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Rice Growth and Yield, and Soil Enzyme Activities in Paddy Rice Field Amended with Legume for Sustainable Agriculture

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Introduction and Purpose

- Sustainable crop production has been required worldwide against resource depletion and environmental pollution.
- We have been cultivated paddy rice only with white clover as green manure without any other input such as chemical fertilizers for more than ten years.
- We investigated dynamics of nutrients and enzyme activities in the soil as well as the growth and yield of rice to clarify the mechanism of this cultivation system.

Picture: Picture of harvest season at the green manure rice field

White clover
(*Trifolium repens*)

Material and Method

Table1. Nutrient application and field management

Treatment	Transplanting day	Green manure aplication	Nitrogen application	P_2O_5 application	K_2O application	Incorporation	Basal Fertilization	Pudding	Transplanting	Mid-season drainage			Harvest
		g/㎡	gN/㎡	g/㎡	g/㎡					start	end	days	
GM1 'Kosihikari'	5/24	1215	8.2	5.2	13.1	18-May	-	21-May	24-May	17-Jul	27-Jul	10	13-Sep
GM2 'Akitakomachi'	6/5	1227	15.2	7.2	14.7	1-Jun	-	5-May	8-Jun	26-Jul	31-Jul	36	21-Sep
GM3 'Kosihikari'	5/28	1941	21.6	8.5	26.3	22-May	-	24-May	28-May	17-Jul	24-Jul	7	18-Sep
GM4 'Nikomaru'	6/15	1562	24.0	8.4	25.7	4-May	-	15-Jun	18-Jun	1-Aug	9-Aug	8	19-Oct
C1～4 'Kosihikari'	6/17,18	0	4.2	4.2	4.2	4-May	14-Jun	15-Jun	18-Jun	25-Jul	4-Aug	10	28-Sep

GM: Green manure, C: Conventional practice
GM plot ploughs in green manure before cultivating rice.
Conventional Practice plot used slow-release chemical fertilizer at 4.2:4.2:4.2 g m^{-2} ($N:P_2O_5:K_2O$) on 14th Jun .
Planting density is 15.2plant m^{-2} (plant between roots 22cm, distance between planting two rows 30cm)

- White clover was used as green manure in GM plot.
- After harvest green manure by using a quadrat (50cm x 50cm), we calculated the amount of input nutrients by the green manure.
- Leaf color is measured on whole season by SPAD Meter(Minolta SPAD-502).
- Soil available N was measured by phosphate buffer extraction method Ogawa(1988)
- Each soil enzyme activity measured β-glucosidase activity Hayana (1973), phosphatase activity Hayano (1997) and protease activity Hayano and Yamagata (1997)
- Statistical analysis was performed using Excel Toukei(2016). Data for rice yield components and taste quality were tested with one way ANOVA Tukey Kramer test. Soil properties were tested with t-test.

Result

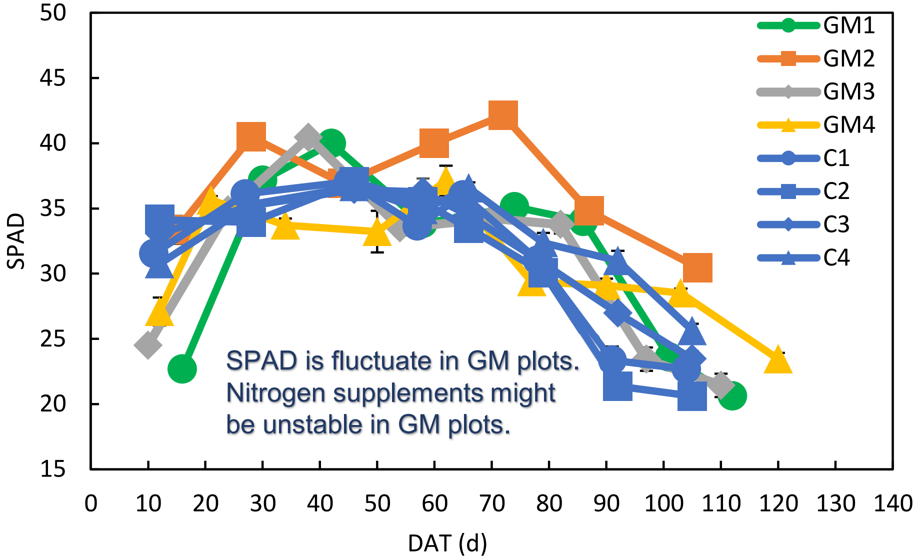


Figure 1. Changes in chlorophyll content (SPAD)
DAT is Days After Transplanting. GM: Green manure application plots.
C: Conventional practice plots.
Data points means, and the error bars represent standard deviations.

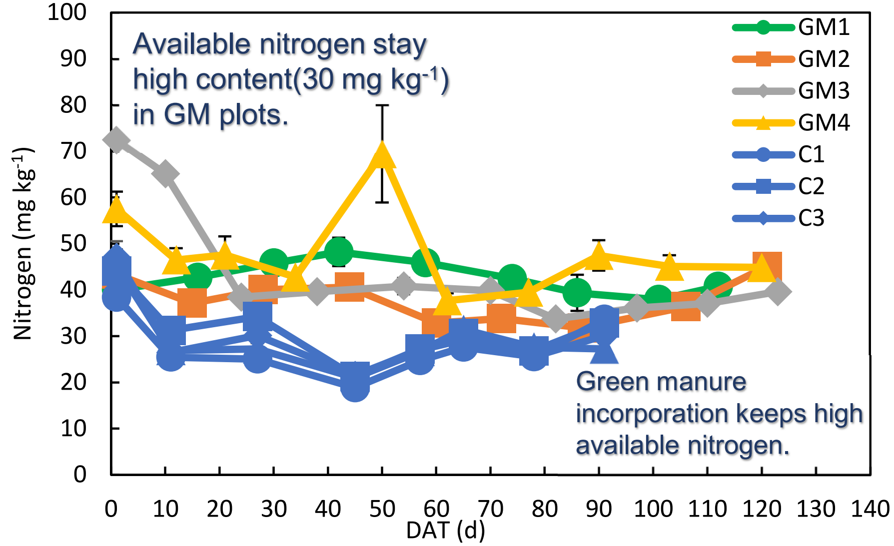


Figure 2. Changes in available nitrogen in the soils of organic and conventional paddy rice fields. DAT means Days After Transplanting.
GM: Green manure application plots. C: Conventional practice.
Data points means, and the error bars represent standard deviations.

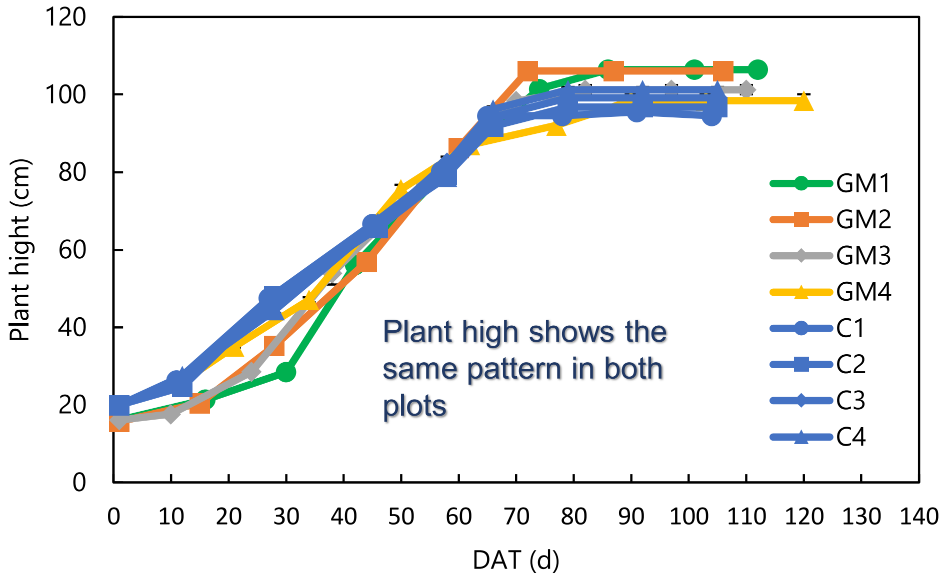


Figure 3. Changes in plant hight
DAT is Days After Transplanting. GM: Green manure application plots.
C: Conventional practice plots.
Data points means, and the error bars represent standard deviations.

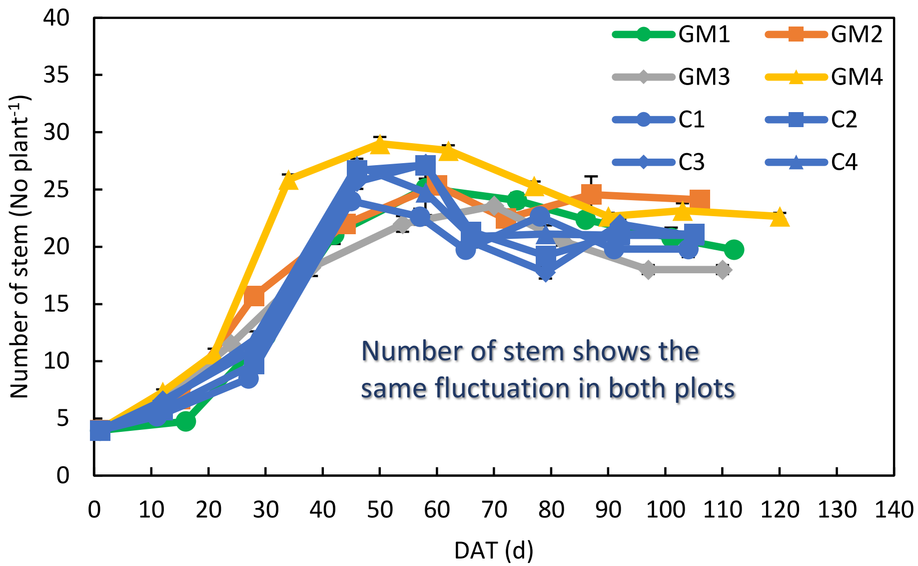
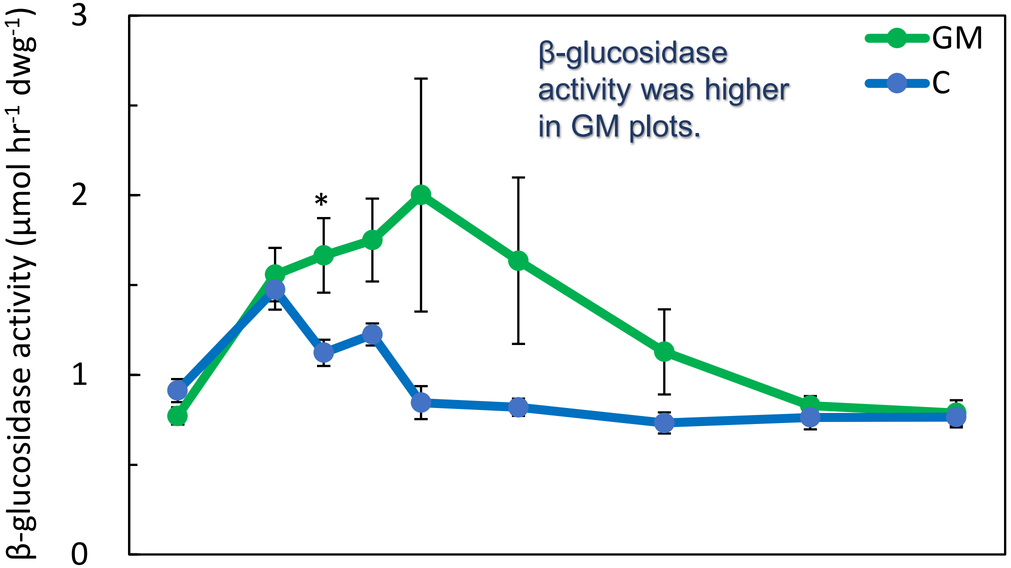
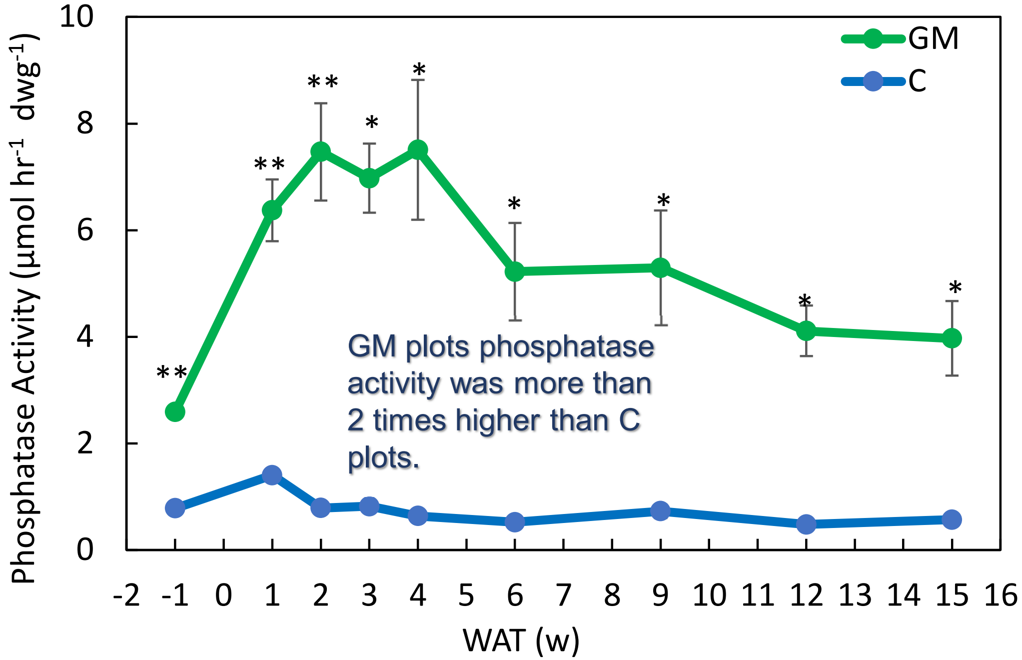


Figure 4. Changes in number of stem
DAT is Days After Transplanting. GM: Green manure application plots.
C: Conventional practice plots.
Data points means, and the error bars represent standard deviations.





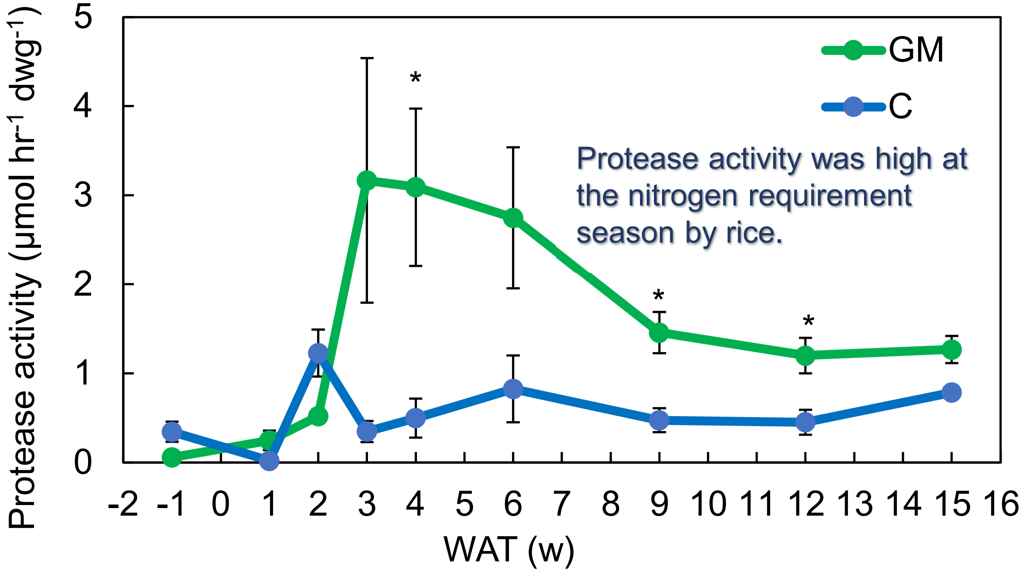


Figure 5. Changes each enzymes activity in the soils.

GM: Green manure application plots. C: Conventional practice.
WAT: weeks after transplanting. Data points means, and the error bars represent standard deviations. *P* values represent the results of t-test between green manure (GM) and Conventional practice (C). * : ($P<0.05$) **($P<0.01$)

Soil enzyme activities increased in the GM plot around 3-4 WAT.

- The incorporation of white clover enhanced the soil microbial activity around 3-4 WAT.
- In C plot, a high concentration of phosphate by fertilization caused a lower phosphatase activity on whole season.
- Protease activity was higher in the GM plots that suggests the incorporation of green manure promoted decomposition of protein derived from the green manure in the soil.

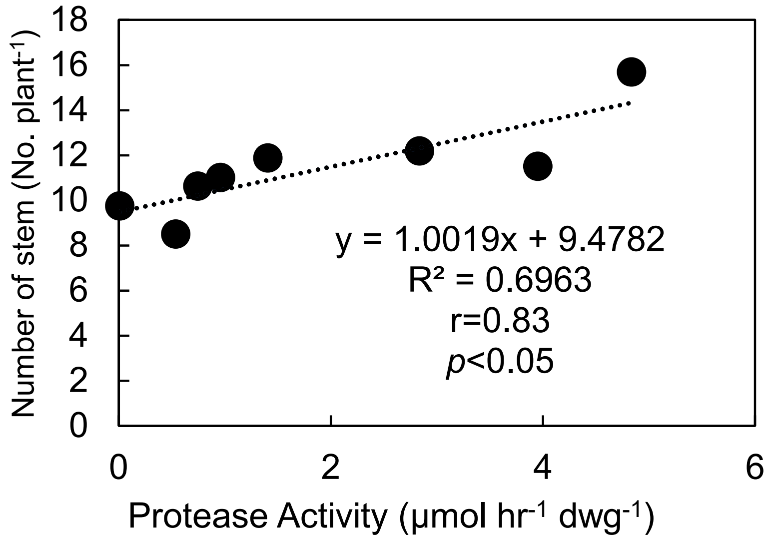


Figure 6. Relationship between protease activity in the soil and the number of stem at 30 days after transplanting.

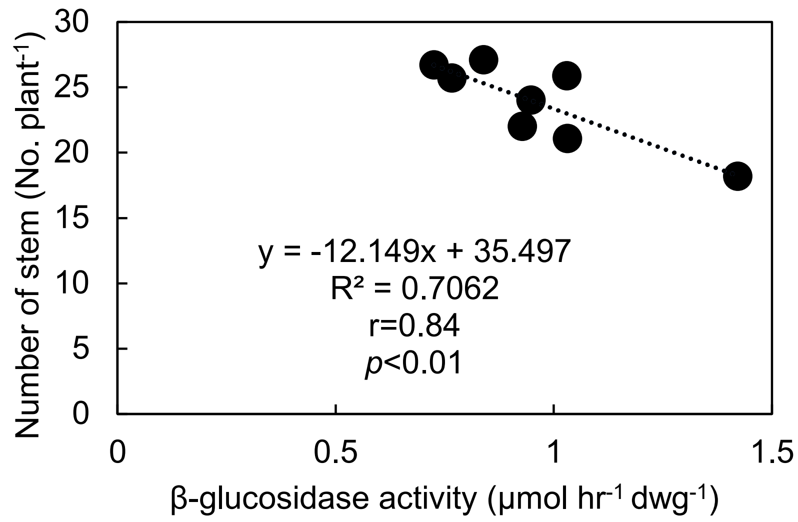


Figure 7. Relationship between β-glucosidase activity activity in the soil and the number of stem at 42 days after transplanting.

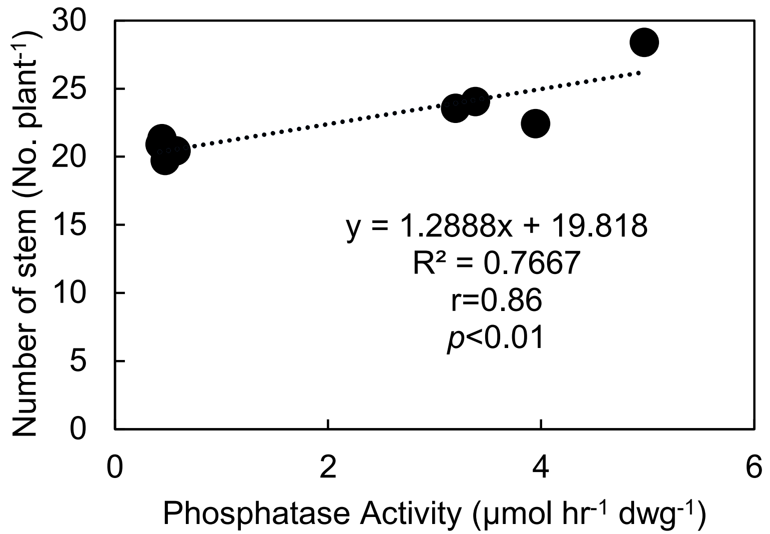


Figure 8. Relationship between phosphatase activity in the soil and the number of stem at 84 days after transplanting.

- High protease activity promoted the number of stem(Fig 6). A higher amount of the mineralized nitrogen may be supplied by the increased protease activity.
- β-glucosidase activity shows an index as not only carbon mineralization but also microbial activity in the soil. Higher microbial activity might cause smaller number of stem in tilling season(Fig 7).
- Increasing number of stem promoted the production of phosphatase from the plant roots or microorganisms in booting season(Fig 8).

Table3. Rice yield components and taste quality

Treatment Rice Cultivar	Grain yield	Number of Panicles	Grain per Panicles	Ripening rate	Thousands Wight	Taste quality	Protein	Moisture	Amylose	Fatty acid
	g/m^{-2}	$pnicles/m^{-2}$	grain/panicles	%	g	-	%	%	mg	mg
GM1 'Kosihikari'	426 a	328 d	90.6 a	77.5 bc	20.7 c	76.0 a	5.93 b	12.9 c	18.5 c	17.6 c
GM2 'Akitakomachi'	420 a	383 a	87.4 ab	75.4 cd	21.8 a	70.5 c	6.85 a	13.3 b	18.7 a	19.4 a
GM3 'Kosihikari'	391 bc	298 e	102.0 a	81.9 a	21.5 a	76.8 a	5.77 b	13.1 bc	18.5 bc	18 bc
GM4 'Nikomaru'	265 d	343 c	80.9 b	55.3 f	20.9 bc	72.7 bc	6.63 a	13.1 bc	18.6 ab	17.8 bc
C1 'Kosihikari'	377 c	310 de	82.7 b	70.7 e	21.3 ab	76.8 a	5.78 b	13.7 a	18.7 ab	18 bc
C2 'Kosihikari'	433 a	386 a	85.0 ab	75.9 cd	21.3 ab	76.5 c	5.88 b	13.5 ab	18.6 b	18.1 bc
C3 'Kosihikari'	420 ab	362 bc	84.0 b	73.0 de	21.0 bc	74.0 a	5.80 b	13.5 ab	18.6 ab	18.1 bc
C4 'Kosihikari'	426 a	353 c	88.9 ab	80.3 ab	21.0 bc	72.5 bc	6.55 a	12.9 c	18.6 ab	18.5b
GM Average	412.8	371.8	91.5	72.4	21.2	75.7	6.03	13.4	18.6	18.2
C Average	448.0	387.8	85.1	75.9	21.2	74.5	6.25	13.1	18.6	18.2

GM: Green manure application plots, C: Conventional practice plots
Different letter shows significant difference ($P<0.05$)

- There is no significant difference between GM and C plots in all the items, because the soil fertility in GM varied in the field.
- GM4 showed the lowest yield and the ripening rate of all, due to a low amount of available phosphorus in the ripe season (data no shown).
- 'Nikomaru' is an anti-heat variety. Since the air temperature was not over 35℃ in booting season. The low ripening rated would be not derived by high temperature.

Conclusion

- Application of green manure could raise rice plant without chemical fertilizers as same as the conventional practice using chemical fertilizers. However, the amount of nitrogen suppled varied in the field.
- GM plots increased microorganisms' activity, such as β-glucosidase, phosphatase, and protease activity, which metabolize C, P, and N in the soil.
- Hight protease activity increased the number of stem in tillering stage.
- Similarly, a high number of stem would promote the phosphatase production from the rice roots in booting stage.
- However, too much microbial activity might increase β-glucosidase activity, led to nitrogen starvation, decreasing the number of the stem in tillering stage.
- In GM, a higher turnover rates of N, P and C, made it possible to supply enough N and P to the plant, resulting in the same level of yield in the conventional practice.
- Taste quality in GM was also the same as the conventional practice.

Green manure application without chemical fertilizers may be useful for sustainable rice cultivation in the southern part of Japan.

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