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Effects of Seeding Date and Rate on Growth and Yield of Barley Cultivar 'Duwonchapssalbori' in Southern Region

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In order to develop an appropriate cultural practice for a newly bred 2-rowed, waxy, naked barley cultivar 'Duwonchapssalbori' in the southern region, 2 varieties, 3 seeding dates, 4 seeding rates were designed with 2 replications. The heading and maturity dates of 'Duwonchapssalbori' were' earlier than 'Saessalbori by 2-5 and 4 days, respectively. Culm length of 'Duwonchapssalbori' was 60 to 66 cm with lodging resistance. Grain yields of both varieties were 4.28-4.33 ton/ha in the plot of Oct. 20 seeding, 4.11-4.18 ton in the plot of Oct. 28 seeding, and 3.7-13.89 ton/ha in the Nov. 5 seeding. Grain yield with different seeding rates highly significantly fitted with secondary polynomial equations in the plots of Oct. 20 and Oct. 28 seedings (R^2=0.84-0.85), showing the greatest yield with seeding rate of 140 kg per ha. However, the grain yield with various seeding rates in the plot of Nov. 5 seeding showed simple linear regression (R^2=0.71), showing the seeding rate over 160 kg in the case of later seeding to be optimal. Number of spikes per m^2 significantly contributed to grain yield, and fitted to simple linear regression (R^2=0.881-0.891), suggesting that plenty of early stands should be established at early seedling stage for high grain yield. Young spikes of 'Duwonchapssalbori' in the plot of Oct. 20 seeding elongated with linear increments since Feb. 10 (6.7 mm), and showed rapid increment since March 7 (15.1 mm). However, elongation of young spikes of 'Saessalbori' began from March 15 with slow increments. From these studies, the optimum seeding date and seeding rate in 'Duwonchapssalbori' were Oct. 20-28 and 140 kg per ha for high grain yield in the southern regions.

Key words : seeding date, seeding rate, duwonchapssalbori, yield

Barley has been the secondary important food cereal grain next to rice in Korea. However, its importance as a staple food is diminished recently due to increase of rice production and import of other cereals from foreign countries. The amount of barley consumption per a person for a year was 39.9 kg in 1974, but only 1.6 kg in 1996. Therefore, it is important to improve the grain and eating quality of barley for domestic barley production and consumption.

In 1986, 'Chalssalbori' with waxy starch was developed and its cultural area has been increased in some regions (Cho *et al.*, 1982; Lim, 1999). In 1998, a new two-rowed naked waxy barley variety, 'Duwonchapssalbori' has been developed. It was characterized by spring type, large kernel size, short culm with lodging resistance and earlier maturity (Gang, 1995). This new variety is recommended for southern regions due to weak freezing resistance.

It was reported in barley that number of spikes per m^2 was decreased linearly with late planting (Im, 1976; Park, 1975; RDA, 1985b; Ryu & Ha, 1986). When late planted, emerging date was delayed and 1,000-kernel weight was increased due to decrease in number of tillers per plant. However, Middleton *et al.* (1964) reported that 1,000-kernel weight and test weight were not affected with late seeding. According to Pendleton & Dungan (1960), optimal seeding densities were varied with different varieties, and high productive varieties had good adaptability to high density. In general, at high seeding density, spike number per m^2 and yield tended to be increased, but tillers, culm length, spike per plant, and 1,000-kernel weight tended to be decreased. However, severe lodging and yield reduction were observed with too much seeding density.

Polished grain characteristics such as yield of final product, whiteness, and 1,000-kernel weight of 'Duwonchapssalbori' were higher than those of 'Saessalbori'. Also, 'Duwonchapssalbori' in the split-polished grain characteristics was higher than 'Saessalbori' (Gang, 1995).

The objective of this study was to examine effects of seeding date and seeding rate on the growth and yield in 'Duwonchapssalbori' in order to determine the optimum seeding date and rate in the southern region.

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MATERIALS AND METHODS

A field study was conducted at the Research Farm of the College of Agriculture, Sunchon National University. Soil in the experimental plots was a sandy loam. 'Duwonchapssalbori' was selected and developed from a cross of (Wafranubet/ Sacheon #6) and Suwon # 258 at National Agricultural Experiment Station in 1998. It has characteristics such as a spring type, two-rowed naked waxy short culm and early maturity (Gang, 1995). Two barley cultivars, 'Duwonchapssalbori' and 'Saessalbori' were hand-planted on 20 Oct., 28 Oct. and 5 Nov. in 1998~1999 with row length of 25 and space of 5 cm within a row. Seeds were sown with four different rates (100, 120, 140, 160 kg/ha), and fertilizers were applied with a rate of 60-100-90 kg/ha (N-P_2O_5-K_2O; RDA, 1985a) prior to seeding. Experimental design was a split-split plot arrangement in a randomized complete block with 2 replications. The main-plots consisted of 2 barley cultivars, the subplots of 3 planting dates and sub-subplots of four seeding rates. Plant height, elongation of young spikes and stage of ear primordium were measured from the second leaf stage to heading date. Five plants were sampled, and stages of ear primordium were determined by the methods of Ham *et al.* (1972). Yield and yield components were measured after harvesting. Data analysis was done by using SAS (SAS Inst. Inc., North Carolina, USA) and New Mystat (Choi, 1990).

RESULTS AND DISCUSSION

Change of major agronomic traits with different seeding dates and rates

Heading dates of 'Duwonchapssalbori' were 11~12 April in the 20 Oct. seeding, 15-16 April in the 28 Oct. seeding, and 23 April in the 5 Nov. seeding. It had earlier heading than 'Saessalbori' by 2-5 days (Table 1). Maturity dates of 'Duwonchapssalbori' were earlier by 4 days than 'Saessalbori'. Plant height of 'Duwonchapssalbori' ranged from 60 to 66 cm, and was shorter than 'Saessalbori' (81-95 cm).

Number of spikes per m^2, 1000-kernel weight and number of spikelets in 'Duwonchapssalbori' were 821-1054, 35.1-

Table 1. Agronomic traits in 'Duwonchapssalbori' and 'Saessalbori' with different seeding dates and seeding rates.

Variety	Seeding date	Seeding rate (kg/10a)	Grain yield (kg/10a)	No. of spikes /m^2	1,000-kernel wt.(g)	No. of spikelet (no.)	Heading date (Apr)	Maturity date (May)	Culm length (cm)	ED (day)	LR (0~5)
Duwonchapssalbori	Oct. 20	10	399	961	36.6	23	12	23	66	11	0
		12	427	980	36.2	21	12	23	64	11	0
		14	454	1034	35.7	19	11	23	63	11	0
		16	431	1054	35.4	18	11	22	62	10	0
	Oct. 28	10	381	912	37.2	22	16	25	62	16	0
		12	409	936	36.9	22	16	25	62	16	0
		14	430	982	36.7	20	15	25	61	16	0
		16	424	995	36.0	19	15	24	61	15	0
	Nov. 5	10	346	821	36.5	20	23	27	61	22	0
		12	370	845	36.4	21	23	27	62	22	0
		14	382	871	36.1	19	23	27	60	22	0
		16	386	888	35.1	18	23	26	60	21	0
Saessalbori	Oct. 20	10	406	563	26.3	53	17	27	95	12	2
		12	432	589	25.6	52	17	27	94	12	3
		14	456	632	25.4	52	16	27	94	12	3
		16	438	648	25.0	51	16	26	93	11	3
	Oct. 28	10	392	531	26.7	53	19	29	93	17	2
		12	413	554	26.2	52	19	29	93	17	4
		14	442	587	25.7	50	18	29	92	17	4
		16	426	612	25.4	49	18	28	90	16	4
	Nov. 5	10	361	478	27.0	53	25	31	88	23	4
		12	382	507	26.0	52	25	31	87	23	4
		14	399	538	26.0	50	24	31	86	23	4
		16	413	573	25.6	48	24	30	85	22	4

ED; emerging days, LR; lodging resistance (0-5, 0; no lodging, 5; 100% lodging)

Table 2. Mean squares of agronomic traits for 'Duwonchapssalbori' and 'Saessalbori' with different seeding dates and seeding rates.

Source of variation		DF	Grain yield	No. of spikes/m^2	1000 kernel wt.	No. of spikelet	Culm length	Heading date	Maturity date	Emerging day
Replication		1	**	**	**	ns	ns	**	**	**
Variety(A)		1	1240.66**	16632213**	1272.06**	11563.02**	9979.21*	140.08**	196.02**	10.08**
Error(a)		1	1.33	0.71	0.17	0.02	0.77	0.75	0.02	0.08
Seeding date(B)		2	1067.60**	56321**	1.29**	4.15ns	96.20**	383.58**	66.02**	463.94**
A×B		2	171.16**	4990.68**	0.99**	3.40ns	26.93ns	0.58**	0.02ns	0.15ns
Error(b)		4	1.83	2.49	0.03	2.02	6.35	0.42	0.02	0.21
Seeding rate(C)		3	4968.22**	17187**	3.59**	27.30**	15.04**	3.36**	3.91**	3.47**
A×C		3	13.56**	42.01**	0.11**	0.35ns	0.79ns	0.03ns	0.08ns	0.25ns
B×C		6	164.72**	85**	0.05*	0.76ns	0.27ns	0.03ns	0.08ns	0.08ns
A×B×C		6	28.22**	93.33**	0.03ns	2.40**	0.85*	0.03ns	0.08ns	0.06ns
Error(c)		18	0.78	8.11	0.02	0.41	1.22	0.03	0.08	0.11
Variety	Duwon chapssalbori		403.0b	939.7a	36.2a	19.9b	61.9b	15.6b	24.3b	15.9b
	Saessalbori		413.0a	567.4b	25.9b	50.9a	90.8a	19.0a	28.3a	16.8a
Seeding date	Oct. 20		430.1a	807.4a	30.8b	35.8a	78.7a	13.0c	24.3c	11.2c
	Oct. 28		414.3b	763.4b	31.3a	35.6a	76.5ab	16.3b	26.3b	16.0b
	Nov. 5		379.6c	689.9c	31.7a	34.8a	73.8b	22.6a	28.3a	21.9a
Seeding rate	10 kg		380.6d	710.8d	31.7a	37.0a	77.5a	17.8a	26.6a	16.5a
	12 kg		405.1c	734.7c	31.3a	36.3a	76.9a	17.8a	26.6a	16.8a
	14 kg		426.8a	774.0b	30.9b	34.7b	76.0b	16.8b	26.5a	16.7a
	16 kg		419.4b	794.8a	30.4b	33.7c	75.0b	16.8b	25.4b	15.6b

*, **Significant at the 5% and 1% levels, respectively. In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

37.2 g and 18-23, respectively, which were 478-648, 25.0-27.0 g and 48-53 in 'Saessalbori'. Due to different seeding dates and seeding rates, the emerging days, heading and maturity dates varied as well as yield components.

Significant mean square differences for gain yield, number of spikes/m^2, 1,000-kernel weight, number of spikelets, culm length, heading and maturity dates and emerging days were found among varieties, seeding dates and seeding rates (Table 2).

Variations of yield and yield components with different seeding dates and rates

As shown in Fig. 1, the highest yield was observed at seeding rate of 140 kg per ha in the 20 Oct. and 28 Oct. seedings followed by seeding rates of 160, 120 and 100 kg per ha. As seeding was delayed from 20 Oct. to 5 Nov., the highest yield was observed at seeding rate of 160 kg per ha. This indicates that above seeding rate of 160 kg/ha is required for later seeding. So, the optimal seeding date was 20 Oct. with seeding rate of 140 kg per ha for the southern regions. The grain yield was not significantly different between varieties in the 20 and 28 Oct. seedings, but

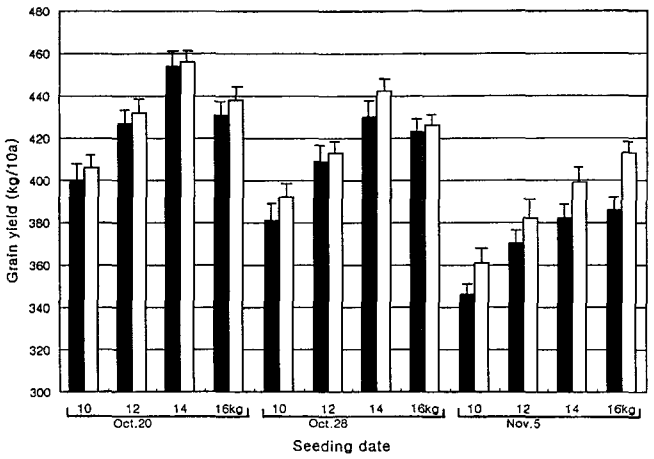

Fig. 1. Comparisons of grain yield in 'Duwonchapsallbori' (▨) and 'Saessalbori' (□) with different seeding dates and seeding rates. The vertical lines indicate the standard error.

'Saessalbori' was more productive than 'Duwonchapssalbori' for the 5 Nov. seeding.

The relationship between grain yield and seeding rate was fitted well to the secondary polynomial equations (R^2= 0.84-0.85) for 20 and 28 Oct. seedings, but to linear simple equa-

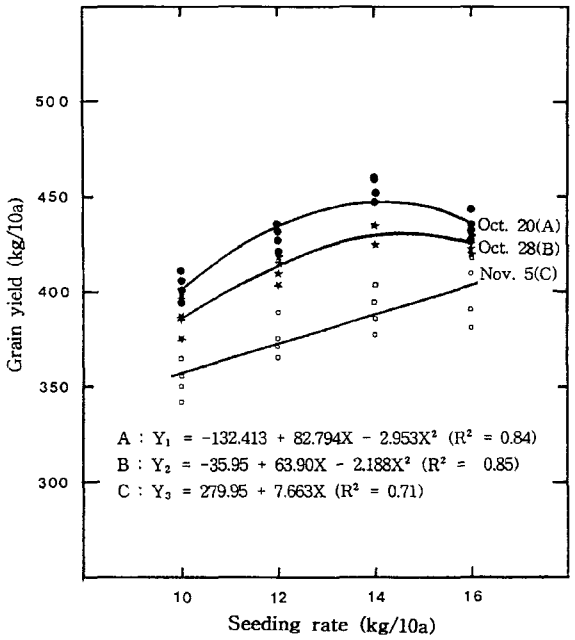

Fig. 2. Changes of grain yield of 'Duwonchapsallbori' and 'Saessalbori' with the different seeding rates.

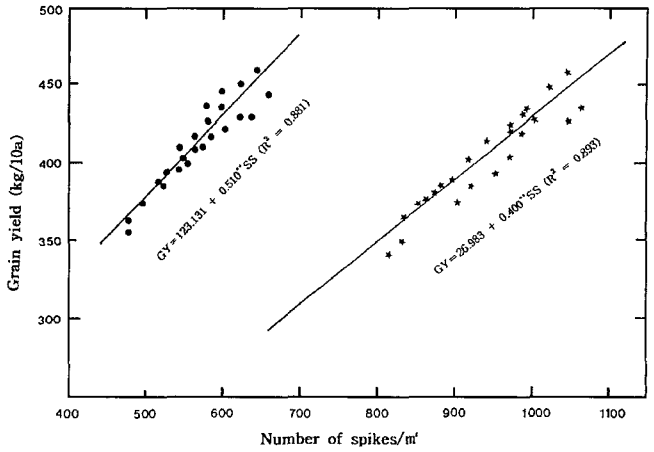

Fig. 3. Relationship between grain yield (GY) and number of spikes per m^2 (SS) in 'Duwonchapsallbori' (★) and 'Saessalbori' (●) with different seeding dates and seeding rates.

tion for 5 Nov. seeding (R^2=0.71). The highest grain yield was observed for 20 and 28 Oct. seedings with a seeding rate of 140 kg per ha, and for 5 Nov. seeding with a rate of 160 kg per ha (Fig. 2).

It was reported in barley that number of spikes per m^2 was decreased linearly with late planting (Im, 1976; Park, 1975; RDA, 1985b; Ryu & Ha, 1986). When late planted, emerging dates were delayed and 1,000-kernel weight increased due to decrease in number of tillers per plant. These studies were similar to the previous reports. However, Middleton *et al.* (1964) reported that 1,000-kernel weight and test weight were not affected with late seeding.

Relationships among major agronomic traits

In 'Duwonchapssalbori', grain yield was highly significantly correlated with number of spikes per m^2 (0.945**), heading and maturity dates (-0.766**, -0.712**), and emerging days (-0.723**) (Table 3). Number of spikes was highly negatively correlated with heading and maturity dates, and emerging days. One thousand-kernel weight was highly positively correlated with number of kernels per spike. 'Saessalbori' had similar trends to 'Duwonchapssalbori' regarding relationships among major agronomic traits.

When grain yield was plotted with number of spikes per m^2 for 'Duwonchapssalbori' and 'Saessalbori', highly significant relationships were observed (Fig. 3). The slope of the regression line for 'Saessalbori' was significantly greater than for 'Duwonchapssalbori'. Number of spikes per m^2 did account for the variation of grain yield (R^2=0.881~0.891), suggesting that number of spikes/m^2 was the most important factor for grain yield (Fig. 3).

The number of spikes per m^2 amongst yield components was linearly decreased with delay of seeding (Im, 1976; Park, 1975). In the case of late seeding, the emerging dates were delayed, and plant growth was not enough to endure severe

Table 3. Correlation coefficients among major agronomic traits of 'Duwonchapssalbori' and 'Saessalbori' with different seeding dates and seeding rates (N=24).

Characteristics	Correlation coefficient (r)						
	GY	SS	TW	GN	HD	MD	ED
Grain yield (GY)	1	0.939**	-0.553**	-0.334	-0.708**	-0.649**	-0.656**
No. of spikes (SS)	0.945**	1	-0.580**	-0.351	-0.713**	-0.722**	-0.690**
1,000 kernel wt. (TW)	-0.144	-0.162	1	0.435*	0.584**	0.644**	0.546**
No. of grain (GN)	-0.201	-0.153	0.686**	1	-0.121	-0.086	-0.186
Heading date (HD)	-0.766**	-0.861**	0.124	-0.176	1	0.956**	0.978**
Maturity date (MD)	-0.712**	-0.841**	0.329	-0.050	0.962**	1	0.983**
Emerging day (ED)	-0.723**	-0.844**	0.188	-0.136	0.975**	0.980**	1

*, **Significant at the 5% and % levels, respectively. Shaded side for 'Duwonchapssalbori', open side for 'Saessalbori'.

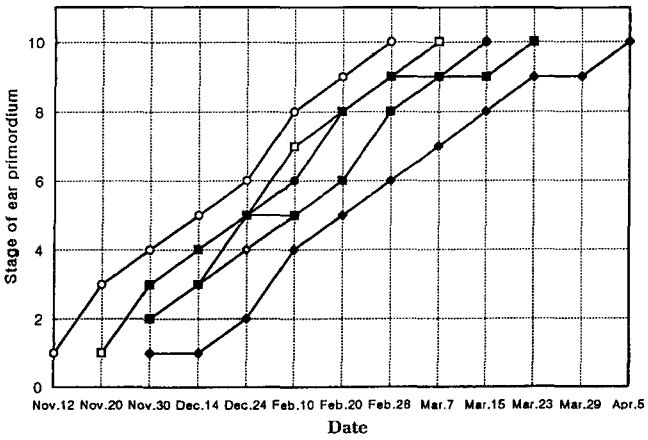

Fig. 4. Changes in stage of ear primordium with time for 'Duwonchapsallbori' (D) and 'Saessalbori' (S) with the different seeding dates and seeding rates. –○–; D Oct. 20, –□–; D Oct. 28, –◇–; D Nov. 4, –●–; S Oct. 20, –■–; S Oct. 28, –◆–; S Nov. 4

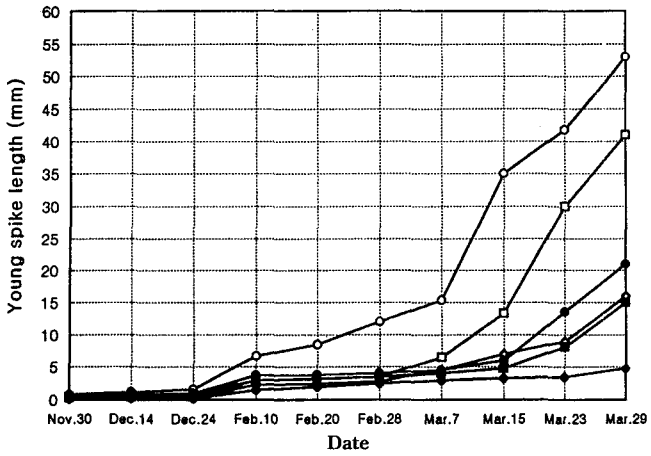

Fig. 5. Changes in young spike length with time for 'Duwon chapsallbori' (D) and 'Saessalbori' (S) with the different seeding dates and seeding rates. –○–; D Oct. 20, –□–; D Oct. 28, –◇–; D Nov. 4, –●–; S Oct. 20, –■–; S Oct. 28, –◆–; S Nov. 4

environmental stress before overwintering. These results coincided with the previous reports (Im, 1976; Park, 1975).

Changes in development of ear primordium and elongation of young spike

Plants of 'Duwonchapssalbori' were developed to reach the stages of VI on 24 Dec. for the 20 Oct. seeding, V for the 28 Oct. seeding, and IV for the 5 Nov. seeding (Fig. 4). However, plants of 'Saessalbori' had the stages of V, VI, and II~III for the same seeding dates as 'Duwonchapssalbori'. The final stage of X of 'Duwonchapssalbori' was observed on 28 Feb. for 20 Oct. seeding, 7 March for 28 Oct. seeding, and 23 March for 5 Nov. seeding, respectively. 'Saessalbori' were delayed by about 7 days as to reach the stage of X compared with 'Duwonchapssalbori'. So, the spring type cultivar, 'Duwonchapssalbori' headed earlier than 'Saessalbori' by 2-5 days.

Elongation of young spike was significantly different between 'Duwonchapssalbori' and 'Saessalbori' (Fig. 5). Young spikes in the 20 Oct. seeding elongated linearly since 10 Feb., and then elongated rapidly since 7 March (young spike length = 15.1 mm). Also, in the 28 Oct. seeding, the young spike appeared later, but rapid elongation began since 7 March (young spike length = 6.5 mm). However, facultative type cultivar 'Saessalbori' showed no remarkable difference depending on seeding dates, and its young spikes elongated slowly since 15 March.

Plants in the early planting reached stages of V=VII on 10 Dec. in Suwon, and stage of V in Jinju (Ryu & Ha, 1986). According to Chun & Lim (1996), varieties with growth habit of I-V reached stage of VI on 8 Dec. in Sunchon. These results showed a little different stages of ear primordium because of different used varieties and seeding dates. In order to breed varieties with early heading and high yield, it is suggested that selection of lines with early heading at relatively low temperature condition in early spring is required (Chun, 1993). Also, these results indicates that 'Duwonchapssalbori' has the characteristics with early heading and high grain yield in the southern regions.

Quality characteristics of barley grains

In 'Duwonchapssalbori', the proportions of grain sizes for

Table 4. Seed characteristics of 'Duwonchapsallbori' and 'Saessalbori' (seed lots from plots of Oct. 20 & seeding rate of 12 kg/10a).

Variety	Kernel wt. (g/100g)			Kernel length (mm)		Kernel width (mm)		Kernel thickness (mm)	Dimension† (mm^3)
	2.5 mm	2.2 mm	2.0 mm	lateral	center	lateral	center		
Duwonchapssalbori	55.1	36.9	8.0	-	7.1	-	3.3	2.3	54.3
CV(%)	4.3	4.0	12.2	-	5.6	-	3.8	3.5	
Saessalbori	27.0	45.2	27.7	5.4	5.7	3.1	3.4	2.4	40.2
CV(%)	5.7	1.3	4.5	4.1	4.9	6.9	7.2	3.4	

†Dimension = kernel length × width × thickness

above 2.5 mm, 2.5-2.2 mm and below 2.0 mm were 55%, 37% and 8%, respectively (Table 4). In 'Saessalbori', the proportions for the same classifications were 27%, 45%, and 28%, respectively. The seed length of 'Duwonchapssalbori' was 7.1 mm with dimension of 54.3 mm^3, but that of 'Saessalbori' was 5.7 mm with dimension of 40 mm^3.

According to Gang (1995), Chun & Choi (1994) and Ha *et al.* (1988), the polished grain qualities for 'Duwonchapssalbori' such as the yield of final product, whiteness, 1,000-kernel weight, water absorption rate, expansibility and β-glucan content were better than those for 'Saessalbori'. Also, the split-polished grain qualities for 'Duwonchapssalbori' were better than those of 'Saessalbori'. In malting barley, the proportions of grain size above 2.2 mm were 95-97% (Chun & Choi, 1994; Ha *et al.*, 1988), and proportion for the same degree was 92% in 'Duwonchapssalbori', suggested that this variety had good quality for producing both polished grain and split-polished grain.

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