Effect of Successive Cultivation of Paddy by Nonirrigated Direct Seeding on Soil Fertility

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Nonirrigated direct seeding has been studied for labor-saving mechanization of rice cultivation over the past years. It is difficult, however, to obtain a stable yield by this method as compared with transplanting cultivation because of the unstable growth of seedlings and the imperfect system of weeding. Accordingly, this method is not widely prevalent at present except in some regions.

Although some technical problems remain to be solved, nonirrigated direct seeding is considered to be an important technique to push forward large-scale rice cultivation under the condition of shortage of labor.

There is a great difference between the nonirrigated direct seeding cultivation and the transplanting cultivation as to the soil condition under which rice plants are grown because the former puddling is not performed and seedlings are kept under a nonirrigated condition until they grow to the two or three-leaf stage, etc.

Such difference of soil condition may have a great influence on the growth of rice plants and the succession of nonirrigated direct seeding cultivation is considered, as a matter of course, to affect not only the growth of rice plants but also the soil fertility of the field.

In this report, a description is made putting special emphasis on the results of an experiment[1)] carried out by the author to clarify these points.

It seems that there is the so-called suitable field for the nonirrigated direct seeding culture from the viewpoint of easier work. The field used in this experiment was a dry paddy field (soil texture: loam; effective soil layer: 1 m or more in depth) of alluvial soil, which is widely distributed in Toyama Prefecture and considered to be a suitable field.

The experiment has continued for six years to compare nonirrigated direct seeding cultivation with transplanting cultivation. For nonirrigated direct seeding, an additional experiment was established to examine the effect of application of organic matter, and dry rice straw cut into pieces were applied to the lot at a rate of 400 kg per 10 ares every year.

Outline and consideration of results

1) Yield of rice

Fertilization technique has almost been established now for the cultivation of rice plants by nonirrigated direct seeding and it is usual at present that the direct seeding cultivation is not different from the transplanting cultivation in rice yield.

Table 1 shows the chronological changes of the yield of brown rice in the experiment. Although the yield showed some change every year according to the climate, it was lower in direct seeding than in the transplanting lot for the first two years.

This result is considered, as mentioned below, to be due to an increased leaching of fertilizer in the direct seeding as a result of much percolation of logged water because there was no consistent difference of yield between the two lots in and after the third

Table 1. Chronological change of unhulled rice yield

Year→ Lot ↓	1965		1966		1967		1968		1969		1970	
	Yield	Ratio	Yield	Ratio	Yield	Ratio	Yield	Ratio	Yield	Ratio	Yield	Ratio
Transplanting	480	100	421	100	572	100	524	100	431	100	392	100
Dry seeding	380	78	326	78	608	106	447	85	437	101	335	85
Dry seeding+Rice straw	420	86	260	62	600	105	495	94	470	109	374	95

year in accordance with a great increase in the amount of fertilizer applied to the direct seeding lot.

The direct seeding lot to which rice straw was added always showed a higher level of rice yield as compared with direct seeding where no rice straw was applied (the reversal of the yield in 1966 was due to the occurrence of root rot caused by abnormally high atmospheric temperature in the latter half of the growing period of rice plants). This result is also likely to have been greatly influenced by the percolation of logged water as mentioned below.

The same phenomenon is also seen already on the result of nitrogen analysis of hull and straw, showing that the larger the amount of nitrogen absorbed is, the higher is the yield.

The amounts of fertilizers applied (per 10 ares) in the experiment were as follows: in the transplanting lot, nitrogen 10 kg (8 kg as base fertilizer), phosphoric acid and potassium 8 kg each (as base fertilizer); in the direct seeding lot, base fertilizer: nitrogen 3 kg, phosphoric acid and potassium 8 kg each, additional fertilizer: nitrogen 9 kg (1st year), 11 kg (2nd year) and 22 kg (thereafter).

The amount of nitrogen applied as additional fertilizer was increased in this way in the direct seeding lot year by year because an increased percolation of logged water caused serious leaching of fertilizers and as a result, the growth of rice plants could not sufficiently be maintained in this lot.

2) Changes in physical property of soil

When nonirrigated direct seeding culture of rice plants was repeated in the same field, it became necessary to increase the amount of nitrogen used as additional fertilizer. This is considered to have resulted in the leaching down of fertilizers caused by an increase in the percolation of logged water as shown in Table 2.

Table 2. Chronological change of percolation of logged water

(cm/day)

Lot ↓ Year→	1965	1966	1967	1968	1969	1970
Transplanting	2.2	6.6	4.5	7.1	3.3	3.3
Dry seeding	11.0	17.2	29.6	26.6	27.5	28.0
Dry seeding+ Rice straw	8.7	15.3	22.5	18.7	21.4	18.5

The values in this table indicate the amounts of water percolated per day. It is said that when a field is changed from the nonirrigated condition to the flooded condition, the percolation is great at first and decreases gradually to reach an equilibrium one month later, becoming nearly the same as in the case of transplanting cultivation according to the type of soil.

Therefore, the values in this table seem to represent the percolation in the flooding period, showing no data of the period when the change of percolation was the greatest. From these data, it is seen that in the direct seeding lot the percolation of logged water increased gradually for the first three years and remained on the same level of about 30 cm a day thereafter.

Such a great percolation causes not only an increased leaching of fertilizer applied but also a decrease in the rise of soil temperature in such a region as ours where the temperature of irrigation water is as low as 17-10°C in the early growing period when the number of rice stems is determined and doing great damage to the rice crop. The application of rice straw was effective for preventing adverse effects.

When soil structure is examined, it is seen in the direct seeding lot, in general, both solid and liquid phase ratios were lower, and the gaseous phase ratio tended to be higher as compared with those in the transplanting lot, respectively.

When nonirrigated direct seeding culture is repeated in the same field, there is a tendency that the solid phase ratio decreases and the pore space ratio increases year by year, although the changes are little. The pore space ratio has slightly increased by the application of rice straw.

In the next place, it is found that soil aggregates less than 0.5 mm in size are increased and those not more than 0.1 mm are decreased in number by nonirrigated direct seeding cultivation. The same tendency is observed not only after draining but also during the flooding period.

It is, however, noticed that soil aggregates of 0.25 mm in size or less tend to increase during the flooding period as clearly seen in Table 3 which shows the results of an analysis of soil aggregates taken from the fields of the sixth cultivation at different culturing stages.

In the direct seeding to which rice straw was added, soil aggregates of 0.1 mm in size or more increase in number during the flooding period as compared with those in the lot with no rice straw. This result suggests that such an increase in the number of small soil aggregates may act as a factor suppressing the increase of percolation of logged water in the lot even if the pore space ratio is slightly increased by the application of rice straw.

3) Changes in chemical property of soil

The change of organic matter content can be used as a means for investigating the change of soil fertility. In Tables 4 and 5 which show the total nitrogen content and the total carbon content of the soil as well as the effect of soil drying and the effect of raising soil temperature, it seems that there is almost no difference in these values between the transplanting and direct seeding lots.

Table 3. Distribution of mechanical composition of soil aggregates

Date	Lot	Amount of aggregates classified by diameter (% by weight)					
		>2.0	2.0 ~1.0	1.0 ~0.5	0.5 ~0.25	0.25 ~0.1	0.1> mm
Dec. 16, 1969 After draining	Transplanting	19.7	16.6	12.3	10.9	12.5	28.0
	Dry seeding	20.0	19.4	13.8	10.8	12.9	23.1
	Dry seeding+Rice straw	29.3	17.1	13.2	10.1	11.4	18.5
May 23, 1970 Dry seeding: before flooding Transplanting: flooded	Transplanting	2.1	4.6	5.9	9.9	16.4	61.1
	Dry seeding	13.7	19.0	22.4	18.1	14.1	12.7
	Dry seeding+Rice straw	19.4	20.4	21.1	16.9	12.3	9.9
June 1, 1970 Flooded	Transplanting	1.6	2.8	6.5	10.5	16.3	62.3
	Dry seeding	12.1	9.5	9.5	12.2	19.3	37.4
	Dry seeding+Rice straw	4.5	5.3	6.6	8.6	15.6	59.4
June 22, 1970 Flooded	Transplanting	2.7	2.6	5.9	9.0	14.5	65.3
	Dry seeding	5.3	4.3	5.7	8.1	12.5	64.1
	Dry seeding+Rice straw	4.3	3.2	5.7	8.0	15.1	63.7
Sept. 11, 1970 After draining	Transplanting	34.7	16.5	7.5	6.1	10.3	24.9
	Dry seeding	34.0	25.1	17.8	7.7	5.1	10.3
	Dry seeding+Rice straw	36.7	28.4	17.9	5.1	4.7	7.2

Table 4. Chronological change of total nitrogen and total carbon in soil (%)

Item	Lot ↓ Year→	1965	1966	1967	1968	1969	1970
Total nitrogen	Transplanting	0.185	0.181	0.187	0.190	0.185	0.185
	Dry seeding	0.184	0.181	0.182	0.186	0.184	0.184
	Dry seeding+Rice straw	0.188	0.270	0.193	0.195	0.221	0.215
Total carbon	Transplanting	1.67	1.67	1.65	1.66	1.65	1.69
	Dry seeding	1.69	1.63	1.61	1.61	1.68	1.66
	Dry seeding+Rice straw	1.80	1.85	1.76	1.82	1.92	2.04
C/N ratio	Transplanting	9.03	9.23	9.35	8.74	8.92	9.14
	Dry seeding	9.19	9.01	8.85	9.67	9.12	9.03
	Dry seeding+Rice straw	9.58	8.95	9.13	8.34	8.70	9.49

Table 5. Chronological change of mineralization of soil organic matter

Item	Lot ↓ Year→	1967	1968	1969	1970
Effect of soil drying	Transplanting	8.24	9.35	11.20	11.84
	Dry seeding	9.63	10.87	11.46	11.48
	Dry seeding+Rice straw	10.10	12.69	14.20	13.84
Effect of raising soil temperature	Transplanting	6.01	3.16	8.80	5.27
	Dry seeding	6.21	3.19	9.94	6.08
	Dry seeding+Rice straw	6.82	4.49	11.94	7.51

(NH_4-N mg/100g dry soil)

In contrast to this, when rice straw is applied, these values became a little higher and tended to increase year by year as compared with the case of no rice straw, and it seems, from the result of a separate experiment on the fractionation of soil humus, that this is due to an accumulation of rotten products at a low degree of humification.

On the other hand, there is a report which says that the nitrogen content and the effect of soil drying were decreased by repeating nonirrigated direct seeding cultivation of rice plants in the same fields[2], but it is not yet clear whether or not such a result is attributed to some difference in regional condition in soil type or utilization form.

From the above-mentioned percolation of logged water and the behavior of organic matter, it seems that when rice plants are cultivated by nonirrigated direct seeding in such a field as ours, a condition under which the potential nitrogenous fertility of soil is made effective can hardly be realized or there is some condition under which the effectual fertility can scarcely be utilized. The application of rice straw may be effective in the point that it makes the fertility of soil easily usable.

Summary

To examine the effect of successive rice cultivation by nonirrigated direct seeding on the fertility of soil, a comparison was made between a direct seeding lot and a transplanting lot in a loamy field representing a type of dry paddy fields.

The successive cultivation of rice plants by nonirrigated direct seeding was observed to have many effects on the physical property of soil and influence the growth of the plants and the yield of rice. For example, in the direct seeding lot the percolation of logged water continued to increase for the first three years, reaching as much as 30 cm a day.

The percolation, however, had no tendency to increase thereafter probably owing to changes of soil structure as seen in a gradual decrease of the solid phase ratio or an increase in number of soil aggregates not smaller than 0.5 mm and a decrease of those

not smaller than 0.1 mm.

As to the organic matter content of soil, almost no difference was observed between the two lots.

In the case of the successive cultivation of rice plants by nonirrigated direct seeding, the application of rice straw was highly effective for maintaining the soil fertility because it improved the physical and chemical properties of the soil and suppressed the percolation of logged water.

From these results, it seems that best attention must be given to the management of field as to fertilization and irrigation when rice plants are successively cultivated by nonirrigated direct seeding in such kind of nonirrigated paddy field as used in this experiment.

References

1) Kutsuna, K. et al.: On the successive cultivation of rice plants by nonirrigated direct seeding on soil fertility. *Sci. Soil & Manure, Japan* 43 (3), 68-91 (1972).
2) Dei, Y.: Science in Soil & Manure. Gihodo, Tokyo, 118-133 (1969).