Korean J. Crop Sci. 46(1): 47~52(2001)

Effects of Ditching on Seedling Stand in Wet Direct Seeding Rice Culture

Nam-Hyun Back*†, Si-Yong Kang*‡, Sang-Su Kim* and Tae-Oh Kwon**

**National Honam Agricultural Experiment Station, Iksan 570-080, Korea*
‡Present : RRC, Cheju National University, Jeju 690-756, Korea
***College of Life Science and Natural Resources, Wonkwang University, Iksan 570-749, Korea*

ABSTRACT : In order to develop more stable seedling stand method in wet direct rice seeding culture, the effect of making the drainage ditches was studied in both methods of broadcast seeding on floody paddy surface and puddled-soil drill seeding. In a broadcast seeding on floody paddy surface, the ditching after seeding using a tractor or small ditch maker improved the seedling stand, and reduced the floating seedling and herbicide injury by accelerating the drainage. Suitable ditching time was at 2 days after seeding (DAS) for the tractor and at 3 DAS for the ditch maker. In the puddled-soil drill rice seeding culture, the ditching before seeding with a ditch maker at 3 days after draining effectively improved the seedling stand due to quick draining through well formed the seeding furrows. In the puddled-soil drill seeding, seedling stand number showed higher in both ditching plots synchronized with seeding compared with both only draining treatment at 1 DAS without ditching and the flooding plot condition for 6 DAS. And the suitable ditching depth was 6 cm, as considered the ditching status and drained status. These results suggest that the ditching in wet direct rice seeding is an resonable practice for improving the seedling stand through the accelerating drainage of field.

Keywords : ditching, drainage, seedling stand, wet direct seeding, broadcast seeding on flooded paddy surface, puddled-soil drill seeding, rice

In 1999, the rice culture area by the wet direct seeding in Korea showed 44,507 ha, 63% of total direct seeding culture area. The wet direct seeding of rice in considered to be more effective in labor saving and prevention of weed occurrence including weedy rice than the dry direct seeding. However the total area of wet direct seeding rice has not increased in recent. The wet direct seeding of rice in Korea have been done practically by two main methods, i.e., broadcast seeding on flooded paddy surface and puddled-soil drill seeding. Between both, the former is considered to have advantage in labor saving, while the latter is more effective to prevent the lodging of rice plant during ripening stage (Lee *et al.*, 1993; Son *et al.*, 1996).

One of the main factors preventing the extension of wet direct rice seeding is unstable seedling stand. In the broadcast seeding on flooded paddy surface, sustaining the flooding condition for about one week after seeding, has been commonly recommended for warming effect during seedling stage, especially under low temperature. In that management condition, directly broadcasted rice seeds onto flooded soil surface sometimes result in many rice seedlings that fail germination or rooting and then rot or float (Hagiwara & Imura, 1996; Back *et al.*, 1998). Our previous study (Back *et al.*, 1999) suggests that seedling emergence and stand can be promoted by water management after seeding with shallow flooding or draining after seeding. Even the draining management just after direct seeding, however, occasionally results in inconsistent seedling stand in a field because seeds are exposed to different conditions from drained seeds in high positioned spots and to submerged seeds in lower positioned spots. Also the puddled-soil drill seeding is some what difficult to get stable seedling stand due to collapse of the seeding furrow and buried seeds by the rainy weather or insufficient draining (Kim *et al.*, 1994b; Song *et al.*, 1994).

Therefore, the development of stable seedling establishment method in both broadcast seeding on flooded paddy surface and puddled-soil drill seeding of rice is important for enlargement of wet direct seeding culture. In this study, we tested the effects of making of drainage ditches in both broadcast seeding on floody paddy surface and puddled-soil drill seeding of rice culture.

MATERIALS AND METHODS

Experiment 1 : Ditching in broadcast seeding on flooding paddy surface

The experiment was conducted at a farmer's paddy field, near of the experimental paddy field of National Honam Agriculture Experiment (NHAES), Rural Development Adm-

†Corresponding author: (Phone) +82-63-840-2167 (E-mail) backnh@rda.go.kr <Received February 16, 2001>

inistration (RDA), in Iksan city of Jeonbuk province. The soil type was a Jeonbuk series silty loam soil (fine silty, mixed, nonacid, mesic family of Aeric-Fluventic Haplaquent). The seeds of a japonica paddy rice cultivar Donganbyeo were sterilized by soaking for one day at room temperature into the mixing solution of a fungicide, prochloraz 0.5 ml l^{-1} and an insecticide, Fenitrothion 1 ml l^{-1} according to the manufacturer's directions. Upon rinsing by tap water, the seeds were germinated at 32°C under dark conditions in a rice seed incubator. The pregerminated seeds with 2~3 mm plumule length were directly broadcasted by hand at the rate of 40 kg ha^{-1} on the surface of puddled soil on May 12, 1998.

All experiment plots were fertilized with 110 kg N ha^{-1} at a split rate of 40 : 30 : 30% before seeding, tillering and panicle formation stage, respectively. Also P_2O_5 fertilizer at the rate of 70 kg ha^{-1} was totally applied before seeding and 80 kg K_2O ha^{-1} was fertilized at a split rate of 70 : 30% before seeding and panicle formation stage, respectively. For weed control, a granule herbicide, Dimepiperate+Bensulfuron at 2.14 kg a.i. ha^{-1} was applied at 15 DAS and 10 DAS for flooding condition and draining condition after seeding, respectively. Other managements were followed by the standard method of NHAES.

As shown in Table 1, the treatments with water management and ditching were divided into six as follows; T1; continuous flooding for 6 days after seeding (DAS) as a control, T2; draining for 6 DAS, T3 and T4; draining for 6 DAS plus ditching by a tractor at 1 DAS and 2 DAS, respectively, and T5 and T6 draining for 6 DAS plus ditching by a ditch maker at 2 DAS and 3 DAS, respectively. The drainage ditches by a tractor (Daedong, Co., Korea, 54 in horse power) mean the tire tracks. The ditching by the tractor was done at 10 m interval in paddy field. And the ditching by the ditch maker (KF22, Oodake Seisakusyo, Japan) was done at 10 m interval in paddy field upon the arranging of plower with 12 cm in depth, 21 cm in upper width and 10 cm in lower width. All plots with the draining treatments were flooded at 7 DAS, while the flooding plot was drained at 7 DAS for rooting for 4 days.

At 7 DAS, the formation status of drainage ditches by both the tactor and the ditch maker was determined by visual test on the scale of 1 (very good) or 9 (very bad). The soil hardness at the seeding date was measured as the depth of penetration of a conical penetrometer (115 g) dropped from 1 m in height. The number of seedling stand and floating seedlings were determined at 20 DAS, and crop injury by application of herbicide was observed at 20 days after application. And field lodging degree of rice was determined at maturity.

Experiment 2 : Ditching before seeding in puddled-soil drill seeding

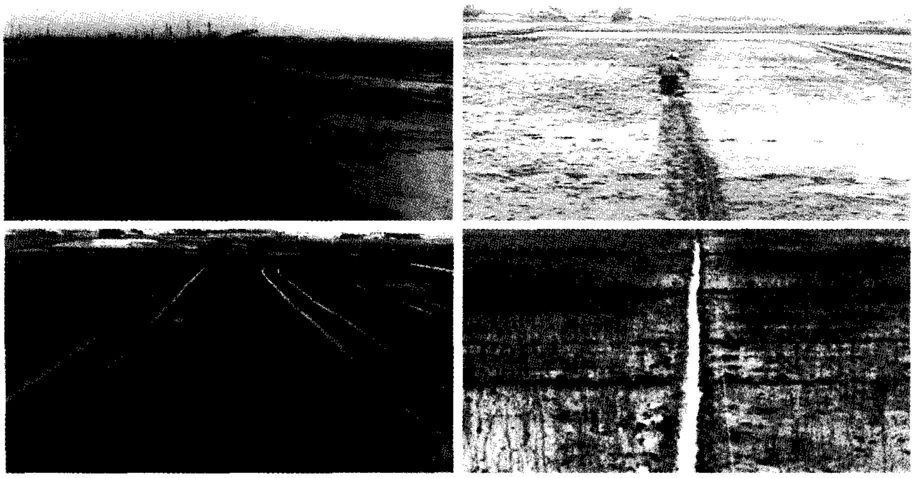
This experiment was conducted at paddy fields of NHAES using a rice cultivar 'Dongjinbyeo' in 1997 and 1998. The sterilized and pregerminated seeds were the same as Experiment 1 and seeded at rate of 50 kg ha^{-1} on May 18.

The treatments were classified into three practices, i.e., (i) soil preparation under flooding condition and then drained for 5 days as a control, (ii) ditching at 2 days after draining and (iii) ditching at 3 days after draining, and then both plots of (ii) and (iii) continued draining until seeding at 5 days after draining. Upon drill-seeding, the draining condition was the sustained until 7 DAS, thereafter the paddy was flooded. The ditch maker was same as the Experiment 1 and each distance between the ditches was 5 m. The rainfall amounts for 5 days before seeding in 1997 and 1998 were 10.0 mm at 1 days after draining and 22.0 mm at 4 days after

Table 1. Effects of ditching after seeding on seedling stand, crop injury of herbicide and field lodging degree in broadcast seeding on wet paddy surface.

Treatment†	Seedling stand number (no. m^{-2})	Seedling stand uniformity (C.V.‡)	Floating seedling rate	Herbicide		Rice field lodging (0~9)
		---------- % ----------		appling time (DAS)	crop injury (0~9)	
T1	79	19.2	13	15	1	3
T2	98	10.3	2	11	0	3
T3	112	9.5	0	10	0	1
T4	118	8.8	0	10	0	1
T5	118	8.3	0	10	0	1
T6	122	7.2	0	10	0	1
LSD(5%)	7	4.2	3			

†T1; flooding for 6 DAS(Control), T2; draining for 6 DAS, T3; draining for 6 DAS + ditching at 1 DAS by a tractor, T4; draining for 6 DAS + ditching at 2 DAS by a tractor, T5; draining for 6 DAS+ditching at 2 DAS by a ditch maker, T6; draining for 6 DAS + ditching at 3 DAS by a ditch maker.
‡Coefficient of variation



(A) Ditching track by a tractor (B) Ditching by a ditch maker

Fig. 1. Ditching appearance in field at 20 DAS by a tractor (A) and a ditch maker (B) in wet direct broadcast seeding on flooded surface.

draining, respectively. The rainfall amount for 6 DAS in 1997 showed 3.0 mm and 3.5 mm at 5 DAS and 6 DAS, respectively, and it showed zero in 1998. Fertilizer application was the same as the Experiment 1, and for the weed control the granule herbicide Dimepiperate+Bensulfuron at rate of 2.14 kg a.i. ha^{-1} was applied at 15 DAS.

Draining status before seeding, soil hardness at seeding time, the status of seeding furrow and seedling stand establishment were determined.

Experiment 3 : Ditching synchronized with seeding in puddled-soil drill seeding

The effects of ditching synchronized with machine seeding in puddled-soil drill seeding were studied on an experimental paddy field of NHAES in 1997 and 1998. On May 18 of both years, the sterilized and pregerminated seeds of a rice cultivar 'Dongjinbyeo' were seeded at rate of 50 ha^{-1} on the paddy field drained for 5 days upon making the drain ditches before seeding. The treatments were consisted four methods i.e., (i) seeding and then flooding for 6 DAS as a control, (ii) seeding and flooding for 1 day and then redraining, (iii) ditching synchronized seeding and flooding for 1 day and then redraining, and (iv) ditching synchronized seeding and draining till emergence of seedling. The reason for setting the flooding treatment for 1 DAS was to mimic the field condition when there may have some rainfall after seeding. The ditching was made synchronically using a hopper (8 cm in upper width, 5 cm in lower width) attached to both side of the automatic drillseeder. Fertilizer application was the same as the Experiment 1. For the weed control the granule herbicide Dimepiperate+Bensulfuron at rate of 2.14 kg a.i. ha^{-1} was applied at 15 DAS for (iii) and (iv) plots, 17 DAS for (ii) plot and 19 DAS for (i) plot.

Drained status in drain ditches, seeds buried depth and seedling stand establishment were determined at 6 DAS.

RESULTS AND DISCUSSION

Effects on seedling stand by ditching in broad cast seeding on flooding paddy surface

In our previous study (Back *et al.*, 1999), we suggested that the draining management after seeding in direct wet seeding rice is the most effective method to improve the seedling stand rate. But, occasional rainfall during the draining period after seeding cause lower seedling establishment. The seedling stand also show the inconsistency in a field with draining management after seeding, where it show good on higher area and bad standing on lower area (Hagiwara & Imura, 1993; Park *et al.*, 1996). In this study, we compared the ditching effects on seedling stand during the draining period. The seedling stand number showed the highest (122 m^{-2}) on the plot of draining for 6 DAS + ditching at 3 DAS by a ditch maker (T6), and lowest (79 m^{-2}) on the flooding for 6 DAS (Table 1). The plot of only draining for 6 DAS (T2) also showed significantly lower seedling stand number than other plots with ditching treatments. And the seedling stand number on both plots of draining for 6 DAS+ditching at 2 DAS by a tractor (T4) or ditch maker (T5) was similar to that of the draining for 6 DAS+ditching at 1 DAS by a tractor (T3). The uniformity of seedling stand represented by the coefficient of variation (C.V.) showed negative correlation with the seedling stand number. Float-

Table 2. Soil hardness, ditch status, drained status and working hours among the different ditching methods.

Treatment	Soil penetration depth (cm)	Ditch status (1~9)†	Drained status at 7 DAS (1~9)†	Working hours (Min. ha^{-1})
T2	-	-	6	-
T3	13	5	3	20
T4	11	2	1	20
T5	11	6	4	40
T6	8	4	2	40

†1; Very good, 9; very bad

ing seedling rate was 13% in flooding management after seeding and 2% in draining after seeding without ditching, while that was not founded in all plots with ditching treatments.

In the rice wet direct seeding, the first application of herbicide after seeding was usually recommended after rooting of seedlings. The results of this study indicated that the ditching management after seeding did not caue the crop injury due to herbicide application at 10~11 DAS, but the crop injury by the herbicide occurred in flooding management after seeding applied even at 15 DAS (Table 2). Rice lodging at maturity was also reduced by the ditching treatment after seeding compared with flooding or only draining management after seeding.

In broadcast rice seeding on wet paddy surface, one of most important factors for improving seedling establishment is the better rooting of rice seedling, which is stimulated by aerobic condition under drained soil (Back *et al.*, 1999; Hagiwara & Imura, 1993). The positive effects of ditching after seeding on seedling stand number and less floating seedling may also be affected by improvement of rooting of rice seedling. And the ditching also made to be early applied the herbicide as well as decreased the field lodging of rice (Table 1), which may also derive from improved rooting of rice plant not only at seedling stage, but also during mid-late growth stage by accelerated midsummer drainage through the drain ditches. And the drain ditches can be used as the path for the working practices such as applying fertilizers, herbicides and pesticides. Although there was a rainfall of 22 mm at 4 DAS, the ditching plots were effective to improve the seedling stand by the accelerated drainage.

As shown in Table 2, the soil hardness, draining ditch status by ditching methods were determined to clarify the suitable ditching time. The drainage ditch status and drained status by a tractor were not good in the ditching at 1 DAS, where the ditches were collapsed and therefore draining was done slowly due to delayed soil hardening, showing 13 cm in soil penetration depth. Compared to the ditching at 1 DAS, both drainage ditch and drained status showed very nice in ditching at 2 DAS, where the penetration depth of conical penetrator was 11 cm. For the ditch maker, on the other hand, the ditching status at 3 DAS was better compared with the ditching at 2 DAS. These results suggest that the suitable ditching time are at 2 DAS by a tractor and at 3 DAS by a ditch maker, although the suitable ditching time vary depending on the differences of soil properties, drained status and plowing depth, etc. Between both ditching methods, the plot with tractor made ditches showed not only better draining than with the ditch maker, but also shorter working hours such as 20 minutes and 40 minutes per ha, respectively.

Improvement of seedling stand and draining by the ditching before seeding in puddled-soil drill seeding

In the puddled-soil drill seeding of rice, soil hardening after soil plowing and leveling under flooding condition is one of important factors to form the good seeding furrow for stable seedling stand (Kim *et al.*, 1994a; Son *et al.*, 1996). However, if there is some rainfall during the field draining, unstable draining particularly in lower positioned spots of field cause collapsing of the seeding furrow and burying of seeds into the soil due to late soil hardening (Hwang *et al.*, 1994; Kim *et al.*, 1994b). In this study, therefore, we studied the effects on draining and seedling stand of the ditching by a ditch maker during draining period before seeding (Table 3). The status of seeding furrow showed the best in the ditching at 3 days after draining, although there were some rainfall at 1 day after draining in 1997 and at 3 days after draining in 1998.

The seedling stand number decreased following in order as the ditching plot at 3 days after draining and then seeding at 2 days after, the ditching plot at 2 days after draining and then seeding at 3 days after ditching, and the draining plot without ditching as the control.

Thus the ditching with a ditch maker during draining before seeding in puddled-soil drill seeding culture of rice can improve the seedling stand derived from the good formed seeding furrow due to accelerating the draining. The suitable ditching time may be 3 days after draining, although if there is rainy weather the ditching and seeding times should be rearranged.

Effects on seedling stand by ditching synchronized with seeding in puddled-soil drill seeding

In puddled-soil drill seeding of rice culture, poor seedling stand usually occur in poorly drained field spot during the seedling stage after seeding, especially when some rainfall

Table 3. Drained status, soil hardness, seeding plough status and seedling stand number affect as ditching treatments before seeding in puddled-soil drill seeding.

Treatments after soil leveling under flooding	Drained status (1~9)		Soil penetration depth (cm)		Seeding furrow status (1~9)		Seedling stand number (No. m^{-2})	
	1997	1998	1997	1998	1997	1998	1997	1998
Draining for 5 days→Seeding	4	5	7	8	6	7	113	107
Draining for 5 days with ditching 2 days after draining→Seeding	2	3	6	7	3	4	154	146
Draining for 5 days with ditching 3 days after draining→Seeding	1	2	5	6	2	3	166	152
LSD(5%)							14	23

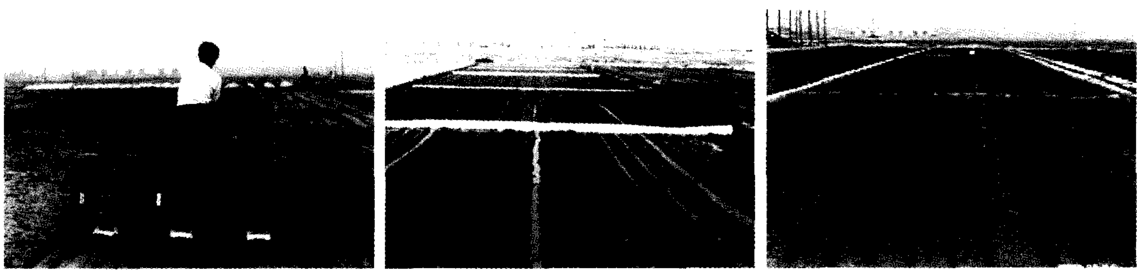
after seeding result stored water into the seeding furrow and then collapsed seeding furrow (Kim *et al.*, 1996). And most buried seeds fail to emerge due to soil reduction, absence of oxygen and diseases (Hagiwara & Imura, 1996). Therefore, the efficient water management methods are essential for improving the seedling stand in puddled-soil drill seeding. We made the draining ditches synchronized with seeding by machine seeder, and then studied the ditching effects on seedling stand (Table 4; Fig. 2). Seedling stand number showed the highest in the plot with ditching synchronized with seeding and then draining till seedling emergence that might be caused by minimizing burial of seeds into soil. And the ditching and draining treatment at 1 DAS also showed better seedling stand and drained status. On the other hand, only draining treatment at 1 DAS without ditching showed unstable seedling stand on lower spots of the plots due to delayed draining and some deeply buried seeds. The flooding polt for 6 DAS, as a conventional method, resulted in collapsed seeding furrow, deep buried seeds, late seedling emergence and bad seedling stand.

In conclusion, the ditching synchronized with seeding results in good seedling stand by early draining of seeding furrow and few seeds burying into soil. And ditching also permitted to apply the herbicide on earlier time at 15 DAS compared with at 17 DAS and 19 DAS in both plots of flooding for 1 day and then draining and flooding for 6 DAS, respectively.

Finally, in order to clarify the resonable ditching depth, three ditching depths were compared for ditch status and drained status in seed furrows (Table 5). Both ditching depths of 4 cm and 6 cm were good for ditching status, but 8cm-depth ditching was impossible due to overload of direct seeding machine. And drained status was best in 6 cm-depth ditching.

Table 4. Effects of ditching and water management treatments synchronized with seeding in puddled-soil drill seeding against the seedling stand.

Ditching and water management treatment	Drained status in seeding furrow at 6 DAS (1~9)	Seed buried depth at 6 DAS (mm)	Seedling emergence time (DAS)	Seedling stand number (No. m^{-2})	Seedling stand uniformity (C.V.) (%)
Seeding→Flooding for 6 days	-	3	11	94	20.3
Seeding→Flooding for 1 day→Draining till seedling emergence	5	2	10	120	17.1
Seeding+Ditching→Flooding for 1 day→Draining till draining	2	1	8	148	12.4
Seeding+Ditching→Draining till seedling emergence	1	0	-	162	10.2
LSD (5%)		2		6	



(A) Seeding (B) At 6 DAS (C) At 30 DAS

Fig. 2. Ditching synchronized with seeding (A), draining status (B) and seedling stand (C) in puddled-soil direct rice seeding.

Table 5. Ditching status and drained status by the ditching depth in puddled-soil drill seeding of rice culture.

Ditching depth (cm)	Ditching status (1~9)	Drained status at 7 DAS
4	2	good
6	2	very good
8	Overload	very bad

In conclusion, the results of this experiment suggest that the ditching in wet direct rice seeding is an recommendable practice for improving the seedling stand through the accelerating drainage of field. And for the adopting this method, the seeding rates should be reduced from the recommended rates of 4 kg and 5 kg per 10a for broadcast seeding on flooded surface and puddled-soil drill seeding, respectively, to prevent the excess of rice growth caused by too higher seedling stand.

ACKNOWLEDDGEMENTS

A part of this study was supported by Wonkwang University in 2000.

REFERENCES

Back, N. H., S. S. Kim, I. B. Im, M. G. Choi, W. H. Yang, and S. Y. Cho. 1998. The optimum of seedling date and rate on growth and yield of rice in water seeded rice at southern plain area. RDA. J. Crop Sci. 40(2) : 33-38.

Back, N. H., S. S. Kim, S. Y. Kang, M. G. Choi, H. T. Shin, and T. O. Kwon. 1999. Seedling stand influenced by management after seeding and seed soaking with plant growth regulators in direct wet seeding rice. Korean J. Crop Sci. 44(3) : 225-229.

Hagiwara, M. and M. Imura. 1993. Varietal difference and temperature response of local soil-reduction around germinating rice seed. Jpn. J. Crop Sci. 58 : 105-110.

Hagiwara, M., and M. Imura. 1996. Interaction between germinating rice seed and soil influences seedling emergence in direct seeding into flooded soil. *In* Crop Research in Asia: Achievements and Perspective. Eds R. Ishii and T. Horie. pp. 224-227. Proceedings of the 2nd Asian Crop Science Conference. Fukui, Japan.

Hwang, D. Y., S. C. Kim, B. T. Jun, and B. C. Moon. 1994. Appropriate soil hardening method for wet-seeding rice. RDA. J. Crop Sci. 36(2) : 13-18.

Kim, S. K., B. W. Lee, W. H. Lee, K. S. Lee, and B. S. Choi. 1994a. Promotion of the emergence and establishment of seedling in paddy rice sown into puddled soil. RDA. J. Crop Sci. 36(2) : 6-12.

Kim, S. S., N. H. Back, S. J. Seok, S. Y. Lee, J. H. Kim, and D. S. Cho. 1994b. Effect of drainage duration before seeding and furrow depth seedling establishment and growth in direct seeding culture of rice on puddled soil. Korean J. Crop Sci. 39(6) : 531-536.

Kim, S. S., H. G. Park, W. Y. Choi, S. Y. Lee, S. Y. Cho, and D. S. Cho. 1996. Effects of sprout length, CaO_2 coating and seedling depth on seedling stand and early growth in puddled-soil drill seeding of rice. Korean J. Crop Sci. 41(3) : 295-301.

Lee, S. Y., S. S. Kim, I. B. Im, S. J. Seok, and C. H. Kim. 1993. The current status, problems and future research projects of direct seeded cultivation in flooded paddy field in Korea. Direct Seeding Cultivation Research. HCES. pp. 58-76

Park, S. H., C. W. Lee, W. H. Yang, and R. K. Park. 1986. Direct seeding cultivation on submerged paddy in rice. 1. Seedling emergence and early growth under different temperature and seeding depth. Korean J. Crop Sci. 31(2) : 204-213.

Son, Y., D. Y. Hwang, B. C. Moon, S. T. Park, and S. C. Kim. 1996. Improvement of initial seedling establishment in wet drill seeded rice. RDA. J. Agri. Sci. 38(1) : 34-40.

Song, Y. J., S. J Kwon, and C. J. Hwang. 1994. Sowing method and flooding time at furrow sowing culture of rice in paddy field. Korean J. Crop Sci. 39(3) : 205-210.