Weed Control by Applying Organic Materials in Cultivation Practices of Rice

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Abstract *: It was confirmed in 26 paddy fields from central to eastern parts of Japan that there exist paddy soils where the growth of rice was promoted while the weeds were controlled by cultivation practices. The advantages of rice or the weed (M. vaginalis) and the damages by pest (L. oryzophilus) changed with alternations of the application depth of rice straw with different decomposing extent and quantity. The adverse effects from the raw materials were overcome by mulching organic materials on the soil surface with positive effects of promoting activities of earthworms, improving soil structure and depressing weeds. Moreover, applications of organic materials confirmed the growth promotion from weed control by earthworms and activities of photosynthetic bacteria. A long-term experiment conducted in the fields with M. vaginalis as the main weed and without any pesticide applications also confirmed that there exist paddy soils where rice growth is promoted and weeds are depressed. It is possible to adjust the soil nitrogen concentration and earthworm population by applying organic materials and changing puddling methods in addition to soil water management for weed control.*

Introduction

In rice production, the beneficial organisms such as photosynthetic bacteria, earthworms even the unwanted weeds, pests and pathogens, all are related with the recycling of organic matter. It is expected that pests can be depressed by increasing the tolerance and competition of rice under appropriate conditions favorable for the decomposition and utilization of organic matter in the soil. Such paddy fields are expected in nature farming rice production systems where rice growth is promoted and weeds are depressed (Iwaishi et al., 1998). Actually, undecomposed organic matter accumulates on the soil surface, decomposes during rice growth period and increases the organic matter in the root layer. This is why we say that there should exist paddy fields where weeds are not easy to propagate due to the cultivation practices. It is possible to control weeds by returning the rice crop residuals to the paddy fields and producing a condition for the residuals to be decomposed, as practiced by some farmers. In this research, the actual conditions of nature farming practitioners and the good experiences were analyzed and possibility of the practical use as a technique is discussed. Several experiments were conducted in the paddy fields with weeds thriving to search a practical technique.

Methodology, Results and Discussion

Experimental Relationship between Weeds and Soil Inorganic Nitrogen

Examinations were conducted in 1997with 26 paddy fields of nature farming rice producers in Eastern Japan. The soils involved are 9 Glay, 5 Glay Lowland, and 12 Andosol. The fields or examination were selected with similar geographic and management conditions with different weeds thrift. The average grain yield was 4.81 ± 0.82 t ha^{-1}, the working time for manual and mechanic weeding was 186 h ha^{-1}, but in fields with weeds controled by cultivation practices the weeding time was 0-20 h ha^{-1} and decreased to lower than 23%. The average weeds cover degree during weeding season (Wc) was 27 %, the rice cover degree (Rc) was 24%, and the correlation coefficient with weeding time was +0.774 for Wc and -0.550 for Rc and +0.885 for Wc/Rc. Soil samples were taken 2 to 5 cm beneath the soil surface 5 to 19 days after transplanting and the moist soil samples were used to determine the inorganic nitrogen. The inorganic nitrogen was negatively correlated in a logarithm manner to Wc degree or Rc degree, and to weed-rice cover degree ratio (Wc/Rc) in an exponential manner with an equation of $y=-6.00\ln(x)+25.4$ when Wc/Rc was taken as x and the inorganic nitrogen in the soil as y. The threshold point for dominance change between weeds and rice can be detected from the yield point of the curve by the correlation equation, for example, the soil inorganic nitrogen is 25.4mg kg^{-1} when Wc/Rc=1.This suggests that soil inorganic nitrogen concentration after transplanting determines whether weeds or rice are dominant in the field.

Effect of The Application Depth of Rice Straw on Weeds Population

The experiment was done in paddy fields with Andosol in Nagano. "Koshihikari" rice was grown with treatments shown in Table 1.

Table 1. Experimental Treatments (Rice Straw): One Plot with $20m^2$, Half Weeded 3 times by Hand, 2^4=16 plots

Level	A Depth	B Rate	C Decomposing	D Block
1	10 cm mix	200 kg/10a	Raw	Outer (half of ridge)
2	0 cm surface	400 kg/10a	Silage	inner

Table 2. Details of Cultivation (Application rate per10 a)

M/D	Tillage Previously 11/10	Tillage 4/11	Puddling 5/3	Leveling 5/15	Transplanting 5/18	Dressing 7/10
Organic Rate	Rice straw incorp. 200kg	Molasses 50L Fish meal 30kg	Oil sludge 90 kg	In corp Rice Straw	Surface appl. Rice straw	Bokashi 60 kg

Bokashi is organic fertilizer fermented anaerobically for 20 days using organic materials such as rice bran, oil mill sludge and fish processing by-product with a ratio of 8:3:3 (w/v), a total nitrogen concentration of 5% and a water content of 30%.

The soil inorganic nitrogen concentration was high but the cover degree was depressed in the treatment with rice straw mixed. At the same time, the damage by *L. oryzophilus* increased, *M. vaginalis* became dominant and both weed cover degree, Wc, and Wc/Rc increased (Table 3). The effects of application rate and decomposing extent on weeds depression were lower than that of application depth. Although the weeds cover degree was also depressed as the application rate increased, it did not affect Wc/Rc but increased rice screenings. In case the decomposed rice straw (silage) was mixed to application, the weeds mass increased in ripening stage (Table 4). As mentioned above, *M. vaginalis* was strongly affected by undecomposed rice straw and the weed depression was affected by the application depth of the rice straw. Moreover, the rice straw compost decomposed in middle way increased the biomass of weeds or rice if the compost was incorporated into the soil. Soil surface applications of compost were more effective.

Thrift of weeds is the indication whether or not rice plant residuals are returned to the soil, which can be used to estimate suitability of the cultivation practices. As reported by Tsuno and Oda (1985), sesame leaf scorch resulting from nitrogen deficiency is due to organic matter decomposition and the consequent root damage. When organic materials are adopted as the main fertilizer, not only the germination of *E. crusgalli* but also growth of rice is inhibited by the undecomposed raw rice residuals. Raw residuals cause fast reduction of soil in emerging conditions and at the same time the growth of rice is depressed and germination of weeds such as *M. vaginalis* is enhanced to a dominant level. Growth of weeds is limited by soil status, which also changes the parasite of *L. oryzophillus* to the rice. The improvement of soil conditions that are suitable for rice growth also shows effect of depressing weeds and pest. It is well known that rice blast and plant hoppers are caused by excessive nitrogen in the leaves. In the fields, nutrition deficiency or sufficiency caused by organic matter decomposition in the soil is a reason why weeds and pest are enhanced. The avoidance of yield reduction by disturbance from weed control practices varied with weed population (Wc/Rc) and damage by *L. oryzophilus* and the total mass of rice decreased despite of weeding or not as the yield decreased with the infection degree of *L. oryzophilus* increased. The yield reduction, despite of weeding, was due to the favorite soil conditions for the *M. vaginalis* and *L. oryzophilus.* In contrary, with the soil management to accumulate the rice residuals on the soil surface, it is possible to control weeds and pest by cultivation practices.

Table 3. Correlation coefficients between the variables of weeds and *L. oryzophillus*

Variables	Rc-1	Wc-1	Wc/Rc	Ww-1	Ww-2	Av. N_{0-2}
M. vaginalis cover degree	-0.76	0.71	0.79	0.41	0.72	0.41
Weeds[2] population ratio	-0.91	0.61	0.94	0.12	0.94	0.68
L oryzophillus Damage	-0.86	0.41	0.83	0.13	0.57	0.76

Rc-1 and Wc-1 are rice and weeds cover degrees at the tillering stage; Ww is the weeds weight, Ww-2 is at ripening stage.

Table 4. Means and Variance Analysis

Factor	Level	Available	*L. oryzophillus*	Cover degree (%)		
		$N_{0\text{-}2}$	damage	Rc	Wc	Wc/Rc
A Depth	Incrop	35.6*	0.41**	14.6**	62.4**	5.0**
	Surface	5.3	0.14	23.4	36.9	1.6
B Rate	200	13.1	0.25	19.6	56.7 Δ	3.5
	400	27.8	0.30	18.4	42.6	3.2
C Decomp.	Raw	20.3	0.30	19.1	47.8	3.1
	Silage	20.6	0.25	18.9	51.5	3.5
A x B		n.s	*	Δ	n.s	Δ
A x C		n.s	n.s	n.s	n.s	n.s
B x C		n.s	n.s	n.s	n.s	n.s

Factor A, application depth; B, application rate; C, decomposing extent.
**, P<0.01; *, P 0.05; Δ, P<0.10; n.s., P≥0.10. N0-2, nitrogen concentration in the surface layer of 0 to2 cm (mgN/kg). Samples from 0-2 cm and 2-5 cm layers were taken 7 days after transplanting. *L. oryzophillus* damage was shown as the ratio of infected to total calms. Rice and weeds cover degrees were examined at the full tillering stage. Algae and duckweeds were not included in weeds population.

Effects of Rice Residuals and Bokashi Applications and Earthworm Invest on Weed Population

Paddy field earthworms (*B. sowerbyi* BEDDARD) were raised in glass containers (45 cmx30 cm x35 cm) and activities of the earthworms were observed from June1999. The earthworms, which thrived in weed depression paddy fields, were obtained from the nature farming paddy fields at Nagano Prefecture. The number of earthworms appearing on the soil surface was counted and recorded as earthworm investment. The soil surface swallow-up increased as the earthworm invest increased, especially at the early stage of 9-46 days after puddling. At later stages, 46-95 days after puddling, interaction effects were observed between earthworm and Bokashi or Bokashi +rice straw in addition to the main effects. At the early stage, the effect of Bokashi application on soil surface swallow-up was amplified by earthworm invest. However, the effect of Bokashi application on soil surface swallow-up diminished at latter stages if earthworm population was low.

The winter-over adult earthworms moved up to the soil surface. For weed depression not only the earthworm population but also organic materials (straw and Bokashi) application as well as the duration from puddling to leveling must be considered. Kurihara (1983) has invested earthworms to the soil and found that the 0-1.7 cm soil surface layer contained only 3% of the total *M. vaginalis* seeds in the earthworm invest plots but the same soil layer contained 89% of the *M. vaginalis* seeds in the control plots. Due to the activities of earthworms, the weed seeds sank to the deeper soil layer, where it is not easy for weed seeds to germinate. Koarai (1995) has examined the *M. vaginalis* germination in paddy fields and found that it is difficult for this weed to germinate if the seed is located deeper than 5 cm from the surface and the optimum depth is 2 cm. Therefore, in paddy fields with organic materials applied, the soil swallow-up by earthworms' activities is effective in weeds control, especially at the later stages. The weeds depression effect is better if the duration from puddling to transplanting is longer. The *M. vaginalis* depression effect was confirmed by the tracing experiment by Harada et al. (2001). As indicated by Hakoishi (1995), weeds control by cultivation practices is promoted as the soil properties are improved by earthworm thrift.

Effects of Microorganisms with Organic Materials on Rice Crop

An experiment of surface EM application was conducted in 2000. Big yield differences were observed among treatments of EM application, straw application and Bokashi application (Table 5). According to Yoo et al. (1989), rice straws applied to soil surface release various organic and inorganic nutrients and increase development and nitrogen fixing activities of photosynthetic bacteria and algae. Therefore, promotion of rice plant growth by photosynthetic bacteria is due to the utilization of rice straw applied to the soil surface.

Table 5. Effects of Applications of EM and Organic Materials on Rice Yield and Quality

Treatment Mass	Level W.	Total N	Yield	Kernel	Rice	Amylose	Glutinous	Taste
A EM	Mi	1601	632	20.9	0.89	0.18	0.96	1.23
	Co	1466	552	20.5	0.86	0.17	1.00	1.27
		*	**	*	n.s	n.s	n.s	n.s
B Straw	300	1391	546	20.4	0.86	0.17	1.01	1.24
	600	1676	639	21.0	0.89	0.17	0.95	1.26
		**	**		Δ	n.s	*	n.s
C Bokashi	200	1430	561	*20.6	0.85	0.17	1.01	1.27
	300	1637	623	20.8	0.90	0.18	0.95	1,22
		**	*	n.s	*	*	*	n.s
Interaction	A*B	*	*	n.s	n.s	n.s	n.s	*
	A*C	n.s	n.s	n.s	n.s	n.s	n.s	n.s
	B*C	**	Δ	Δ	*	Δ	Δ	n.s
	A*B*C	**	Δ	n.s	n.s	n.s	n.s	Δ

Mi in EM treatment: EM1 with lactic acid bacteria and east as the main microbes was applied totally 5L/10a to organic materials and to the soil surface at plough and puddling. EM3 with photosynthetic bacteria as the main components were applied totally 2.5 L/10 a for 3 times by spraying after application of rice straw. Co treatment: Water spray. Rice straw and bokashi were applied 3 times before puddling and at transplanting stage and at ripening stage. Rice straw was cut into 2-3 cm pieces and applied after transplanting.

Conclusions

The advantages of rice or the weeds *(M. vaginalis)* and the damages by pests *(L. oryzophilus)* changed with alternations of the application depth of rice straws. Raw rice straws incorporated into the soil depressed growth of rice, increased the risk of *L. oryzophilus,* and enhanced weed development. However, the adverse effects from the raw materials can be overcome by mulching organic materials on the soil surface. The extent of the blast is increased by increasing nitrogen fertilization although the weed problem was diminished. In this case, the existence of weeds can prevent the blast emergence. Moreover, the growth of rice was promoted and weeds were controlled by earthworms and activities of photosynthetic bacteria. Weeds were sharply decreased by changing the puddling method where the soil nitrogen concentration was adjusted to appropriate level with application of organic materials. It concluded that there exist paddy soils whereby rice growth is promoted and weeds are depressed and it is possible to adjust the soil nitrogen concentration and earthworm population by applying organic materials and changing puddling methods in addition to soil water control.

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