(Korean J. Crop Sci.) 43(4) : 264~268(1998)

Effect of Tillage and Seeding Methods on Percolation and Irrigation Requirement in Rice Paddy Condition

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ABSTRACT

The experiment was conducted to clarify irrigation requirement and percolation rate in rice paddy. The four rice cultural system of no-till, till, transplanting, and direct seeding condition were treated in the lysimeter filled with sandy loam soil. The amounts of irrigation and soil percolation were measured daily, and irrigation requirement was estimated. The daily percolation was 19.5 l/m^2 in no-till direct seeding on flooded paddy surface, 17.4 l/m^2 in both of till-direct seeding on flooded surface and no-till transplanting, and 15.2 l/m^2 in transplanting plot. This is equivalent to 19.5, 17.4, and 15.2 mm per day, respectively. Highest irrigation requirement was 3,770 l/m^2 in no-till direct seeding plots. Others were 3,249, 2,577, and 2,321l/m^2 in till-direct seeding, no-till transplanting and transplanting plot, respectively. The estimated irrigation requirement of no-till transplanting, till-direct seeding and no-till direct seeding was increased by 11, 37, and 59% compared to till-transplanting plot. Percolation rate of no-till transplanting, till direct seeding and no-till direct seeding was increased by 12%, 40%, and 66%, respectively compared to the till-transplanting plot. The percolation rate in paddy soil was increased greatly after reproductive stage of rice.

Key words : no-till direct seeding, no-till transplanting, direct seeding, transplanting, irrigation requirement, rice paddy, percolation.

The planted area for a rice direct seeding technique as a labor-saving culture system has been increased since 1990 up to 110,562 ha in 1997, which is approximately 10% of the total area of rice paddy field in Korea. No-till direct seeding culture has also been increased recently. It was reported that a direct seeding culture system requires more irrigation requirement than a transplanting culture. The amounts of percolation water during growing period under cultural methods of transplanting, direct seeding on dry paddy and direct seeding on flooded paddy surface were known to be 500, 800, and 845 mm, and their average percolation rate per day was 5 mm, 8 mm, and 5~6.5 mm, respectively (Lee, 1995). Their irrigation requirement was also estimated to be 838 mm, 998 mm, and 1,263 mm, respectively (Lee, 1995). Kim (1994) reported that a direct seeding on dry paddy needed 25% more irrigation requirement than that of the transplanting culture (Kim, 1994). It is assumed that the water percolation rate and irrigation requirement are higher in no-till-rice culture than do transplanting or direct seeding culture with tillage. However, much information have not been known on that issue. Objective of this experiment was to clarify irrigation efficiency including percolation rate under different rice cultural system, no-till or till, transplanting, and direct seeding condition.

MATERIALS AND METHODS

This experiment was carried out in plastic lysimeter which is 94×49×64 cm in size, 4,606 cm^2 of surface area and 0.32 m^3 in volume. The lysimeter was made on April, 1997 and rice was cultured for one year, so it was considered that the soil condition was established well like natural field condition. The diameter of lysimeter drain pipe was designed to prevent water percolation from clogging. Four levels of cultural methods, no-till direct seeding on flooded paddy surface, no-till transplanting, direct seeding on flooded paddy surface, and transplanting were applied by randomized block design with 3 replications. The used soil was sandy loam with 22.1% of clay, 34.1% of silt and 43.8% of sand at depth of 30 cm, and with medium-low fertility. Rice variety Chucheong-byo was seeded directly at 2 days after first irrigation on 25 April 1998. Seventy-two seeds per lysimeter were sown and then thinned to 36 plants at 4th leaf stage in direct-seeding. The 21 day-old seedlings raised in the box for machine transplanting were transplanted on the transplanting plots with a spacing of 30 cm×15 cm (36 plants per lysimeter) on 25 May 1998. Fertilizer application rates were N-P-K=180-120-140 kg/ha in direct seeding and N-P-K=150-100-120 kg/ha in transplanting plots, respectively. Nitrogen was applied splitly by 40 (basal) - 30 (4th leaf stage) - 20 (panicle initiation stage) - 10% (heading stage) in direct seeding plots and 50 (basal) - 30 (tillering stage) - 20% (panicle initiation stage) in transplanting plots. Phosphorus was applied once as a basal, and potassium was applied splitly by 70 (basal) - 30% (panicle initiation stage). Flooding depth of lysimeter was maintained 1~5 cm throughout the growing period. Other cultivation managements were applied by standard methods. The amounts of irrigation water, water percolation and rainfall was monitored daily just after direct seeding and transplanting treatment. Irrigation requirement was calculated from daily measured

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Received 11 Nov. 1998

irrigation water plus effective precipitation. Evapo-transpiration was estimated from irrigation requirement minus water percolation.

RESULTS AND DISCUSSION

Growth and yield of rice

Changes of the plant height of rice after direct seeding on 25 April and transplanting on 25 May are shown in Fig. 1. The plant height of rice on 1 June was the highest in till-direct seeding, about 28.4 cm, second in no-till direct seeding, about 23.3cm, third in till transplanting, about 14.0 cm, and no-till transplanting, about 13.7 cm. However active tillering stage, plant height of till-transplanting and till-direct seeding plots became higher than those of no-till direct seeding and no-till transplanting plots after active tillering stage.

The changes of tiller number of rice affected by tillage and seeding method are presented in Fig. 2. The number of tillers per m² was 210 on 1 June and increased to 1, 220~1,320 at maximum tillering stage on 29 June in direct seeding plots which was seeded one month earlier than did transplanting plot. The number of tillers in transplanting plots was increased slowly and the maximum tillering stage came 15 days later than that of direct seeding plots. Besides, the highest numbers of tillers per m² were 806 in till-transplanting and 615 in no-till-transplanting plot.

Heading date, yield and straw weight of rice affected by tillage and seeding method was shown in Table 1. Heading date was 22~23 August in transplanting plots and 19 August in direct seeding plots. The highest yield, 6.93 ton/ha, was attained from transplanting plot. The plots of no-till direct seeding, no-till transplanting and till-direct seeding had lower yield of 5.52, 5.36, and 5.34 ton/ha, respectively, compared to the plot of transplanting.

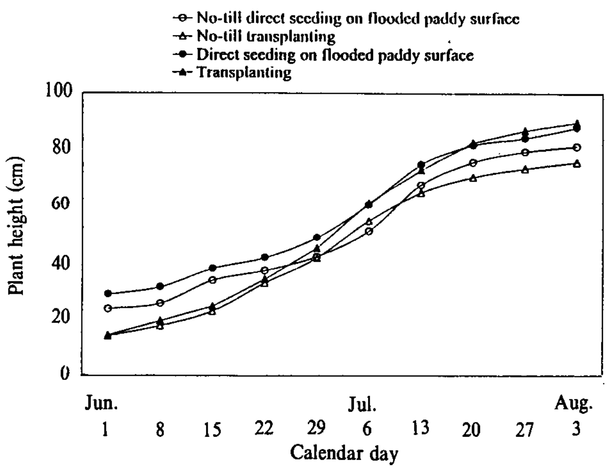

Fig. 1. Changes of plant height of rice affected by tillage and seeding method under lysimeter condition.

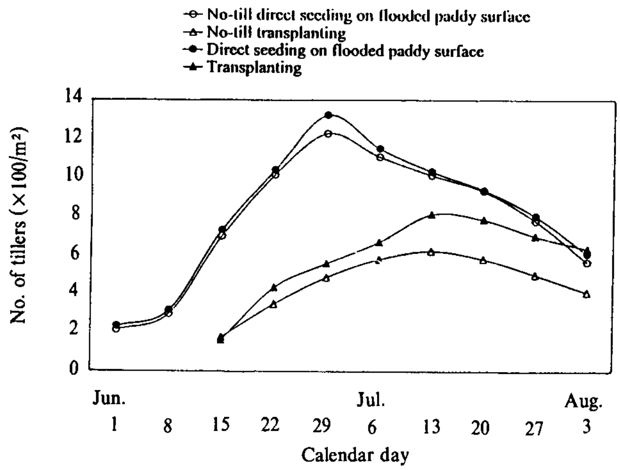

Fig. 2. Changes of tiller number of rice affected by tillage and seeding method under lysimeter condition.

Changes in amount of irrigation water

Changes of amount of irrigation water influenced by tillage and seeding methods are shown in Fig. 3. The amount of irrigation, which is related to the amount of evaporation, transpiration and rainfall, showed 30~90 *l* per lysimeter at the early stage of rice growth, increased after reproductive growth stage and reached to 80~150 *l* per lysimeter at the heading stage. No-till plots including no-till direct seeding and no-till transplanting exhibited a larger amount of irrigation water than that of till-plots at the early stage of rice growth, while direct seeding plots had larger amount of irrigation water than transplanting plots after the panicle initiation stage regardless of tillage. Relatively a small amount of irrigation water was needed in no-till transplanting plots after the panicle initiation stage. This could be interpreted as the result of lower rate of growth in stem and leaf growth including plant height and tillers.

Changes of amount of percolation water

Changes of amount of soil water percolation, and average percolation rate per day were presented in Fig. 4 and Table 3, respectively. Relatively a larger amount of percolation was observed in direct seeding plots after seeding and then it was decreased drastically within 3~4 days as the soil was settled. During the vegetative growth stage, the amount of percolation was 11~17 *l*/m² (Table 2) in no-till direct seeding and till-direct seeding plots. The amount of percolation was increased linearly both in no-till and till-direct seeding plots after the panicle initiation stage, and then decreased just before heading stage. In the till-transplanting plots, large percolation was

Table 1. Effect of tillage and seeding method on yield of rice.

Tillage and seeding treatments	Heading date	Unhulled rice yield (ton/ha)	Rice straw weight (ton/ha)
No-till direct seeding on flooded paddy surface	August 19	5.52 a	6.58 ab
No-till transplanting	August 22	5.36 a	5.47 b
Direct seeding on flooded paddy surface	August 19	5.34 a	5.92 ab
Transplanting	August 23	6.93 a	7.02 a

Means followed by same letters are not significantly different at p=0.05 by DMRT.

Table 2. Average percolation rate per day (l/m^2).

Tret.†	Apr.	May				Jun.					July				Aug.				Sept.			Daily mean
	25 ~	2 ~	9 ~	16 ~	23 ~	1 ~	8 ~	15 ~	22 ~	29 ~	6 ~	13 ~	20 ~	27 ~	3 ~	10 ~	17 ~	24 ~	1 ~	8 ~	15 ~	
T1	21	12	10	11	13	13	15	14	12	11	12	17	21	29	36	37	36	34	35	35	35	19.5 a
T2	–	–	–	–	25	23	22	18	16	14	13	12	11	11	12	15	17	22	26	28	28	17.4 ab
T3	13	8	8	8	8	8	9	8	7	8	9	15	19	25	34	36	35	32	32	33	33	17.4 ab
T4	–	–	–	–	14	12	8	4	3	3	2	5	9	12	27	31	33	32	31	30	30	15.2 c

† T1 : No-till direct seeding on flooded paddy surface
T2 : No-till transplanting.
T3 : Direct seeding on flooded paddy surface
T4 : Transplanting
Means followed by same letters are not significantly different at p=0.05 DMRT.

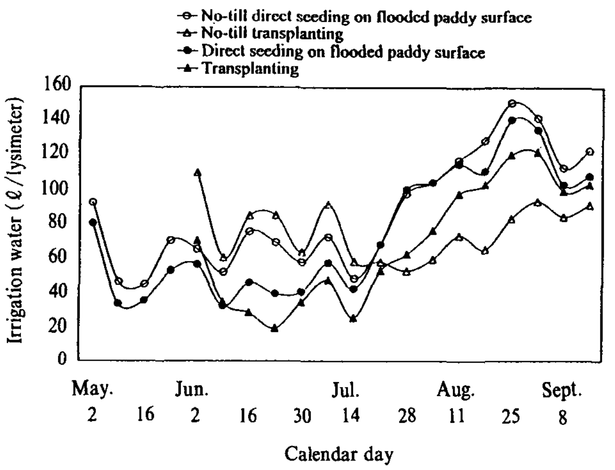

Fig. 3. Changes of amount of irrigation water of rice paddy affected by tillage and seeding method under lysimeter condition.

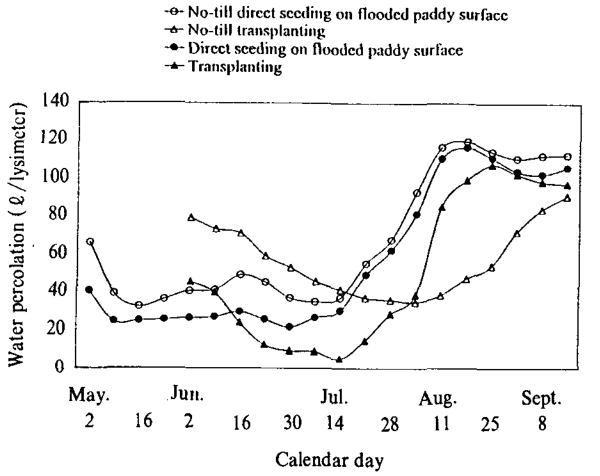

Fig. 4. Changes of the amount of percolation water of rice paddy affected by tillage and seeding method under lysimeter condition.

observed at the early days after transplanting, and decreased as the soil was settled. This decreasing tendency was continued after the panicle initiation stage, however, it was increased remarkably after the reproductive growth stage. In the no-till transplanting plots, a large amount of percolation was measured at the early days after transplanting and decreased gradually, and then it was increased drastically after the middle of

Table 3. Effect of tillage and seeding method on soil percolation and irrigation requirement in rice paddy during rice growing period under lysimeter condition (l/m^2).

Treatments†	Irrigation period (day)	Irrigation water	Effective precipitation	Irrigation requirement	Percolation water	Evapotranspiration
T1	150	3101 a	669	3770 a	2963 a	807 a
T2	120	1959 b	618	2577 b	1996 bc	581 a
T3	150	2580 ab	669	3249 ab	2500 ab	749 a
T4	120	1703 b	618	2321 b	1785 c	536 a

† T1 : No-till direct seeding on flooded paddy surface
T2 : No-till transplanting
T3 : Direct seeding on flooded paddy surface
T4 : Transplanting
Means followed by same letters are not significantly different at p=0.05 by DMRT.

ripening stage. But the percolation of no-till transplanting plots was smaller than other plots even after the reproductive growth stage.

In every experimental plot, a relatively large amount of percolation was observed after seeding and transplanting, and became stable with the passage of time. But this tendency was changed so that the amount of percolation increased greatly after panicle initiation stage in the middle of July.

The soil in the lysimeter used for this experiment was fully hardened and stable during one year standard rice cultivation in 1997. Also, there was a special care for preventing abnormal percolation caused by crack between lysimeter and soil. Therefore, it is assumed that aging of rice root after reproductive growth stage caused the increase in the amount of percolation water. And it is also considered that the absence of underground water table in lysimeter condition which is differ from natural paddy field, resulted in the large amount of percolation water.

It has been known that the number of rice roots reached the maximum of 700~800/hill (Hoshikawa, 1975) or 595/hill (Chae, 1980) at approximately 20 days before heading. It has also been reported that root growth decreased remarkably with the beginning of internode elongation, and there was no more root growth after the heading stage (Hoshikawa, 1975; Lee, 1996). Moreover, the number of roots in no-till direct seeding on dry paddy was known to the largest and the number decreased in till direct seeding on dry paddy, till direct seeding on flooded paddy and transplanting in order (Hoshikawa, 1975). Therefore, it is considered that rice root was generated in the early stage of rice growth and passed through plow beneath layer declined in its function and rotten partially, and consequently, it stimulated water percolation. Especially, the increased percolation at the late growth stage in direct seeding plots was considered to its large amount of roots.

Average percolation rates per day during irrigation period influenced by tillage and seeding methods are in Table 2. No-till direct seeding needed the largest daily percolation of 19.5 l/m^2, and was followed by till direct seeding and no-till transplanting of 17.4 l/m^2, and transplanting of 15.2l/m^2. Those results are equivalent to 19.5, 17.4, and 15.2 mm per day, respectively.

Irrigation requirement

Irrigation requirement estimated by adding up daily the amounts of irrigation water and effective precipitation during rice growth period is listed in table 3. Direct seeding plots under till condition having 30 days longer growth period exhibited larger amounts of irrigation water and irrigation requirement than those of transplanting plots under no-till condition. Irrigation requirement was the largest in no-till direct seeding plots (3, 770l/m^2) and was followed by till-direct seeding (3, 249l/m^2), no-till transplanting (2,577l/m^2), and transplanting (2,321l/m^2), respectively.

In previous reports, irrigation requirement was estimated by the following formula, (evapotranspiration + percolation water - effective precipitation). Lee (1996) reported that irrigation requirement in direct seeding on flooded paddy surface was 1,263 mm by above method. However, in this experiment, the irrigation requirement was estimated by adding up the amount of daily measured irrigation water and the effective precipitation. Considering that the used soil was sandy loam, irrigation requirement in this experiment was estimated two times larger than results in previous studies. The estimated irrigation requirements of no-till transplanting, till-direct seeding and no-till direct seeding were increased by 11, 37, and 59%, respectively.

The direct rice seeding, especially no-till direct seeding adopted increasingly recently in Korea, needs large irrigation requirement due to high percolation rate. On the other hand, it has been a critical issue that the increase of nitrogen leaching caused by percolation could aggravate environmental pollution. As the result of this experiment using of sandy loam soil, it is confirmed that direct seeding and no-till culture needed larger amount of percolation water and irrigation requirement than transplanting and till culture respectively. Supposing that the irrigation requirement of till-transplanting plot is a standard, the irrigation requirement of no-till transplanting, till-direct seeding and no-till direct seeding plot increased 11%, 37%, and 59%, respectively. The percolation rate of no-till transplanting, till direct seeding and no-till direct seeding plot increased by 12%, 40%, and 66%, respectively, compared to till-transplanting plot. It is also considered that the increase of percolation rate in paddy soil after reproductive stage implies the environmental pollution may be caused by nitrogen leaching could be greater than the early fertilizer application stage.

ACKNOWLEDGEMENTS

This study is supported by the research fund of Dankook University.

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