Optimum Water Potential, Temperature, and Duration for Priming of Rice Seeds

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ABSTRACT

Experiments were carried out to find out the optimum water potential, temperature, and duration for the priming of rice seeds, *Oryza sativa* L. (cv. Ilpumbyeo) for better germination at sub-optimal temperatures. Seeds were primed in 0, −0.2, −0.4, −0.6, −0.8, and −1.0 MPa PEG (polyethylene glycol) solutions at 25℃. The optimum water potential for seed priming, the highest water potential at which rice seeds did not germinate, was −0.6 MPa. To find out optimum priming temperature and duration rice seeds were primed in −0.6 MPa PEG solution and 0 MPa (water as a control) for various durations at 15 and 25℃ and the seeds were germinated at 17, 20, and 25℃. Considering germination rate and speed, the optimum priming time in water (0 MPa) was 4 days at 15℃ and 1 day at 25℃, while 4 days was the optimum priming time in a −0.6 MPa PEG solution, regardless of the priming temperature. Priming reduced the actual time of germination, especially at sub-optimal temperatures. Priming did not affect germination rate in −0.6 MPa PEG solution at 15℃, but overpriming reduced the final germination rate in water at 15℃ and in −0.6 PEG solution at 25℃. Total sugars and α-amylase activity induced during the seed priming were negatively correlated with the final germination rate and there was no noted relationship with the speed or uniformity of germination.

Key words : rice seeds, PEG solution, water potential, germination rate, uniformity of germination.

Traditionally, rice seedlings have always been transplanted in Korea, but in recent years, direct seeding has been extensively studied to reduce production costs, i.e. removing the expenses for raising and transplanting rice seedlings. In the transplanting of rice seedlings, the seeds were presoaked in water and then germinated at the optimum germination temperature. The well germinated seeds were sown in a protected nursery bed of soil. However, when dry seeds are planted directly in field under upland conditions, poor emergence rate and delayed germination were often serious problems, especially at early planting. When seeds were planted at low temperatures, the seeds germinate slowly and display significant individual variation. However, uniform and rapid germination are necessary to obtain the optimum plant population in the direct seeding of rice.

The priming of seeds in a proper PEG solution improved the overall germination rate and uniformity of growth, and reduced the time to germination, particularly in many vegetable crops such as celery (Drew and Dearman, 1993; Rennick and Tiernan, 1978), parsley (Akers, 1987), tomato (Muhyaddin and Wiebe, 1989), onion (Furutani et al., 1986), leek (Nienow et al., 1991). Also, similar priming effects were observed in some field crops such as corn, barley, wheat, sorghum, and soybean (Bodsworth and Bewley, 1981) under the adverse environmental conditions such as suboptimal temperatures or inadequate soil moisture conditions. However, such information is limited in the priming of rice seeds. Therefore, in these experiments, optimum priming conditions such as temperature, water potential, and duration of the priming time for rice seeds were studied to improve seedling establishment at early planting of rice seeds.

MATERIALS AND METHODS

Seeds of a rice variety, Ilpumbyeo, grown at the Kyongbuk Provincial Rural Development Administration Farm in Taegu, Korea in 1995 were used in these experiments in 1996.

To find out the optimum water potential for the priming of the rice seeds, 0, −0.2, −0.4, −0.6, −0.8, −1.0 MPa PEG solutions were used with molecular weights of 8000 PEG (Michel, 1983). Seeds were primed in a selected optimum water potential of −0.6 MPa in PEG solution and in 0 MPa of water as a control at both 15 and 25℃. For the seed priming in water, rice seeds were soaked for 1, 4, 7, 10, and 13 days at 15℃ and another batch of seeds for 1 and 2 days at 25℃. In the −0.6 MPa PEG solution, seeds were soaked for 1, 4, 7, 10, and 13 days at both 15℃ and 25℃. Twenty five grams of the seeds were soaked in 500ml of the priming solution in glass cylinders and air-bubbled during the priming period. After the priming the seeds were washed in running tap water and then dried at room temperature. Prior to use, the dried seeds were stored in a freezer, set at −12℃.

Germination rates were observed on a daily basis at 17, 20, and 25℃, according to the AOSA method (AOSA, 1990). To study the physiological characteristics and changes during the priming, the seeds were ground in a Wiley Mill (General Electric, USA) and then passed through a #20 mesh screen. For the determining of total sugars, 1.0g of the ground samples was soaked in 10ml of purified water for 24 hours, filtered through Whatman #42 filter paper, and then water was added to get the final volume of 10ml. Total sugars were determined using a phenol-sulfuric method (Dubois et al., 1956). For the determination of α-amylase activity, 0.25g of seeds were soaked in water for three days and the activity was mea-

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sured by an iodine method (Reiss and Bernstein, 1994). For determination of the water content, 3.0g of the seeds were dried at 105℃ for 48 hours and then the water content was calculated by the following equation:

Water content (%) = 100×(wet weight − dry weight) /wet weight.

RESULTS AND DISCUSSION

Optimum water potential for the priming of the rice seeds

To find out the optimum water potential of the PEG solution for the priming of the rice seeds, water uptake and the time of germination were studied in different PEG solutions at 25℃ (Fig. 1). In general, the water content of the seeds was higher as the water potential of PEG solutions increased. In the first 6 hours, water content increased rapidly and then increased gradually up to 2-day period. After 2 days the water content of seeds primed in −0.6 MPa and lower PEG solutions was levelled off. However, in 0, −0.2, and −0.4 MPa PEG solutions, water content increased again after germination. In water (0 MPa), seeds germinated in 3 days and the water content of the seeds was 35.0%. In a −0.2 MPa PEG solution, seeds germinated in 4 days after soaking and the water content was 33.5%. In a −0.4 MPa PEG solution, seeds germinated in 5 days and the water content was 32.0%. After germination, the water content of the seeds increased rapidly due to a higher water content in both the radicles and plumules. However, in priming solutions where water potentials were lower than a −0.6 MPa, seeds absorbed water less than 30% and the seeds did not germinate. Therefore, in this experiment −0.6 MPa PEG

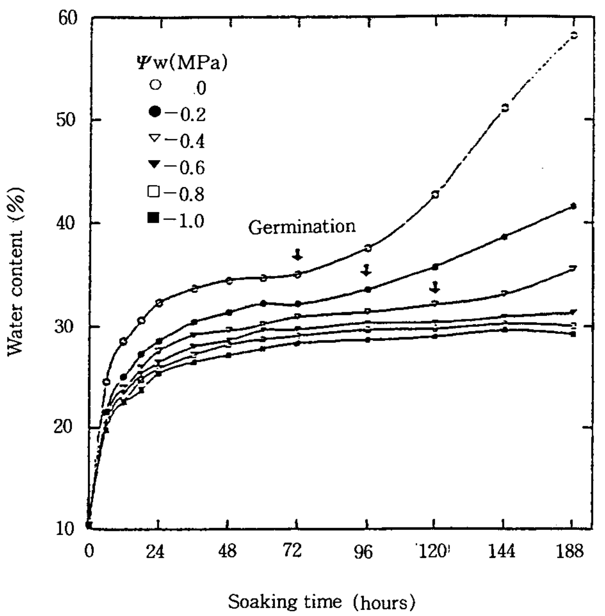

Fig. 1. Changes in water content of rice seeds in PEG solutions with different water potentials(Ψ_w) at 25℃.

solution was used for the priming of rice seeds. Also, water (0 MPa) was used as a control group.

Optimum temperature and duration of rice seed priming

Temperature, duration of time, and water potential of PEG solutions for the priming of rice seeds were significant factors in effecting the ultimate germination rate, the time to obtain a 50% germination level, and the uniformity of seed germination especially at the sub-optimum temperatures (Table 1). At the priming temperature of 15℃, the final germination rate of seeds primed in water for 1 to 4 days was similar to unprimed seeds, while seeds primed longer than 7 days decreased in their germination rate demonstrably. In contrast, in a −0.6 MPa PEG solution, the final germination rate was not changed until 13 days of priming time.

At a priming temperature of 25℃, the optimum priming duration both in water and 0.6 MPa PEG solution was 1 and 4 days, respectively. With 2 days priming in water, the germination rate tended to decrease, although it germinated 2.2 days earlier when germinated at 17℃. The seeds were not primed for more than 3 days because of germination in the preliminary experiment. In −0.6 MPa PEG solution, the final germination rate of seeds primed for 4 days was at the same level as unprimed seeds, while it decreased significantly with more priming time. The seeds primed for 4 days in −0.6 MPa PEG solution germinated faster by 2 days at 17℃ compared with unprimed seeds.

The time required to obtain a 50% germination level and uniformity of germination (the number of days from 25%-75% germination) decreased up to 4 days when primed in either water or −0.6 MPa PEG solution, but increased as the priming duration was longer.

Seeds primed in water and −0.6 MPa PEG solution for 4 days germinated earlier by 1.4 and 1.0 days, respectively, compared with unprimed seeds at a temperature of 17℃. The priming effect on early seed germination was only 0.5 day when germinated at 25℃.

Physiological changes in rice seeds during priming

Physiological changes in seeds during the priming period are shown in Fig. 2. Total sugars and α-amylase activity of seeds primed in water at 15℃ and 25℃ were higher than those primed in −0.6 MPa PEG solution. At 15℃, the priming duration did not affect the levels of total sugars and α-amylase activity, while at 25℃ the levels increased significantly as priming duration was longer, especially primed more than 7 days in −0.6 MPa PEG solution.

Higher levels of total sugars and α-amylase activity of primed seeds were negatively correlated with the final germination rate (Table 2). However, they did not show noteworthy, consistent relationships with the time to 50% germination and no relationships with germination uniformity. The slightly higher levels of total sugars and α

Table 1. The germination rate, the time to 50% germination (T50), and uniformity of rice seeds primed at different temperatures, water potentials, and durations of time at varying temperatures.

Priming temperature (℃)	Water potential (MPa)	Priming duration (days)	Germination rate (%)			T50 (days)			Uniformity (days)†		
			17℃	20℃	25℃	17℃	20℃	25℃	17℃	20℃	25℃
15	0	0	93a‡	94a	100a	9.8	6.4	4.0	1.5	1.0	0.9
		1	90a	94a	97a	8.8	5.9	4.0	1.5	1.3	0.6
		4	90a	94a	96ab	8.4	5.6	3.6	1.0	1.1	0.4
		7	83a	82b	87b	8.7	6.2	3.7	2.3	1.3	1.0
		10	62b	69c	75c	10.3	6.8	3.6	—	—	3.4
		13	40c	34d	40d	—	—	—	—	—	—
	−0.6	0	93ns	94ns	100ns	9.8	6.4	4.0	1.5	1.0	0.9
		1	93	96	97	9.3	6.8	4.4	1.2	1.1	0.6
		4	93	97	97	8.8	5.7	3.5	1.3	1.0	0.7
		7	94	96	96	9.5	6.3	4.4	1.5	1.2	0.8
		10	88	94	94	9.6	6.3	4.4	1.9	1.2	0.8
		13	89	93	94	9.4	6.6	4.3	2.1	1.1	0.9
25	0	0	93ns	94ns	98ns	9.8	6.4	3.5	1.3	1.0	0.9
		1	91	96	98	8.4	6.4	3.1	1.5	1.0	1.0
		2	86	91	91	7.6	5.7	2.7	1.9	1.0	0.9
	−0.6	0	93a	94a	98a	9.8	6.4	3.5	1.3	1.0	0.9
		1	96a	96a	96a	9.0	6.4	3.5	1.3	0.9	0.8
		4	90a	95a	98a	7.8	6.1	2.8	2.0	1.3	0.8
		7	45b	52b	64b	—	8.5	3.1	—	—	—
		10	27c	25c	32c	—	—	—	—	—	—
		13	18c	21c	30c	—	—	—	—	—	—

† Uniformity : Days from 25% to 75% germination.
‡ Means within a column followed by the same letter in the same water potential are not different by the Duncan's New Multiple Range Test at the 5% level.

Table 2. Correlation coefficients between total sugars and germination rate, time to a 50% germination level (T50), and uniformity of germination.

Item	Germination rate			T50			Uniformity†		
	17℃	20℃	25℃	17℃	20℃	25℃	17℃	20℃	25℃
Total sugars	−0.749**‡	−0.725**	−0.699**	0.085	0.697**	0.024	0.452	0.454	0.125
α-amylase	−0.496*	−0.509*	−0.500*	−0.606**	−0.298	−0.795**	0.188	−0.060	0.093

† Uniformity : Days from 25% to 75% germination.
‡ *, ** : Significant at the 5%, 1% level, respectively.

-amylase activity in the 1-4 days primed seeds could be beneficial for the fast germination of seeds (Sung and Chang, 1993), but high levels of total sugars and poor germination of seeds primed for longer than 7 days in −0.6 MPa PEG solution need further research.

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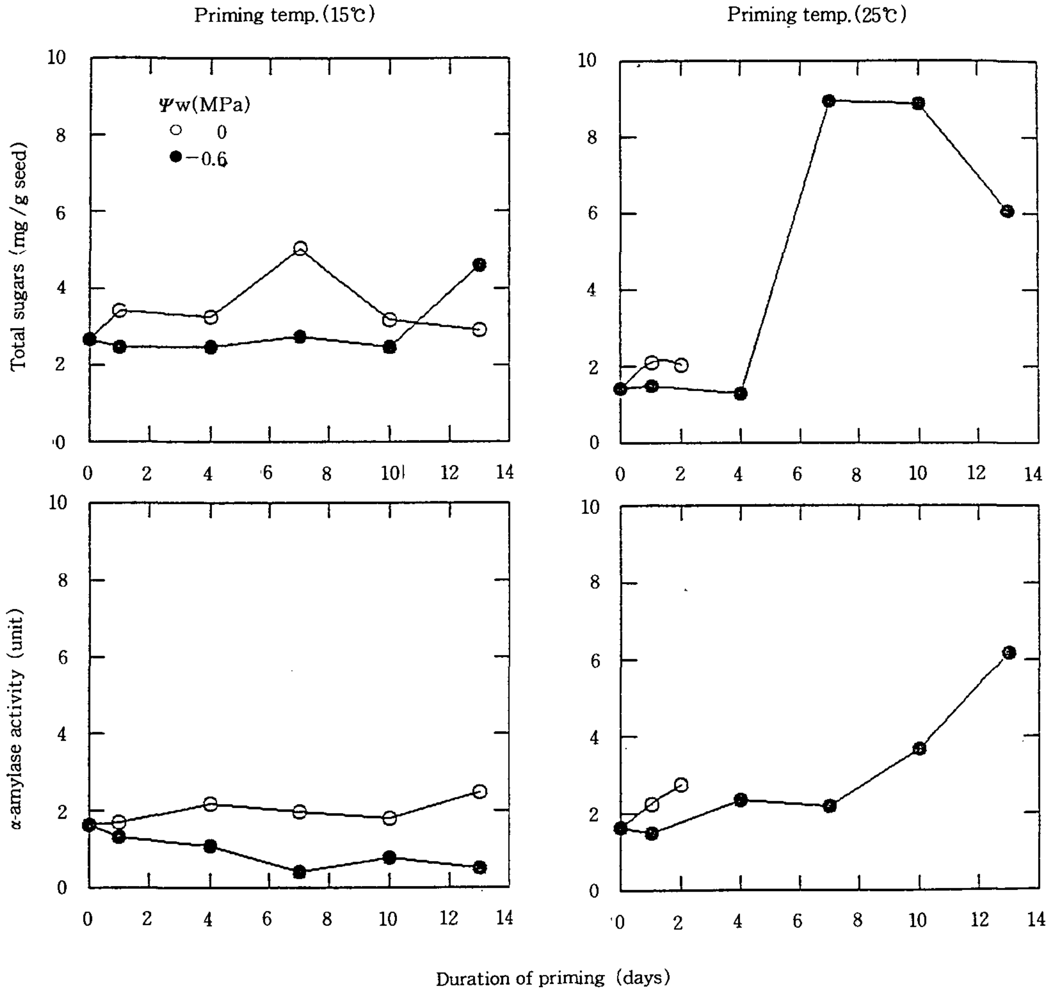

Fig. 2. Changes in total sugars and α-amylase activity of rice seeds primed in water (0 MPa) and in −0.6 MPa PEG solutions at 15 and 25℃ for different time periods.

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