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Effect of Seed Coating with Polymers on Seed Vigour and Seedling Stand in Direct Seeded Rice

Dong Seog Song* and Sheong Chun Lee*

ABSTRACT

These experiments were conducted to investigate water uptake, electrical conductivity, germination percentage, seedling growth, and seedling establishment rate in direct seeding cultivation of rice. The rice seeds of six japonica type varieties were coated with 12 kinds of polymers in a standard concentration of 0.2% using seed coating machine.

The water absorption of the polymer-coated seeds under saturation conditions was not different among varieties, and was the highest in kulcel, maltrin, and waterlock on the polymer-coated seeds. The electrical conductivity with waterlock (55.0 $\mu scm^{-1}g^{-1}$) was higher than the control plot (45.6 $\mu scm^{-1}g^{-1}$) and other treatments. The germination of the polymer-coated seeds was 95.9% at control plot, 92.7% at low temperature and 35.7% at high temperature. The total dry weight of seed decreased in the order of low temperature, control plot, and high temperature, and was effective in pvp (polyvinyl pyrrolidone), opadry, and sacrust.

The seedling establishment rate in direct seeding cultivation ranged from 74.9 to 81.0% in flooded paddy surface, and ranged from 64.7 to 76.6% in dry paddy. In both cases, it decreased in the order of early, medium and medium-late varieties, but was enhanced in daran 8600, sepirect, and sacrust.

According to this study the recommended polymers for direct seeding cultivation of rice are daran 8600, sepirect, and sacrust.

Key words : water uptake, electrical conductivity, germination percentage, seedling growth, seedling rate, polymer-coated.

It is very important to develop a rice cultivation practice saving labor and production costs so that the price of Korean rice could be compatible to foreign rice prices in international trade markets. Although direct seeding seems to be one of the most promising cultural practices in this respect, it has several disadvantages compared to transplanting cultivation. One of the most prominent problems encountered in direct seedeing is the unstable establishment of seedling stands. For example, re-seeding is often required because of poor germination even when seeds with the highest germination rate are used.

If adverse weather conditions on and after seeding occur, they can cause seed injury, poor seedling stand, delayd maturation, decreased yield and thereby great economic loss. Accordingly, research for adapting seeds to adverse environment conditions has been attempted.

Seed coating is a mechanism of applying needed materials in such a way that they affect the seed or soil at the seed-soil interface. Thus, seed coating provides an opportunity to package effective quantities of materials, so that they can influence the micro-environment of each seed (Baxter & Watwer, 1986; Kwak 1992; Lowther, 1987; McDonald et al., 1988; Scott & Blair, 1987; Taylor et al., 1991; Valdes & Bradford, 1987; Wadha et al., 1989). The coated seeds with polymers at germination temperature were prevented from uptaking water until pre-germination and were perfectly protected from soil microorganisms. Germination started at germination temperature by means of solving of itself (Calero et al., 1981; Ellis et al., 1991).

Low rates of seeds germination often result from soaking injury brought about by the rapid imbibition of water under saturated soil conditions. In species with highly permeable seeds such as soybean, this injury can be prevented by coating the seeds with hydrophobic polymers which can reduce the rate of water uptake (Kuo, 1989; McDonald et al., 1988; Nooden et al., 1985; Taylor, 1987). On the other hand, when the lack of soil moisture is predicted, the seeds are coated with the polymers which can increase the rate of water uptake (Bouaziz & Bruckler, 1989; Meshcheryakov et al., 1992). If we are able to predict the lack of supply of oxygen, coating the seeds with the polymers which can increase the rate of oxygen is very effective. Also another effective method is to coat the seeds with micro and macro-nutrient and growth regulators for seedling growth (Al-Ani et al., 1985).

Burris & Mcgee (1991) reported that the germination percentage of seeds of soybean and maize was measured at low and high temperature after coated with 20 kinds of polymers. Baxter & Watwar (1986) reported the germination percentage and emergence rate under upland conditions after they were coated with waterlock. Dadlani et al. (1992) reported that when seeds of rice were re-coated 10 g/l with Na-alginate and were dried 24 hours at 30℃, the germination percentage of the polymer-coated seeds was higher than polymer-uncoated seeds. West et al. (1985) reported that when seeds of soybean for

* College of Agriculture, Sunchon National University, Sunchon 540-742, Korea
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perfect storage at high temperature and high moisture were coated with including PVOH, the effect of preventing water uptake at 100% moisture conditions was excellent. Hwang & Sung (1991) reported that poor field emergence commonly occurred in edible soybean subjected to preemergence flooding. The phenomenon is due in part to soaking injury brought about by the rapid imbibition of water. Accordingly, to protect the seeds, ethyl cellulose, which did not stop water uptake completely but slowed it down, was applied to the seeds. This ethyl cellulose coating produced major improvements in germination of seeds receiving soaking treatment. Also, seed coating has evolved from those which protect the seed from fungal and insect attack to a diverse range of coatings, the supply of oxygen (Langan et al., 1986), the supply of micro-and macro-nutrient for seedling growth (Hathcock et al., 1984; Lowther, 1987; Scott et al., 1987; Scott & Blair, 1988), and the supply of selective herbicides or herbicide antidotes (Scott and Blair, 1987). Research on seed vigor, uptake water and electrical conductivity in polymer-coated seeds was conducted on 10 species of crop seeds. The coated seeds with several polymers promoted the germination ratio, and the water uptake was best with waterlock (Lee & Burris, 1994). The electrolyte leakage solution according to electrical conductivity of polymer coated seeds was higher 4 to 5 times higher than amino acid solution of uncoated seeds (Wadha et al., 1989).

This study was hardly conducted to adaptative experiment of crops with polymer coated seeds, and showed special aspects in varieties and treatment concentration at same crops. To stabilize field emergence through coating seeds, the uptake water, germination ratio, seedling growth and field emergence of seeds of rice were measured after they were coated with 12 kinds of polymers.

MATERIALS AND METHODS

This study was conducted at the paddy fields and laboratory of the College of Agriculture in Sunchon National University from 1996 to 1997. The rice seeds of six Japonica type varieties were coated with 12 kinds of polymers in a standard concentration of 0.2% using a seed coating machine (Seed Science Center of Iowa State University).

The germination percentage, moisture uptake, electrical conductivity and seedling growth of uncoated and coated seeds of 6 varieties (2 early, 2 medium, and 2 medium -late maturing) were measured by methods of Burris & McGee (1991).

The water uptake of seeds was estimated for 50 seeds with 3 replicates for 24 hours at room temperature (25℃) and with remeasuring after being dried for 24 hours at 105℃ in dry oven.

For electrical conductivity test of seeds, 150 rice seeds with the moisture range 14 to 17% was soaked in 75 ml deionized water, then the electrical conductivity tests were conducted at 12 and 24 hours at room temperature (AOSA, 1987).

Germination percentage and seedling growth of the polymer-coated seeds: seed germination rate in low temperature was measured on the 5th after seeding at 25℃ germinator after being kept for 7 days at 10℃ germinator. Seedling growth was measured on the 14th after seeding. After the seeds were kept for 2 days at 45℃ accelerated aging treatment with 100℃ moisture, seed germination rate under high temperature was measured on the 5th day after seeding in a 25℃ germinator, with 3 replicates of 50 seeds in pH 7.0 paper towel (30×60 cm, Anchor Co.).

The emergence percentage of direct seeding on dry paddy with polymer-coated seeds was observed on the 14th day after broadcasting with Keumobyeo and five other varieties. Seeds of rice were coated with 12, kinds of polymers in a standard concentration (0.2%), and were broadcasted of 40 kg/ha.

RESULTS AND DISCUSSION

Seed vigor of polymer-coated seeds

1. Water uptake and electrical conductivity of seeds

The water uptake of seeds is shown in Table 1. The water absorption after the seeds soaking ranged from 28. 9 to 30.3% in early varieties, 28.1 to 30.5% in medium varieties and 26.6 to 30.2% in medium-late varieties, respectively. The water absorption was not significantly different among varieties. Also the water absorption according to polymers was slightly greater compared to the control plot (23.9%) and polymer treatment (29.2%). The water absorption at 24 hours after the seeds soaking showed 34.2% in the coated Odaebyeo (early variety) with klucel, 33.3% in Gancheogbyeo (medium variety) with maltrin and 37.2% in Ilpumbyeo (medium-late variety) with waterlock.

Lee & Burris(1994) also suggested that polymer-coated seeds under saturation conditions showed the highest water absorption at klucel and waterlock, and similar results were observed in some rice varieties used in this experiment. However, the degree of water absorption by polymer treatment in this experment was far less than that of the other researchers; for example Baxter & Watwer (1986) reported the increase in water absorption by 2,000 times in waterlock-coated seeds, while only slight increases were observed in this experiment. This difference may be due to the environmental condition of 100% saturation, not practical field conditions.

The results of measuring electrical conductivity of seed for estimating the seed vigour, are shown in Table 1. It is the change of quantity of electrolyte leakage, which was measured on the 24 hours after the seeds soaking with 14 to 17% moisture content at 25℃ germinator. The electrolyte leakage on the 24 hours after the seeds soaking ranged from 40.8 to 42.5 $\mu S\ cm^{-1}g^{-1}$ for early maturing varieties, 40.7 to 46.4 $\mu S\ cm^{-1}g^{-1}$ and for medium varieties, and 33.9 to 47.5 $\mu S\ cm^{-1}g^{-1}$ for medium-late

Table 1. The water uptake at 24 hours after soaking and electrolyte leakage from various polymer-coated seeds and maturity types in rice.

Polymer	Maturity type												Mean	
	Early				Medium				Medium-late					
	Keumo		Odae		Gancheog		Nongan		Dongjin		Ilpum			
	A[‡]	B[§]	A	B	A	B	A	B	A	B	A	B	A	B
CON[†]	27.4	58.4	28.3	38.8	31.3	42.7	27.5	54.6	29.2	26.8	27.8	42.5	23.9	45.6
DW	25.6	49.3	32.5	40.9	31.7	49.8	29.3	37.2	27.5	29.5	30.5	42.3	29.5	41.5
PVP	29.2	42.0	28.5	31.2	31.6	43.3	27.9	36.1	24.1	32.7	29.2	43.5	28.4	38.1
WL	32.5	42.8	31.7	56.7	22.4	56.0	26.1	57.3	29.1	63.0	37.2	53.9	29.8	55.0
DAR	28.5	39.4	30.1	42.3	33.2	45.5	28.5	31.1	25.6	27.9	30.2	54.2	29.4	40.1
SUR	31.3	39.1	29.3	36.2	31.8	44.3	28.7	32.5	29.4	36.5	29.5	43.3	30.0	38.7
AVL	28.9	33.4	29.9	33.6	27.4	47.2	28.6	32.5	23.6	32.3	29.7	42.5	28.0	36.9
MAL	28.5	44.5	33.1	47.2	33.3	42.8	25.8	38.4	28.5	32.2	31.7	48.6	30.2	42.3
SEP	27.4	36.5	28.4	33.0	30.1	48.7	30.6	34.2	26.9	29.5	29.2	47.1	28.8	38.2
SAC	30.9	32.5	30.3	39.3	32.3	45.2	26.7	43.5	25.4	31.5	28.8	44.8	29.1	39.5
OPA	26.4	49.6	26.9	51.1	30.2	41.4	32.4	39.9	27.7	33.9	27.6	50.1	28.5	44.3
KLU	30.2	42.4	34.2	39.1	30.3	49.7	24.6	51.1	26.7	31.1	31.2	57.5	29.5	45.2
Mean	28.9	42.5	30.3	40.8	30.5	46.4	28.1	40.7	26.6	33.9	30.2	47.5	29.1	41.9
LSD 0.05	3.9	6.3	3.3	5.3	3.4	5.2	4.2	6.0	3.2	4.3	3.7	6.4		

‡ ; Water uptake (%)

§ ; Electrolyte leakage (μS cm^{-1} g^{-1})

† ; CON : Control, DW : Distilled water, PVP : Polyvinyl pyrrolidone, WL : Waterlock,
DAR : Daran 8600, SUR : Surelease, AVI : Avicel, MAL : Maltrin,
SEP : Sepiret, SAC : Sacrust, OPA : Opadry, KLU : Klucel.

varieties. If observing the kinds of polymer coated seeds, the electrolyte leakage on the 24 hour after the seeds soaking ranged from 32.5 to 33.4 μS cm^{-1}g^{-1} for Keumobyeo (early variety) coated with avicel and sacrust, whereas showed 58.4 μS cm^{-1}g^{-1} at control plot. Also, from 31.2 to 33.0 μS cm^{-1}g^{-1} for Odeabyeo coated with pvp and sepiret, whereas showed 56.7 μS cm^{-1}g^{-1} with waterlock. The medium variety, Nonganbyeo was ranged from 31.1 to 32.5 μS cm^{-1}g^{-1} with daran 8600, surelease, and avicel, whereas, from 56.0 to 57.3 μS cm^{-1}g^{-1} for Gancheogbyeo and Nonganbyeo, coated with waterlock. The medium-late variety, Dongjinbyeo ranged from 27.9 to 29.5 μS cm^{-1}g^{-1} with daran 8600 and sepiret, whereas showed 63.0 μS cm^{-1}g^{-1} with waterlock. Also, Ilpumbyeo showed 57.7 μS cm^{-1}g^{-1} with klucel. Accordingly, each varietiy was differently observed according to polymer characters. Also, the electrolyte leakage ranged from 38.1 to 55.0 μS cm^{-1}g^{-1} in polymers. The electrolyte leakage was observed slighty low in avicel and 12 other kinds of polymers comparison with control plot (45.6 μS cm^{-1}g^{-1}), the next, showed 45.2 μS cm^{-1}g^{-1} with klucel and the highest (55.0 μS cm^{-1}g^{-1}) with waterlock. It was thought that the klucel and waterlock was high in electrolyte leakage, because of the chemical characteristic of polymers. The difference of variety was higher than grain-filling periods.

The final low level of leakage is usually reached within 30 minutes after placing seeds in water (Duke et al., 1986). However, this pattern of leakage has been shown to occur from heat-killed pea embryos in which membranes are likely to be functional, and was repeated over four imbibed/dry cycles (Powell & Matthews, 1981). This suggested that the time course of solute leakage resulted from the physical properties of diffusion and solute concentration (McKersie & Stinson, 1980).

2. Germination percentage of seeds

The germination percentage for seeds kept at 25℃ for 14 days is shown in Table 2. The uncoated seeds were used in the control plot of seeds, and DW was coated with distilled water as other seeds were coated with other polymers. The germination percentage was surveyed on the 14th day after the seeds soaking at 25℃. The germination percentage ranged from 94.6 to 96.3% in early varieties, from 90.3 to 96.3% in medium and from 98.9 to 99.1% in medium-late, respectively.

Each variety showed over 90% germination percentage, and over 97% for varieties Donjinbyeo and Ilpumbyeo. The averaged germination percentage of control plot showed 97.2%, and 97.5% with DW. Also, slightly low germination percentage showed 95.5% with PVP, 95.3% with matrin. But other polymer-coated seeds were similar to seeds of control plot.

Table 2-B shows the germination percentage of en-

Table 2. Germination percentages (%) of rice seeds with polymer-coated, low temperature and accelerated aging treatment and maturity types.

A) : Control plot (14th day in 25℃ incubator)

Maturity type	Variety	Polymer†												LSD
		CON	DW	PVP	WL	DAR	SUR	AVL	MAL	SEP	SAC	OPA	KIU	0.05
Early	Keumo	97	90	90	99	100	98	100	94	96	96	100	96	8.4
	Odade	96	100	94	93	96	89	94	89	93	98	100	94	6.6
Medium	Gancheong	98	100	96	97	100	97	98	98	100	97	94	98	6.0
	Nongan	96	97	93	96	100	100	94	93	95	98	97	97	5.8
Medium-late	Donjin	100	98	100	100	100	98	98	100	100	97	100	98	ns
	Ilpum	96	100	100	100	97	100	98	98	100	100	100	98	ns
	Mean	97.2	97.5	95.5	97.5	98.8	97.0	97.0	95.3	97.3	97.6	98.5	96.8	

B) : Low temperature (14th day in 25℃ incubator after 7 days at 10℃)

Maturity type	Variety	Polymer												LSD
		CON	DW	PVP	WL	DAR	SUR	AVL	MAL	SEP	SAC	OPA	KIU	0.05
Early	Keumo	100	96	84	96	81	86	96	96	87	92	96	88	7.5
	Odade	88	95	100	100	93	92	92	100	100	94	92	92	8.0
Medium	Gancheong	88	100	100	97	100	100	95	94	87	95	92	94	7.6
	Nongan	100	88	82	100	88	68	88	96	92	93	92	91	10.2
Medium-late	Donjin	98	98	100	100	92	100	91	100	100	100	95	94	8.1
	Ilpum	91	96	96	97	100	100	95	96	96	96	96	84	9.8
	Mean	94.2	95.5	93.7	98.3	92.3	91.0	92.8	97.0	93.7	95.0	93.8	90.5	

C) : Accelerated aging (14th day in 25℃ incubator after 2 days at 45℃)

Maturity type	Variety	Polymer												LSD
		CON	DW	PVP	WL	DAR	SUR	AVL	MAL	SEP	SAC	OPA	KIU	0.05
Early	Keumo	33	32	35	23	20	20	35	54	40	30	75	40	12.5
	Odade	30	41	25	25	45	47	50	40	35	40	55	33	10.8
Medium	Gancheong	13	37	57	35	20	62	33	30	23	30	54	35	14.3
	Nongan	25	13	15	33	35	25	20	26	29	15	37	25	9.7
Medium-late	Donjin	40	33	35	22	24	40	35	25	19	27	65	22	12.2
	Ilpum	46	40	70	45	30	25	36	65	30	20	74	55	13.6
	Mean	31.2	32.7	39.5	30.5	29.0	36.5	34.8	40.0	29.3	27.0	60.0	35.0	

†; CON : Control, DW : Distilled water, PVP : Polyvinyl pyrrolidone, WL : Waterlock,
DAR : Daran 8600, SUR : Surelease, AVI : Avicel, MAL : Maltrin,
SEP : Sepiret, SAC : Sacrust, OPA : Opadry, KLU : Klucel.

vironment adaptation for the polymer-coated seeds measured after the seed placed for 7 days at 10℃ germinator, on the 14th day after soaking at 25℃. The germination percentage of the maturation stage ranged from 91.5 to 94.8% in early varieties, from 89.8 to 95.2% in medium and from 87.3 to 97.3% in medium-late, respectively. Each variety showed over 87% of germination percentage, and over 95% in Gancheong and Dongjinbyeo.

The averaged germination percentage in control plot and DW showed 94.2% and 95.5%. Therefore, germination percentage was not different from other polymer-coated seeds. The germination percentage in the polymer-coated seeds was similar to control plot, and showed over 95% with DW, waterlock, maltrin and sacrust.

Table 2-C shows the germination percentage of environment adaptation of high temperature was measured on the 14th day after soaking at 25℃, 2 days later at 45℃ accelerated aging treatment in 100% moisture conditions. The germination percentage of the maturation stage ranged from 36.4 to 42.1% in early, from 24.8 to 35.8% in medium and from 30.3 to 44.6% in medium-late varieties, respectively. The germination percentage of

the varieties showed the lowest 24.8% in Nonganbyeo, the next, 30.3% in Dongjinbyeo. Sacrust, waterlock, and daran 8600 was lower than the control plot and DW, but showed excellent tendency in maltrin, PVP, and opadry. The special reaction in the effect of germination percentage was observed at high temperature environment.

At heat-killed treatment, germination percentage decreased, for the high temperature destroyed function of seed vigour according to hydration of plasma membrane with phospholipid (Hill et al., 1988; Kuo, 1989).

Seedling growth of the polymer-coated seeds.

1. Root length

Table 3 shows root length. The root length of early maturing varieties ranged from 15.9 to 16.1 cm under low temperature and from 8.4 to 8.6 cm under high temperature. Also, at medium varieties, it ranged from 15.4 to 17.2 cm in control plot, from 18.4 to 18.6 cm in low temperature and from 8.5 to 11.1 cm in high temperature. At medium-late varieties, it ranged from 17.0 to 17.5 cm in control plot, from 20.1 to 20.8 cm in low temperature and from 7.7 to 9.8 cm in high temperature treatment, respectively. The root length in treatment plot was shown in order of low temperature, control plot and high temperature treatment. The root length of the polymer-coated seeds in early varieties was measured 10.4 cm in control plot, but showed 16.1 and 16.2 cm with opadry and waterlock. At medium varieties, showed 11.8 cm in control plot, but 17.0 and 17.1 cm in waterlock and klucel. At medium-late varieties, was 10.7 cm in control plot, but 18.9 and 19.6 cm with sepiret and klucel, respectively.

As one of the efforts to save labor in farming, in direct seeding cultivation of rice have many problems such as poor seedlings, lodging and weed control. In direct seeding cultivation, root lodging occurs frequently because seeds are planted on the surface or just below the top layer of the soil and plants grow with less physical support of the soil (Kim et al., 1993). Thus root distribution has a very close relationship with lodging in direct seeded rice (Kim et al., 1993; Lee & De Datta, 1990).

Table 3. Root length (cm) of various polymer-coated rice seeds under control, cold temperature and accelerated aging treatment and maturity types.

Maturity type	Variety	Treatment	Polymer†												LSD
			CON	DW	PVP	WL	DAR	SUR	AVL	MAL	SEP	SAC	OPA	KIU	0.05
Early	Keumo	Con.‡	15.5	12.9	20.8	20.7	15.3	14.7	13.0	11.8	17.3	9.9	20.1	19.3	4.3
		Low§	17.0	18.7	20.7	17.3	16.6	20.1	24.0	17.7	20.2	18.4	21.8	23.0	3.4
		High¶	8.2	8.0	8.8	9.1	8.3	7.9	8.5	9.5	7.5	7.9	8.7	8.4	ns
	Odae	Con.	10.6	10.9	17.9	20.7	15.5	15.8	14.0	14.4	16.9	17.2	19.7	20.0	3.6
		Low	10.3	12.9	14.5	20.5	17.3	18.7	24.1	21.3	16.5	20.0	17.5	15.1	4.0
		High	7.7	8.3	9.3	8.7	8.5	9.0	9.5	7.9	9.3	7.4	8.8	8.6	ns
		Mean	10.4	12.0	15.3	16.2	13.6	14.2	15.5	13.8	14.6	13.5	16.1	15.7	
Medium	Gancheong	Con.	14.8	15.1	19.5	21.5	16.7	18.4	14.6	15.6	15.6	17.0	19.1	18.7	3.2
		Low	15.2	14.8	19.8	22.6	15.0	20.2	22.9	18.4	23.8	24.3	23.0	23.3	2.9
		High	8.0	9.2	11.6	13.5	10.3	12.2	11.4	9.8	11.2	12.4	13.6	9.4	2.5
	Nongan	Con.	14.3	13.3	20.2	17.8	13.0	13.5	10.2	12.6	15.8	17.3	17.4	19.5	3.4
		Low	11.5	18.6	14.3	19.2	19.0	21.0	17.7	21.9	23.5	20.7	14.4	21.7	3.3
		High	6.7	7.0	11.2	7.0	8.3	8.0	7.9	8.1	10.3	9.8	9.6	10.1	2.7
		Mean	11.8	10.5	16.1	17.0	13.7	15.6	14.1	14.4	16.7	16.8	16.2	17.1	
Mideum-late	Donjin	Con.	12.7	16.9	19.1	24.0	18.3	14.8	11.0	14.4	17.0	17.5	25.0	23.8	4.2
		Low	14.6	17.7	24.1	20.0	19.5	19.2	22.9	22.7	18.2	25.5	20.6	24.8	3.6
		High	6.4	12.3	5.3	6.0	6.7	7.3	7.0	6.9	7.7	8.3	8.4	10.2	3.0
	Ilpum	Con.	13.8	13.9	19.3	17.5	21.0	19.4	12.8	11.0	18.7	21.2	19.5	22.3	3.2
		Low	12.6	16.7	23.1	18.5	16.1	16.2	21.6	25.0	20.3	28.8	20.9	21.4	2.8
		High	4.3	9.9	14.0	5.7	8.3	9.4	9.3	7.6	10.3	12.0	11.4	15.1	3.3
		Mean	10.7	14.6	17.5	15.3	15.1	14.4	14.1	14.6	15.3	18.9	17.6	19.6	

†: CON : Control, DW : Distilled water, PVP : Polyvinyl pyrrolidone, WL : Waterlock, DAR : Daran 8600, SUR : Surelease, AVI : Avicel, MAL : Maltrin, SEP : Sepiret, SAC : Sacrust, OPA : Opadry, KLU : Klucel.

‡ ; control plot.

§ ; Measured on the 14th day at 25℃ after 7 days in 10℃ incubator.

¶ ; Measured on the 14th day at 25℃ after 2 days in 45℃ incubator.

2. Total dry weight

Table 4 shows that the total dry weight of infant plant in early varieties ranged from 0.546 to 0.555 g in the control, from 0.691 to 0.754 g in low temperature and from 0.690 to 0.698 g in high temperature treatments. For medium varieties, from 0.530 to 0.553 g in the control, from 0.690 to 0.698 g in low temperature and from 0.433 to 0.478 g in high temperature treatment. For medium-late varieties, from 0.562 to 0.569 g in the control, from 0.667 to 0.726 g in low temperature and from 0.483 to 0.491 g in high temperature treatments. The total dry weight of the polymer-coated seeds in early varieties was measured 0.430 g in the control treatments, but 0.649 g and 0.692 g with PVP and opadry. For medium varieties, total dry weight was 0.452 g in control, but 0.647 g and 0.650 g with sacrust and opadry. For medium-late varieties, total dry weight was 0.531 g in the control, but 0.633 g and 0. 637 g with opadry and sacrust, respectively.

The seedling stand ratio in direct seeding cultivation

Table 5 shows the seedling stand ratio of maturation stage and the polymer-coated seeds in direct seeding on the flooded paddy surface. The seedling stand ratio of maturation stage ranged from average 80.9 to 81.0% in early varieties, from 77.0 to 77.8% in medium and from 74.9 to 76.6% in medium-late varieties. The seedling stand ratio decreased in the order of early, medium, and medium-late varieties. The seedling stand ratio of the polymer-coated seeds in early varieties, Keumobyeo and Odaebyeo, ranged from 75.3 to 78.6% in the control, but was as good as 87.3% with daran 8600 in Keumobyeo and 86.2% with sepiret of Odebyeo. In medium varieties, results were 72.1 to 73.5% in the control for Gancheongbyeo and Dasanbyeo, but from 80.8 to 84.6% with sacrust. For medium-late varieties from 65.4 to 68.7% in the control, but was as good as 82.4 to 83.7% with sacrust.

The seedling stand ratio of direct seeding on the dry paddy on maturation stage ranged from 73.8 to 74.4% in early, from 68.3 to 69.2% in medium, from 64.7 to

Table 4. Total dry weight(g) of various polymer-coated rice seeds under control, cold temperature and accelerated aging treatment and maturity types.

Maturity type	Variety	Treat-ment	Ploymer†												LSD
			CON	DW	PVP	WL	DAR	SUR	AVL	MAL	SEP	SAC	OPA	KIU	0.05
Early	Keumo	Con.‡	0.463	0.518	0.653	0.582	0.551	0.551	0.499	0.429	0.485	0.596	0.686	0.647	0.063
		Low§	0.431	0.543	0.844	0.809	0.667	0.832	0.623	0.570	0.635	0.692	0.872	0.771	0.068
		High¶	0.322	0.472	0.552	0.493	0.480	0.498	0.422	0.390	0.411	0.483	0.598	0.521	0.056
	Odae	Con.	0.443	0.483	0.591	0.690	0.531	0.457	0.548	0.576	0.534	0.589	0.627	0.484	0.071
		Low	0.497	0.683	0.744	0.858	0.667	0.731	0.746	0.813	0.736	0.827	0.851	0.756	0.067
		High	0.421	0.453	0.507	0.531	0.441	0.403	0.449	0.474	0.462	0.521	0.517	0.447	0.055
		Mean	0.430	0.525	0.649	0.631	0.556	0.510	0.548	0.542	0.611	0.618	0.692	0.604	
Medium	Gancheong	Con.	0.441	0.510	0.640	0.607	0.553	0.502	0.456	0.465	0.540	0.572	0.572	0.497	0.061
		Low	0.578	0.552	0.723	0.837	0.679	0.653	0.668	0.641	0.654	0.823	0.844	0.724	0.068
		High	0.345	0.413	0.514	0.546	0.471	0.435	0.447	0.453	0.447	0.527	0.547	0.485	0.051
	Nongan	Con.	0.438	0.499	0.503	0.574	0.521	0.463	0.470	0.476	0.743	0.587	0.576	0.586	0.059
		Low	0.508	0.623	0.647	0.685	0.637	0.674	0.635	0.651	0.795	0.813	0.824	0.783	0.060
		High	0.402	0.471	0.474	0.435	0.431	0.437	0.479	0.435	0.543	0.561	0.536	0.532	0.059
		Mean	0.452	0.511	0.584	0.614	0.549	0.527	0.488	0.520	0.620	0.647	0.650	0.601	
Medium-late	Donjin	Con.	0.545	0.551	0.573	0.600	0.647	0.575	0.534	0.552	0.580	0.551	0.534	0.505	0.057
		Low	0.647	0.698	0.701	0.740	0.680	0.717	0.692	0.722	0.731	0.815	0.793	0.765	0.063
		High	0.437	0.453	0.481	0.527	0.461	0.483	0.443	0.477	0.471	0.547	0.522	0.493	0.068
	Ilpum	Con.	0.453	0.591	0.616	0.616	0.624	0.644	0.588	0.592	0.531	0.591	0.612	0.596	0.052
		Low	0.662	0.694	0.747	0.778	0.682	0.731	0.641	0.707	0.732	0.794	0.788	0.754	0.044
		High	0.439	0.471	0.485	0.507	0.453	0.519	0.457	0.498	0.504	0.521	0.549	0.486	0.056
		Mean	0.531	0.508	0.601	0.628	0.591	0.612	0.559	0.591	0.592	0.637	0.633	0.600	

†; CON : Control, DW : Distilled water, PVP : Polyvinyl pyrrolidone, WL : Waterlock,
DAR : Daran 8600, SUR : Surelease, AVI : Avicel, MAL : Maltrin,
SEP : Sepiret, SAC : Sacrust, OPA : Opadry, KLU : Klucel.

‡ ; control plot.

§ ; Measured on the 14th day at 25℃ after 7 days in 10℃ incubator.

¶ ; Measured on the 14th day at 25℃ after 2 days in 45℃ incubator.

Table 5. Effect of polymer-coated rice seeds on the percentage of stands per m² and maturity types under direct seeding cultivation.

Polymer	Maturity type												Mean	
	Early				Medium				Medium-late					
	A†		B‡		A		B		A		B			
	Keu§	Oda	Keu	Oda	Gan	Das	Gan	Das	Don	Ilp	Don	Ilp	A	B
CON¶	75.3	78.6	67.4	67.0	73.5	72.1	56.7	59.4	65.4	68.7	55.1	54.4	72.3	60.0
DW	76.5	74.7	67.4	63.1	72.2	70.8	62.3	63.5	68.9	70.1	57.8	60.5	72.2	62.4
PVP	81.7	83.4	79.3	75.8	79.1	80.8	68.7	73.8	73.2	78.7	64.3	69.2	79.5	71.9
WL	75.9	77.3	67.8	68.7	74.1	76.7	65.3	64.7	72.8	71.4	61.7	63.9	74.7	65.5
DAR	87.3	79.5	84.1	71.2	78.2	77.4	73.5	74.6	74.3	77.7	64.0	68.4	79.1	72.6
SUR	80.5	81.9	71.9	74.3	76.8	76.1	65.2	70.9	77.6	78.1	77.6	78.1	78.5	78.5
AVL	82.9	80.5	73.2	70.5	83.3	76.5	69.5	68.1	80.2	72.5	80.2	72.5	79.3	79.3
MAL	81.3	83.4	78.6	76.4	75.3	78.4	65.4	69.3	74.4	78.9	74.4	78.9	78.6	78.6
SEP	81.8	86.2	70.8	79.9	77.8	75.8	73.1	74.0	76.7	77.3	76.7	77.3	79.3	79.3
SAC	83.3	78.5	75.1	72.7	84.6	80.0	74.3	71.9	82.4	83.7	82.4	83.7	82.0	82.0
OPA	83.4	85.7	74.0	76.5	79.4	79.7	72.6	70.5	75.8	73.9	75.8	73.9	80.0	80.0
KLU	81.0	82.6	77.2	79.3	78.7	80.2	72.7	70.2	77.2	78.1	67.7	78.1	78.6	78.6
Mean	80.9	81.0	74.4	73.8	77.8	77.0	68.3	69.2	74.9	76.6	64.7	76.6	77.8	77.8
LSD 0.05	3.6	3.2	3.4	3.0	5.1	4.4	4.8	4.3	6.2	5.7	5.3	6.0	4.4	4.6

† ; Percentage of stands per m² in direct seeding on flooded paddy surface
‡ ; Percentage of stands per m² in direct seeding on dry paddy.
§ ; Keu : Keumo, Oda : Odae, Gan : Gancheog, Das : Dasan, Don : Dongin, Ilp : Ilpum
¶ ; CON : Control, DW : Distilled water, PVP : Polyvinyl pyrrolidone, WL : Waterlock, DAR : Daran 8600, SUR : Surelease, AVI : Avicel, MAL : Maltrin, SEP : Sepiret, SAC : Sacrust, OPA : Opadry, KLU : Klucel.

76.6% in medium-late varieties, respectively. Also, the seedling stand ratio in the polymer-coated seeds, in early varieties was observed 67.4% in the control but was 84.1 % with daran 8600 with Keumobyeo, and 67% in the control but 79.9% with sepiret for Odebyeo.

In medium varieties, Gancheogbyeo and control plot, it was observed 56.7%, but 74.3% in sacrust. At the control plot in Dasanbyeo, it was observed 59.4%, but 74.6% in daran 8600.

In medium-late varieties, Dongjinbyeo was 54.4% and Ilpumbyeo was 55.1%, in the control, but that was 82.4, this was 83.7% with sacrust, respectively. In both cases, seedling stand was decreased in order of early, medium and medium-late varieties, and was enhanced with daran 8600, sepiret, and sacrust.

The seedling stand ratio per m² was directly related to panicle number. Accordingly, the seedling stand ratio per m² was directly related with panicle number and yield. In this study, seedling stand ratio ranged from average 64.7 to 81.0%.

Also, the comparison of germination in paper towel and emergence of direct seeding on dry paddy with polymer-coated seeds, is shown in Fig. 1. The germination in paper towel was measured on the 14th day after seeding in 25℃ germinator in pH 7.0 paper towel, and emergence percentage of direct seeding on the dry paddy with polymer-coated seeds was observed on the 14th after broadcasting. The average germination percentage on the paper towel was measured 95.9%, but emergence percentage in direct seeding on dry paddy showed 60.0% in control

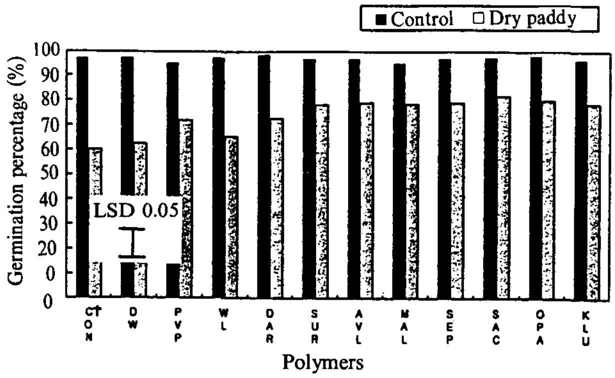

Fig. 1. Comparison of germination in paper towel and emergence of direct seeding on dry paddy with polymer-coated seeds.

†; CON : Control, DW : Distilled water, PVP : Polyvinyl pyrrolidone, WL : Waterlock, DAR : Daran 8600, SUR : Surelease, AVI : Avicel, MAL : Maltrin, SEP : Sepiret, SAC : Sacrust, OPA : Opadry, KLU : Klucel.

plot, and from 65.5% to 82.0% in polymer-coated seeds. Compared to the control, increased from 5.5% to 22.0% in polymer-coated seeds. Therefore, polymer-coated seeds were observed to be effective in direct seeding on dry paddy.

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