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Seedling Stand Influenced by Water Management after Seeding and Seed Soaking with Plant Growth Regulators in Direct Wet Seeding Rice

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ABSTRACT

Unstable seedling stand establishment of wet direct seeding culture of rice is one of the major elements preventing the extension of its culture area. In order to develop methods of seedling stand improvement in direct seeded rice on flooded surfaces, three field experiments were conducted on silty loam soil using a cultivar 'Donjinbyeo' for three years, mainly focusing on water management after seeding and seed soaking with plant growth regulators (PGRs). Under the condition of shallow flooding after seeding, seedling stand rate increased and floating seedling rate decreased in both early and normal season seeding compared to deep flooding. With earlier draining time after seeding, there was a tendency towards preferential growth of the seminal root, increase of seedling stand and decrease of the floating seedling rate. Therefore the highest seedling numbers per unit area and the lowest floating seedling numbers were found upon drainage at 1 day after seeding (DAS), while a contrary tendency was shown upon conventional drainage at 7 DAS. Seed soaking with PGRs such as Metalaxyl or mixing of Metalaxyl with gibberellic acid (GA_3) significantly increased the seedling stand. In addition the effects of PGR treatment on seedling stand and the early growth of plants were greater under flooded conditions than under drained conditions after seeding, although draining of water after seeding improved the seedling establishment rate more when compared with the PGR treatment. These results suggest that draining management after seeding or maintaining of shallow flooding for a week is the most effective method to improve the seedling stand rate in wet direct seeding.

Keywords : rice, wet direct seeding, seedling stand, water management, plant growth regulators.

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SEEDLING STAND BY WATER MANAGEMENT AND PGRs IN WET DIRECT SEEDING

Currently, rice in Korea is directly seeded on dry or wet soil in about 10% of the rice cultivated area, and the wet direct seeding culture under tillage is predominant in the Honam district. However, the area of wet direct seeding has not been increasing since the mid 1990s. The main factors preventing the enlargement of the wet direct seeding culture are unstable seedling establishment and greater susceptibility to lodging (Lee et al., 1993).

Broadcast seeding on flooded paddy surfaces as a wet direct seeding method is considered to be more effective in labor saving and prevention of weed occurrence including weedy rice than dry direct seeding. Rice that is broadcasted onto the flooded soil surface, results in many rice seedlings that don't root and then float to die. The inconsistency of seedling establishment in wet direct surface seeding, which may vary with varieties, cultural conditions, weather and intensity of pest damages (Back et al, 1998; Hagiwara and Imura, 1993; Park et al., 1993), is not only closely related to weed and lodging problems but also an important determinant of yield. Although a seeding rate of about 40kg ha^{-1} is recommended in wet direct seeding, Korean farmers commonly use a higher seeding rate to ensure seedling stand, and it sometimes induces lodging at maturity. In Japan, on the other hand, a wet direct seeding method of sowing seeds coated with calcium peroxide(CaO_2) into flooded soil was developed to stabilize seedling establishment and to improve lodging resistance (Hagiwara and Imura, 1991; Ota, 1984). However, unstable seedling establishment is still observed in the method and the high expense for seed coating is still a problem (Hagiwara and Imura, 1996; Kim et al., 1996).

As the fruit of Korean rice breeder's efforts to breed direct seeding adaptable cultivars, some cultivars have recently been developed, e.g., 'Nonganbyeo', 'Daesanbyeo' and 'Donganbyeo', etc. These cultivars are characterized by improved lodging resistance but not better seedling establishment yet

(Kang et al, 1998). Therefore the development of new management methods to ensure stable seedling establishment is needed immediately to extend the wet direct seeding culture. We performed this study to clarify the effects of water management after wet direct seeding and presowing soaking treatment with PGRs on seedling establishment.

MATERIALS AND METHODS

Experiment 1: Flooding depth after seeding

All experiments were conducted at paddy fields of National Honam Agricultural Experiment Station (NHAES), Rural Development Administration (RDA). Soil type was a Chonbuk series silty loam soil (fine silty, mixed, nonacid, mesic family of Aeric-Fluventic Haplaquent). The seeds of a japonica paddy rice cultivar 'Dongjinbyeo' were sterilized by soaking for one day at room temperature in a solution of fungicide, prochloraz 0.5 $m\ell\ \ell^{-1}$ and an insecticide, fenitrothion 1 $m\ell\ \ell^{-1}$ according to the manufacturer's directions. Upon rinsing by tap water, the seeds were germinated at 32℃ under dark conditions in a rice seed incubator. The pregerminated seeds with 2~3 mm plumule length were directly broadcasted at the rate of 40 kg ha^{-1} on the surface of puddled soil on April 25 and May 14, 1996 as early and normal season seeding date, respectively. Plots 1.3 by 5.2 m were arranged in a split plot design with three replications. The treatments of flooding water regime were three water depths i.e., 1, 3 and 6 cm. The plots were flooded from one day before sowing to 7 DAS and then drained for 3 days before reflooding.

All experiment plots were fertilized with 110kg 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 for seeding on April 25 and at 10 DAS for seeding on May 14.

Seedling number, floating seedling number, seedling length and soil buried crown depth were measured at 20 DAS, and the lodging degree was determined at 20 days after heading following the RDA method.

Experiment 2: Drainage time after seeding

The experiment was done at paddy fields of NHAES in 1996 and 1997. The pregerminated seeds of 'Dongjinbyeo' with 2~3 mm plumule length at rate of 40 kg ha^{-1} were directly broadcasted on the surface of flooded puddled soil on April 25 and May 14 in both years. The treatments of water draining were divided into three, (i) drained at 1 DAS, (ii) drained at 4 DAS, and (iii) drained at 7 DAS. The preparation of seeds, other cultural practices, plot arrangement and investigation methods were done as described in Experiment 1.

Experiment 3: Soaking seeds with PGRs

This experiment was conducted at paddy fields of NHAES using a rice cultivar 'Dongjinbyeo' in 1997 and 1998. The seed sterilization was the same as Experiment 1, and the soaking treatments of PGRs were simultaneously done into a sterilizing solution for 24 hours as follows; (i) GA_3 30 ppm, (ii) Metalaxyl 200 ppm, (iii) GA_3 30 ppm+ Metalaxyl 200 ppm, (iv) GA_3 30 ppm+ Metalaxyl 200 ppm WP + 500^{-1} dilution of Oxadixyl-Mancozeb WP and (v) nontreatment as the control. The dilute concentration of each PGRs for soaking treatment was adopted from the previous experiments (Kim et al., 1991; Kim et al., 1993; Oh, 1989). Fields were drained for 6 days from 1 DAS and drained for 3 days from 6 DAS.

Other cultural practices, i.e., fertilization, seeding and weed control were the same as experiment 1. Seedling number, floating seedling number, plant height and soil buried crown depth were determined at 20 DAS.

RESULTS

Seedling stand affected by flooding depth after seeding

As shown in Table 1, the number of seedlings and percentage of seedling establishment increased at shallow flooding depths at both seeding dates, while the percentage of floating seedling increased at deeper flooding depths. The number of seedlings and percentage of seedling establishment were lower in seeding on April 25 than on May 14, which seemed to be mainly influenced by the difference of air temperature between two dates.

Seedling stand affected by drainage time after seeding

To clarify the effects of drainage time on seedling growth, draining after seeding was done at 1, 4 DAS and conventional method (7 DAS), and the results were shown in Table 2. The earlier the drainage time was, the plumule length was shorter but the seminal root was longer. Also, the length of plumule and seminal root was longer in late seeding (May 14) than in early seeding (April 25).

Compared with drainage at 7 DAS, the number of seedlings and percentage of seedling establishment

Table 1. Seedling stand number, percent of seedling establishment and percent of floating seedling as influenced by flooding depth after rice direct seeding on flooded paddy surface at two seeding dates in 1996.

Seeding date (SD)	Flooding depth (FD)	Seedling stand number per m^2	Percentage of seedling establishment	Percentage of floating seedling
April 25	1 cm	97	71	0
	3 cm	91	66	2
	6 cm	84	61	17
May 14	1 cm	105	77	0
	3 cm	101	74	6
	6 cm	97	71	22
LSD(5%)				
SD		9	6	6
FD		4	3	3
SD×FD		5	4	4

Table 2. Length of plumule and seminal root influenced by seeding date and drainage time on direct seeded rice at 7 days after seeding (DAS).

Seeding date (SD)	Drainage time (DT)	Length (mm)	
		Plumule	Seminal root
April 25	1 DAS	9	16
	4 DAS	14	8
	7 DAS	17	5
May 14	1 DAS	16	21
	4 DAS	21	11
	7 DAS	24	9
LSD(5%)			
SD		4	2
DT		3	2
SD×DT		4	3

were significantly increased in drainage at 1 DAS at both seeding dates and in both years (Table 3). Floated seedlings were not found in drainage at 1 DAS, while they were slightly increased in drainage at 3 DAS and 7 DAS. The plant height at 20 DAS was not greatly different among the drainage times in both years, although the value was slightly higher in drained at 7 DAS than that of 1 DAS. And the crown burial depth of a seedling at 20 DAS was increased by early drainage.

Wet direct seeded rice is more susceptible to lodging than dry direct seeded or transplanted rice because the crown base of a surface seeded rice plant is buried in shallow depth of soil. The field lodging at ripening stage was reduced by the early draining time.

Effects of seeds soaking with PGRs

Table 4 shows the effects of PGRs treatments on seedling stand and seedling growth at 20 DAS. GA_3 and Metalaxyl stimulated the seedling stand and reduced the floating seedling in both years and both water management conditions. The effect on seedling stand and growth was greater in mixing treatments of GA_3+Metalaxyl or GA_3+Metalaxyl+Oaxadixyl-Mancozeb.

The number of seedlings per unit area was higher in draining conditions than flooding conditions, but the promotive effect on seedling stand by PGRs treatment was larger under flooded condition than drained conditions, although under drained conditions, number of seedlings per m^2 in non-treated seeds was 92 to 102 plants over the critical minimum seedling stand level of 80 plants m^{-2} in both years.

DISCUSSION

In wet direct seeding rice culture, it has been recommended that flooding conditions be sustained for about one week after seeding until the emergence stage of the first complete leaf, and thereafter, drainage for rooting for 2 to 4 days. The advantage of flooding conditions on wet direct seeded rice is thought to be the warming effect during seedling emergence, especially under low temperature. However, the results of present experiments showed that seedling emergence and stand were hindered by deep flooding after wet direct seeding, and those defects were improved by water management after seeding with shallow flooding or draining after seeding. In particular, the seedling establishment was substantially promoted in plots drained at 1 DAS. And it also reduced the algae infestation (data not shown). It seems that the oxidation of soil around the seed by draining rather than the warming effect is more important for the promotion of emergence and establishment of seedling. Oba (1997) also reported that draining just after seeding improved the seedling stand in wet direct seeding.

Hagiwara and Imura (1991, 1996) reported that soil reduction around seeds under flooding condition is one of the major factors inhibiting emergence and seedling establishment and even a CaO_2-coating does not maintain the soil oxidizing effects long or strong enough to stabilize seedling emergence under flooded conditions. When a pregerminated seed was sown onto or into the flooded soil, the coleoptile and first leaf started to elongate much faster than the root (Park et al., 1993), because the coleoptile of rice develops even in the absence of oxygen but roots do not (Alpi and Beevers, 1983). When drained under this condition, many rice plants fail to anchor their

Table 3. Seedling stand and growth characteristics as influenced by drainage time after direct seeding on flooded paddy surface.

Seeding date (SD)	Drainage time (DT)	No. of seedling stand per m^2		Percentage of floating seedling		Plant height (cm)		Crown burial depth of plant(cm)		Lodging degree (0~9)	
		1996	1997	1996	1997	1996	1997	1996	1997	1996	1997
April 25	1 DAS	95	115	0	0	10.0	9.6	2.6	2.2	1	1
	4 DAS	79	97	0	6	10.5	10.1	2.3	1.9	3	3
	7 DAS	79	74	2	9	10.4	10.4	2.1	1.7	3	3
May 14	1 DAS	105	121	0	0	15.1	15.1	3.1	2.7	0	0
	4 DAS	99	109	3	9	15.3	15.3	2.7	2.3	3	3
	7 DAS	93	77	7	12	15.7	15.9	2.5	1.9	3	3
LSD(5%)											
	SD	5	16	1	4	0.1	0.6	0.1	0.2	1	1
	DT	6	6	1	2	0.5	0.3	0.3	0.3	1	1
	SD×DT	8	9	1	3	0.7	0.5	0.5	0.4	1	1

Table 4. Seedling stand and growth characteristics at 20 days after seeding as influenced by water management methods and PGRs after rice direct seeding on flooded paddy surface.

Water management after seeding (WM)	PGR treatment †	No. of seedling stand		Plant height (cm)		Percent of floating seedling		Root dry weight (g 30 $plant^{-1}$)	
		1997	1998	1997	1998	1997	1998	1997	1998
Flooding	Control	77	82	8.8	9.1	11	17	0.23	0.40
	GA_3	91	88	10.4	10.8	8	13	0.25	0.44
	Metalaxyl	95	98	9.1	9.4	5	9	0.29	0.46
	GA_3+Metalaxyl	101	104	10.9	11.2	3	7	0.32	0.47
	GA_3+Metalaxyl+Oxa.	108	112	11.1	11.4	2	6	0.33	0.47
Draining	Control	92	102	8.4	11.4	0	0	0.27	0.47
	GA_3	100	106	9.7	12.3	0	0	0.28	0.49
	Metalaxyl	105	113	8.8	11.7	0	0	0.33	0.54
	GA_3+Metalaxyl	113	118	10.3	12.6	0	0	0.35	0.56
	GA_3+Metalaxyl+Oxa.	120	122	10.7	12.8	0	0	0.36	0.54
LSD(5%)									
WM		6	6	0.4	0.4	3	5	0.04	0.04
PGR		4	6	0.4	0.3	1	1	0.02	0.03
WM×PRG		6	8	0.6	0.5	2	2	0.03	0.04

†; GA_3; 30 ppm of gibberellic acid, Metalaxyl; 200 ppm of Metalaxyl, Oxa.; 500^{-1} dilution of Oxadixyl-Mancozeb.

roots in the soil and then float upon re-irrigation. Our observation also showed such a tendency, as relatively dominative growth of shoot than of seminal root under flooding condition, but under drained condition it showed a reversed growth tendency. This may also be one important reason why the seedling establishment becomes unstable under flooding conditions after seeding.

The PGRs also stimulated seedling stand and growth of wet direct seeded rice, especially in mixing treatments of GA_3+Metalaxyl and GA_3+Metalaxyl+Oxadixyl. It was reported that GA_3 stimulated the seedling emergence (Kim et al., 1993) as well as elongation of seedling shoots (Helms et al., 1991; Kim et al., 1989), and Metalaxyl also promoted seedling growth, particularly rooting or mat formation (Kim et al., 1991; Oh, 1989). And the promotive effects by PGRs on seedling stand and growth were higher in flooding than in drained condition, although the absolute value of seedling stand per unit area was higher in the drained condition than in the flooding condition. On the other hand, low temperature also inhibited seedling development (Park et al., 1986), and in this study the difference of seedling stand between two seeding times may reflect the effects of temperature. We could not elucidate, however, the warming effects by flooding after seeding on seedling stand. In an area or early season with low temperature at seeding time of wet direct seeding culture, if it is necessary to sustain flooding conditions after seeding to give a warming effects to seeds, the presowing soaking treatment with PGRs, Metalaxyl or GA3, can also be recommended to improve the seedling stand as indicated by the effects of PGRs in the present study.

In conclusion, the results of this experiment suggest that shallow flooding (1~2 cm in depth) or draining just after seeding (at 1 DAS) are the most resonable methods for improving seedling stand in wet direct seeding culture. The maintenance of shallow flooding may be more difficult than draining just after seeding, therefore the latter will be more practical. Draining at 1 DAS (or just after seeding) means that when the seeds and soil particles were submerged on surface soil for one day and initial 5~6 days until cracking of surface soil water should be drained to provide enough soil oxygen for seed germination and good root anchor. However, draining at 1 DAS probably 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, and damage by birds and rats. Also in drainage just after seeding, the seedling stand may be hindered due to seed dehydration on sandy soil with severe water leaking under strong sunny days. In draining just after seeding the seeding rate of 40 kg $10a^{-1}$ may be too much because an improved seedling stand can induce plant overgrowth and lodging occurrence in some cases. Therefore, some subsequent practices to solve such problems in drainage management after seeding will be required for a stable seedling stand.

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