground surface in cover crop residue mulch, thus enhancing weed emergence.

When a field was covered with HV residue, only a few weeds emerged. However, the emerged weeds grew vigorously because of HV residue mulch effects such as N supply, retention of soil water (Sainju and Singh, 1997 ; Unger and Wiese, 1979), and the stability of soil temperature (Teasdale and Mohler, 1993). Teasdale (1993) reported HV was effective for herbicide reduction in early periods, and this conclusion agrees with the present result.

Lettuce growth was accelerated in HV and CV residue mulch, and DW of lettuce was twice of that in the tilled field for control in 1999. N supply from plant residue and weed control until middle in July accounted for large DW of lettuce in HV and CV residue mulch. In 2000, a little higher yield was obtained in bristle oat and HV residue mulch field. Higher yield of lettuce in 2000 was contributed to the weed control during lettuce growth in bristle oat mulch and promotion of early growth of lettuce by N supply in HV residue mulch. In CC living mulch, competition occurred between CC and lettuce and lettuce did not reach higher yield.

Non-legume cover crops reduced NO_3^- leaching more than legumes. Especially rye has the capacity to prevent NO_3^- pollution in underground water because it reportedly absorbed NO_3^- in the deep soil layer, 30–90 cm in depth (Gu *et al*, 2004). Sainju *et al* (1998) recognized that root distribution was important in soil N cycling, and Sainju and Singh (1997) pointed out the importance of cover crops comprised of legumes and non-legumes for achieving both objectives, N supply and preventing NO_3^- leaching. The establishment of mix-cropping between grass and HV will be desired in the future.

From the observation in 1999 and 2000, HV and rye will be promising winter cover crops in the Hokuriku district because of the large AGB production. There are some problems for cropping system with these cover crops. It is necessary to establish cropping techniques so that seedlings can overwinter in HV and suckering will be suppressed when rye is mowed in spring.

Summary

For the purpose of introduction cover crops into summer crop production in the Hokuriku district, grass (wheat, barley, rye and bristle oat), legume (hairy vetch, HV ; common vetch, CV ; milk vetch, MV ; crimson clover, CC) and Brassica (rape) cover crops were sown in October of 1998 and 1999, and above-ground biomass (AGB) in the following spring and weed control effect were observed at the University Farm of Niigata University. A large amount of AGB (646 kg・DW and 591 kg・DW per 10 a in rye and in HV, respectively) was provided as organic matter to the field. In particular, nitrogen content of HV was 4.2% (DW) and approximately 24 kg/10 a organic N was supplied to the field grown HV. After mowing, although HV residue covered the ground surface completely, ground surface cover by residue of other cover crops was insufficient. Suckering occurred from the stubble of rye, and living mulch was formed by seed germination on the ground surface in wheat, barley and CC. These cover crops should be mowed earlier for residue mulch formation. There was little difference in AGB between 1999 and 2000 ; however, HV-AGB obtained in 2000 was reduced compared to that in 1999 because of long period of snow cover in 2000. Emergence and growth of weed in the grass residue mulch were smaller or the same compared with the tilled field for control. In the HV residue mulch field, weed emergence was smaller but final weed DW was larger than the tilled field and grass mulch fields. DW of lettuce grown in HV, CV and bristle oat

mulch was larger than those in tilled or other mulch fields. From these observations, HV and rye will be promising cover crops in the Hokuriku district because of the large AGB production. However, it is necessary to establish cropping techniques so that seedlings can overwinter in the snow cover region in HV and suckering will be suppressed after mowing in rye.

Key Words

Cover crops, Above-ground biomass, Plant residue mulch, Weed control, Hokuriku district (snow cover region)

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摘要

北陸地域においてカバークロップを導入した生産体系を確立するために，1998 年と 1999 年の秋季にイネ科（コムギ，オオムギ，野生エンバク，ライムギ），マメ科（ヘアリーベッチ，コモンベッチ，クリムソンクローバ）およびアブラナ科（レープ）のカバークロップを播種し，翌年春季のバイオマス生産と雑草抑制およびカバークロップ残渣マルチ圃場での作物生産について調査した．

1999 年の刈り倒し時の地上部バイオマス（AGB）はライムギとヘアリーベッチで大きく，それぞれ 10 a あたり 646 kg と 591 kg の乾物重を示し，多量の有機物が圃場に投入された．特に，ヘアリーベッチは乾物あたり 4.2% の窒素を含有し，24 kg/10 a の有機態窒素が圃場に投入された．ヘアリーベッチは地表面を完全に被覆したが，コモンベッチの被覆は不完全であった．刈り倒し後に，ライムギの切り株から萌芽が見られた．また，コムギ，オオムギおよびクリムソンクローバ圃場では落下した子実からの発芽によりリビングマルチが形成された．これらのカバークロップのデッドマルチを形成するには早期の刈り倒しが必要であった．イネ科カバークロップの AGB は 1999 年と 2000

年で大きな差異はなかったが，2000年のヘアリーベッチのAGBは積雪期間が長かったために，1999年のそれより著しく減少した．

両年ともカバークロップ残渣マルチはマメ科よりイネ科で維持され，特にライムギと野生エンバクで残存率が高かった．カバークロップ残渣マルチ圃場での雑草の発生量と生長は，対照とした耕起圃場より少ないか同程度であった．ヘアリーベッチマルチ圃場では雑草発生量は少なかったが，発生した雑草の乾物重は耕起圃場より大きくなった．レタスの乾物重はヘアリーベッチとコモンベッチまたは野生エンバクのマルチ圃場で耕起圃場より有意に大きくなった．

以上の観察から北陸地域において秋播きマメ科カバークロップとしてはヘアリーベッチがバイオマス生産と夏作物の生長促進から有望であるが，雑草抑制効果はマルチ形成後約1.5か月間であった．積雪下で越冬しても春季の生存率を向上させる技術が必要である．イネ科ではライムギがバイオマス生産と雑草抑制の視点から有望であるが，切り株からの萌芽を抑制する技術が必要であった．

キーワード

カバークロップ，地上部バイオマス，植物残渣マルチ，雑草抑制，北陸地域（積雪地域）