Korean J. Crop Sci. 45(2): 73~78(2000)

Growth, Yield and Grain Quality affected by Seeding Rates and Fertilizing Combinations in Spring-sown Jinyangbori

Dae Ho Kim*,†, Su Kyeong Kim*, Eun Seok Kim*, Guen Woo Song* and Dong Ju Kang*

**Kyongnam Agricultural Research and Extension Services, Chinju 660-370, Korea.*

ABSTRACT : This study was conducted for 2 years at Chinju region to establish suitable seeding rate and fertilizing levels of nitrogen, phosphorous and potassium in spring-sown Jinyangbori. Heading and maturing were delayed by increasing fertilizers, especially nitrogen. Number of spikes per were secured by much seeding and increased application of nitrogen. One thousand grain weight reduced with increasing fertilization at any seeding rate. Relatively high harvest indices were observed with 12-10-4 at 10 kg · 10a^{-1} seeds planted, followed by 6-10-8 at 15 kg · 10a^{-1}, and 6-10-4 kg · 10a^{-1} at 20 kg · 10a^{-1} of N-P-K fertilizing combinations, respectively. There was no distinct differences on yield for various seeding rates in spring-sown barley. When seeding rate increased up to 15 kg · 10a^{-1}, the positive effect of fertilizers was recognized as the function of balanced-application. It was possible to recommend 10 kg · 10a^{-1} as seeding rate and 6-5-4(N-P-K)kg · 10a^{-1} as fertilizing combination in spring-time seeding considering low input and sustainable agriculture. There was no significant difference of protein content in grain by seeding rate. Increase of nitrogen fertilizer enhanced protein content in grain.

Keywords : malting barley, spring-seeding, seeding rate, fertilizing combination.

Cropping acreage of barley has reduced gradually because of low income, labor competition with rice harvest, and poor meteorological environment at seeding time in autumn. For domestic dietary life and self-sufficiency of food, however, a certain level of cultivation of barley has to be maintained. Cultivation of barley is also important regarding the environmental sustainability. Recently, spring-time seeding of barley has been examined to solve the problems of labor competition and delaying of seeding time, especially, at southern regions.

Ha and Maeng (1989) reported that there were a lot of genetic resources of barley having spring-habit in Korean peninsular. Epidemic of Barley Yellow Mosaic Virus (BYMV) disease severely occurred in autumn-sown malting barley may be reduced in spring-time seeding. Land-use capability can be enhanced with change of cropping system with spring barley. Short growth period results in low grain yield in spring-sown barley. More efforts will be made to increase yield, such as breeding cultivars for spring seeding and establishing cultivation practice with optimum seeding rate and fertilizing levels.

It is profitable to plant early for extension of growth period of barley and following rice planting. Kim *et al.* (1998) reported that suitable seeding date for spring-time seeding of barley was early~mid in February at Chinju province. Nitrogen use efficiency(NUE) for cereal production is approximately 33 (Raun *et al.*, 1999). Loss of fertilizer N was caused by gaseous plant emission, soil denitrification, surface runoff, volatilization, and leaching. Nitrogen fertilization was most effective to increase number of spikes per in barley (Black *et al.*, 1946). Pendleton (1953) reported similar result and emphasized that increase of fertilization was more effective than increase of seeding rate. Also, in hydroponic cultivation of barley, Mactedd (1969) recognized the effect of nitrogen, phosphorus, and interaction between nitrogen and potassium on tillerling, number of spikes per , and yield. In malting barley, increase of seeding rate resulted in increase of number of spikes per and yield, and decrease of 1,000 grain weight (Lee *et al.*, 1975). Choi *et al.* (1976) reported that heading date was moved up by increasing seeding rate, and was delayed by fertilizing by about 2 days.

Our study was conducted to establish the suitable seeding rate and fertilizing combination of nitrogen, phosphorus and potassium for stable yield in spring-sown Jinyangbori at Chinju province for 2 years, and our results were reported here.

MATERIALS AND METHODS

Soil series of experimented site was Cheongwon-tong having silt loam text. Before experiment, organic matter content was 2.5 mg/kg. Exchangeable cation for K, Ca and Mg were 0.31, 3.0 and 0.8 cmol$^+$/kg in order. P_2O_5, NH_4-N and NO_3-N were contained 201, 10 and 25 mg/kg in soil before experiment. Malting barley seeds (cv. Jinyangbori) were broadcasted to 90 cm-width ridge with 3 seeding rates and 8 fertilizing combinations (nitrogen-phosphorus-potas-

†Corresponding author: (Phone) +82-591-750-6218 (E-mail) kimdho@mail.knrda.go.kr, <Received February 2, 2000>

sium) on February 15th in 1997 and 1998. Plots were arranged by split-plot design with 3 replications. Combined fertilizers were applicated before seeding as well as non Farm Yard Manure (FYM). On October 25th, 15 kg · $10a^{-1}$ seed were sown with the fertilizing levels of nitrogen-phosphorus-potassium-FYM=12-10-8-1,000 kg · $10a^{-1}$ at the check plot. Nitrogen was applied by split-dressing at seeding time and top-dressed by 6 kg · $10a^{-1}$on early March. Agronomic traits and yield components, such as culm length, spike length, heading and maturing date, lodging (degree 0~9), number of spike per m^2, 1,000 grain weight, were measured according to the standard investigation method of Rural Development Administration (RDA). Plants per 3.3 m^2 were harvested and harvest index (HI) was calculated with the ratio of grain yield versus top dry matter weight. Grain protein was estimated by multiflying by 6.25 (nitrogen coefficient) to total nitrogen analyzed by using Kjeltec system (2,300 Kjeltec Analyzer Unit, Foss Tecator).

Significance by LSD and F-test for variables, and relationships between parameters were analyzed by correlation coefficient and regression using statistical package, SAS program.

RESULTS AND DISCUSSION

Agronomic Traits and Growth response

As shown in Table 1, there were no significant differences in heading and maturing dates depending on seeding rates. Heading and maturing were delayed by increased fertilizers, especially nitrogen, at the same seeding rate. According to Park (1975), there was no difference of heading date in

Table 1. Changes of heading, maturing date, and other agronomic traits as affected by different seeding rates and fertilizing combinations in spring-sown Jinyangbori.

Seeding rate (kg · $10a^{-1}$)	Fertilizing combination (kg · $10a^{-1}$)=N-P_2O_5-K_2O	Heading (date)	Maturing (date)	Culm length (cm)	Lodging (0~9)	Spike length (cm)	No. of tillers per m^2	No.of spikes per m^2	Effective tillering ratio (%)
10	0-0-0	May 5	Jun. 6	73	0	5.8	1,321	700	53
	6-5-4	May 5	Jun. 6	79	1	6.0	1,313	800	61
	6-10-4	May 5	Jun. 7	77	2	5.8	1,414	905	65
	6-10-8	May 5	Jun. 7	75	2	5.9	1,274	834	66
	12-10-4	May 5	Jun. 7	78	3	6.0	1,260	836	67
	12-10-8	May 6	Jun. 8	80	2	6.1	1,214	894	74
	15-10-8	May 6	Jun. 8	80	3	6.4	1,400	843	60
	15-10-12	May 6	Jun. 9	77	3	6.1	1,271	877	69
	Mean	May 5	Jun. 7	77	2	6.0	1,308	836	64
15	0-0-0	May 3	Jun. 6	75	0	5.7	1,118	896	70
	6-5-4	May 4	Jun. 6	78	2	5.8	1,328	914	69
	6-10-4	May 4	Jun. 7	77	3	5.9	1,456	964	67
	6-10-8	May 4	Jun. 7	76	3	5.9	1,225	903	74
	12-10-4	May 5	Jun. 8	81	3	5.9	1,365	931	69
	12-10-8	May 5	Jun. 8	78	3	5.8	1,464	947	66
	15-10-8	May 6	Jun. 8	79	4	5.9	1,474	857	58
	15-10-12	May 6	Jun. 9	79	4	6.2	1,285	976	77
	Mean	May 5	Jun. 7	78	3	5.9	1,339	924	69
20	0-0-0	May 3	Jun. 4	73	1	5.7	1,200	808	67
	6-5-4	May 4	Jun. 5	76	3	5.6	1,460	920	64
	6-10-4	May 4	Jun. 6	76	3	5.9	1,380	885	64
	6-10-8	May 4	Jun. 6	77	3	5.7	1,573	1,048	67
	12-10-4	May 5	Jun. 6	78	3	5.8	1,700	1,058	62
	12-10-8	May 5	Jun. 7	77	3	5.8	1,485	976	68
	15-10-8	May 5	Jun. 7	78	4	5.9	1,489	1,024	70
	15-10-12	May 5	Jun. 7	77	4	5.7	1,675	970	58
	Mean	May 5	Jun. 6	77	3	5.8	1,495	961	65
15	Autumn-sown	Apr. 17	May 25	85	5	6.4	1,273	937	74
LSD(0.05)		Seeding rate					NS	86	NS
		Fertilizing combination					156	73	NS
		Interaction					270	126	16

warm season with different seeding rates, and showed earlier heading by increased seeding rate in cold year. Heading and maturing was delayed by about 18 and 13 days by increased fertilizing combinations in this study as compared to those of autumn-sown barley. Culm became longer with increasing of nitrogen rate, however, phosphorous and potassium didn't effect on that largely at any seeding rate. Culm length in spring-sown barley was shorter than that of autumn-sown barley, and this was due to different growth days. Lodging was not serious at less-sown plots and was serious with increased application of nitrogen. A half of autumn-sown barley lodged due to long culm length. Spike length showed similar tendency as the case of culm length. Increased seeding resulted in much tillers with no significant difference, while significances were recognized among fertilizing combinations and their interaction between seeding rate and fertilizing combination. Number of spikes per m^2 was secured by much seeding and increased nitrogen, showing no clear differences with fertilizing combination. In less-sown plot, it was possible to secure a level number of spikes with decreased fertilization, while much fertilization was needed in increased seeding rate. In autumn-sown barley, previous studies were reported that coefficient of variation of effective tillering ratio ranged from 30 to 70% and was widely affected by different seeding dates and rates, and highest yield was observed at around 50% of effective tillering ratio (Singh *et al.*, 1972; Park, 1975). With no significant differences by seeding rates and fertilizing combinations, effective tillering ratio ranged from 53 to 77% in present study, and highest yield was observed at about 65% of tillering ratio. This difference between present study and other previous results on most effective tillering ratio was due to short growth days and environmental change in spring-sown as compared to autumn-sown barley.

Results on yield components, such as selective grain ratio, harvest index, and yield as affected by different seeding rates and fertilizing combinations are given in Table 2.

It showed no difference on grain number per spike between treatments, and the spring-sown barley had less grain number per spike than autumn-sown barley. Declined grain number resulted from short growth period which caused imperfect development of juvenile panicle. One thousand grain weight is unique character of a variety with little variation depending on environmental changes(Cho, 1974). One thousand kernel weight was known to be reduced by increasing of seeding rate (Guh *et al.*, 1984). In present study, 1,000 grain weight was the greatest when 10 kg $\cdot$ $10a^{-1}$ of seeds were sown, and reduced with increased fertilizing at any seeding rate. This result coincided with previous reports (Lee *et al.*, 1975; Choi *et al.*, 1987). There was no apparent relationship between grain size ratio and different seeding rates. Increase of dressing of fertilizer decreased selective grain ratio. Especially, when N-P-K fertilized over 15-10-8 kg $\cdot$ $10a^{-1}$ selective grain ratio dropped below 85% in the plots where 15 and 20kg $\cdot$ $10a^{-1}$ were sown. Similar result was observed in 1,000 grain weight. Plant harvest index, the ratio of grain weight to total plant weight, is an important trait associated with crop yield. Harvest index reflects the partitioning of photosynthesis between the grain and the plant. Improvement of harvest index emphasizes the importance of carbon allocation in grain production. Accumulation of high levels of nitrogen is essential for high grain yield, and thus, high levels of nitrogen are commonly associated with crops having high harvest indices(Sinclair, 1998). There were no significant differences on harvest indices for different seeding rates. Relatively high harvest indices were observed with 12-10-4 (sown by 10 kg $\cdot$ $10a^{-1}$ seeds), 6-10-8(15 kg $\cdot$ $10a^{-1}$), and 6-10-4 kg $\cdot$ $10a^{-1}$ (20 kg $\cdot$ $10a^{-1}$) of N-P-K fertilizing combinations, respectively. Low harvest index by increased fertilizing was regarded as the shortage of sink(number of grain per spike) in spite of abundant source(total plant weight). To secure optimum source-sink output is primary target to be improved. There was no distinct differences on yield as affected by seeding rate in spring-sown barley. When seeding rate increased up to 15 kg $\cdot$ $10a^{-1}$, the positive effect of fertilizers was recognized as the function of balanced application.

As reported by Choi *et al.* (1976), when spikes per unit area were secured above optimum level, grain number per spike had more effect on yield than spike numbers. In present study, grain yield of spring-sown barley was lower than autumn-sown due to shortage of grain number per spike. There was no serious nitrogen starvation in spring-sown barley with a half level of fertilizing in autumn seeding. Thus, it is possible to recommend 10 kg $\cdot$ $10a^{-1}$ as seeding rate and 6-5-4(N-P-K) kg $\cdot$ $10a^{-1}$ as fertilizing combination in spring-time seeding in term of input and sustainable agriculture.

Analysis of variance, correlation, and regression analysis

Analysis of variance on yield components, yield, harvest index and grain protein for different seeding rates, fertilizers and their interactions are given in Table 3. It is commonly known that there is negative relationship between potassium and NH^4-N, and that nitrogen promotes phosphorus uptake. According to Yoon *et al.* (1991), there was no interactive effect of seeding rate and fertilizing level on grain number per spike, while clear interactive effect of seeding rate and fertilizing level on spike number per m^2 and grain yield in wheat. Mossedaq *et al.* (1994) documented different nitrogen

Table 2. Comparisons of yield components, selective grain ratio, harvest index and yield as affected by different seeding rates and fertilizing combinations in spring-sown Jinyangbori.

Seeding rate ($kg \cdot 10a^{-1}$)	Fertilizing combination ($10a^{-1}$) = N-P_2O_5-K_2O	No. of grain /spike	1,000 grain weight (g)	Grain size ratio (%)			Harvest index	Grain yield ($kg \cdot 10a^{-1}$)	Index
				2.2 mm>	2.22.5	2.5 mm<			
10	0-0-0	22	47.9	1.3	3.2	95.5	52.9	354	70
	6-5-4	23	45.1	2.8	6.3	90.9	53.7	416	83
	6-10-4	22	44.8	3.4	7.2	89.5	51.6	422	84
	6-10-8	22	44.8	3.5	7.5	89.0	54.3	428	85
	12-10-4	23	44.0	4.3	8.3	87.0	54.5	456	90
	12-10-8	22	43.3	4.3	10.3	85.5	50.3	428	85
	15-10-8	23	44.7	3.6	8.4	88.1	48.1	425	84
	15-10-12	22	43.8	4.7	9.6	85.7	47.5	388	77
	Mean	22	44.8	3.5	7.6	88.9	51.6	415	(82)
15	0-0-0	22	46.8	1.2	3.6	95.2	52.4	323	64
	6-5-4	23	44.3	3.5	7.3	89.2	51.3	406	81
	6-10-4	22	44.8	3.5	6.5	90.0	49.5	426	85
	6-10-8	22	43.5	3.4	7.8	89.2	53.9	441	88
	12-10-4	23	42.7	4.6	9.8	85.6	49.0	432	86
	12-10-8	22	43.6	4.4	8.6	87.0	51.7	451	89
	15-10-8	22	42.5	6.1	10.9	83.0	49.5	417	83
	15-10-12	22	41.9	6.1	11.7	82.8	49.5	475	94
	Mean	22	43.8	4.1	8.3	87.8	50.9	421	(84)
20	0-0-0	21	46.3	1.4	3.7	94.9	50.9	331	66
	6-5-4	22	44.4	3.1	6.3	90.7	51.5	409	81
	6-10-4	22	44.2	3.2	6.9	90.0	52.0	397	79
	6-10-8	20	45.3	2.6	5.8	91.7	48.5	423	84
	12-10-4	21	43.0	4.7	9.5	85.9	50.3	442	88
	12-10-8	22	43.2	4.4	9.5	86.1	49.5	440	87
	15-10-8	22	42.2	5.3	10.9	83.8	45.9	418	83
	15-10-12	21	42.8	5.3	10.0	84.7	46.9	396	79
	Mean	21	43.9	3.8	7.8	88.5	49.4	407	(81)
-	Autumn-sown	26	39.6	7.4	13.8	78.7	54.6	504	100
LSD(0.05)	Seeding rate		0.5			NS	NS	NS	
	Fertilizing combination		0.7			1.9	3.2	27	
	Interaction		1.2			3.2	5.6	47	

uptake and its effect in wheat.

In Table 3, analysis of variance on spike number per m^2 and 1,000 grain weight showed significance by seeding rate, nitrogen, phosphorus, potassium, and the interactive effect of nitrogen × phosphorus, nitrogen × potassium, phosphorus × potassium, and nitrogen × phosphorus × potassium. There was no significance on grain number per m^2 spike by all treatments except for seeding rate.

On yield, significance was observed by changes of nitrogen, phosphorus, and potassium levels, and their interactions. Significance was observed on harvest index with different nitrogen application, nitrogen x phosphorus interaction and nitrogen x potassium interaction. As above mentioned, application of fertilizers and their interactions were recognized on most of yield components and yield, but the interaction between seeding rate and fertilizers was not recognized.

As reported previously, there was highly positive correlation between yield and number of spike per unit area in barley (Arny *et al.*, 1918; Im, 1975; Park, 1975). Park (1975) observed negative correlation between yield and grain number per spike and no significance between yield and 1,000 grain weight. The correlation relationships among yield and agronomic traits in present study are given in Table 4. It showed significantly positive correlation between spike number per m^2 and effective tillering ratio, and protein content in grain and/or negative correlation between spike number per m^2 and 1,000 grain weight, and harvest index, respectively. As reported by Ryu *et al.* (1992), grain weight was negatively related to yield in spring-sown barley. And negative correlation was also observed between 1,000 grain weight and protein content in grain. According to Lee *et al.*

Table 3. Analysis of variance on yield components, yield, harvest index, and crude protein content for seeding rates, fertilizers, and their interactions in spring-sown Jinyangbori.

Source	No. of spikeper	No. of grain per spike	1,000 grain weight	Yield	Harvest index	Crude protein
SR	**	**	**	NS	NS	NS
N	**	NS	**	**	**	**
P	**	NS	**	**	NS	**
K	**	NS	**	**	NS	**
SRN	NS	NS	NS	NS	NS	NS
SRP	NS	NS	NS	NS	NS	NS
SRK	NS	NS	NS	**	NS	NS
NP	**	NS	**	**	**	**
NK	**	NS	**	**	**	**
PK	**	NS	**	**	NS	**
NPK	**	NS	**	**	NS	**

* ,** : represent significance at 5 and 1 probability, respectively.
NS : not significant.

Table 4. Correlation coefficient between agronomic traits in spring-sown Jinyangbori.

Item	NS	GN	WT	Y	HI	ET
GN	-0.22					
WT	-0.402**	-0.096	-0.469**			
Y	0.25*	0.023	0.281*	0.067		
HI	-0.368**	0.169	-0.178	0.177	0.006	
ET	0.421**	-0.081	-0.569**	0.436**	-0.255*	0.032
TN	0.343**	0.013				

NS : No. of spike per m^2, GN : No. of grain per spike, WT : 1,000 grain weight, Y : Yield, HI : Harvest index, ET : Effective tillering rate, TN : Protein in grain.

(1975), leaf nitrogen content was significantly correlated with grain yield, and similar result was obtained between grain protein content and yield in present study. Conclusively, significant relationship was observed between yield and spike number per unit area in spring-sown Jinyangbori.

By regression of nitrogen and potassium on yield at any seeding rate, optimum amount of nitrogen and potassium for maximal yield were estimated as 9.6 and 6.5 kg · 10a^{-1}, respectively, with seeding rate of 10 kg · 10a^{-1}. When 15 kg · 10a^{-1} seeds were sown, 11.8 of nitrogen and 11.6 kg · 10a^{-1} of potassium were required for maximal yield. In case of phosphorus, it was impossible to estimate optimum fertilizing level because of linear relationship between phosphorous and yield. Park *et al.* (1973) reported that phosphorus response was reduced when barley grew under higher soil

Table 5. Regression analysis on yield vs fertilizer and optimum dressing for maximal yield at each seeding rate in spring-sown barley.

Seeding rate (kg · 10a^{-1})	Fertilizer	Regression of yield vs fertilizer	R^2	Optimum dressing for maximal yield
10	N	$Y = 350.8+18.1x-0.94x^2$	0.450	9.6
	P	$Y = 364.6+6.15x$	0.313	-
	K	$Y = 360.1+23.6x-1.81x^2$	0.458	6.5
15	N	$Y = 326.5+21x-0.89x^2$	0.549	11.8
	P	$Y = 332.4+11x$	0.560	-
	K	$Y = 336.4+21.6x-0.93x^2$	0.566	11.6
20	N	$Y = 326.9+20.5-0.98x^2$	0.568	10.5
	P	$Y = 344.1+7.75x$	0.425	-
	K	$Y = 355.2+26.4x-1.8x^2$	0.524	7.3

temperature in maturing stage. In present study, the amount of phosphorus was insufficient to find optimum level for growth in warm season as compared to autumn-sown barley. Considering soil chemical and physical properties before seeding, controlled application for nitrogen, phosphorous and potassium is needed.

Seed protein content

Protein content in malting barley grain is very important for brewing and malting quality. Generally grain containing protein below 11% is used for brewing. MacGregor *et al.* (1993) reported protein content in matured seed ranged from 8 to 15% in barley. Nam *et al.* (1990) reported the coefficient of variation(C.V.) in protein content ranged from 11.6 to 14.9%. According to Cho *et al.* (1996), pro-

Table 6. Comparison of crude protein as affected by different seeding rates and fertilizing combinations in spring-sown Jinyangbori .

Fertilizing combination N-P-K (kg · 10a^{-1})		Seeding rate (kg · 10a^{-1}) 10	15	20
0 - 0 - 0		10.5	10.2	10.2
6 - 5 - 4		10.3	10.9	11.3
6 - 10 - 4		10.6	11.2	10.9
6 - 10 - 8		11.1	10.7	11.2
12 - 10 - 4		11.1	11.4	11.1
12 - 10 - 8		10.8	11.3	11.2
15 - 10 - 8		11.2	11.3	11.3
15 - 10 - 12		11.0	11.7	11.2
Mean		10.8	11.0	11.0
Autumn-sown		-	10.1	-
LSD (0.05)	seeding rate		NS	
	fertilizing combination		0.53	

tein content and husk ratio became higher by increase of nitrogen application. They proposed that protein content could be controlled by balanced-application of nitrogen, phosphorous, and potassium. In present study, there was no significant difference for protein content in grain by seeding rate (Table 6), which was in accordance with Choi *et al.* (1987). At the same seeding rate, increased fertilizing, especially nitrogen, enhanced protein content in grain. In any seeding rates and fertilizing combinations, protein content didn't exceed over 12%.

Conclusively, 10 kg $\cdot$ $10a^{-1}$ as seeding rate was suitable in spring-time seeding of barley. Fertilizing levels of nitrogen, phosphorus and potassium were recommended as 6, 5, and 4 kg $\cdot$ $10a^{-1}$ in spring-time seeding of barley, which were half amount of autumn-seeding.

REFERENCES

Arny, A. C. and R. J. Gaber. 1918. Variation and correlation in wheat with special reference to weight of seed plants. *J. Agric. Res.* 14:359-392.

Black, C. A., N. B. Nelson, and W. C. Pritchett. 1946. Nitrogen utilization by wheat as affected by rate of fertilization. *Soil Amer. Proc.* 11:393-396.

Cho, C. H. 1974. Studies on the inheritance of heading in wheat. *Korean J. Crop Sci.* 15:1-31.

Cho, C. H., Y. W. Ha, K. S. Kim, S. H. Kim, and C. H. Choi. 1996. Breeding history of malting barley in Korea. OB Brewing Co. p. 169.

Choi, H. K., T. S. Kim, H. C. Park, and G. Y. Park. 1987. Effects of local difference and cultural practices on yield and major character of malting barley. *Res. Rept. RDA*(Crop). 29(1):147-153.

Choi, J. H. and J. Y. Cho. 1976. Variation of yield and yield components of wheat and barley cultivars in accordance with different seeing rate and fertilizer level. *Korean J. Crop Sci.* 21(2): 233-249.

Guh, J. O., Y. M. Lee, K. Y. Ha, and D. Y. Shin. 1984. Response of malting barley cultivars to different seeding rates. Variation of yield components and yields in different seeding rates. *Korean J. Crop Sci.* 29(4):409-415.

Ha, Y. W. and D. J. Maeng. 1989. Comparison of inner factors of Korean native and bred barley on heading time. Barley Genetics V. Proceeding of the 5th International Barley Genetics Symposium. Okayama. pp. 119-126.

Im, B. G. 1975. The ecological variation of yield and its related characters among the spring barley varieties under the different growing season. *Korean J. Breeding.* 7(1):29-34.

Kim, D. H., S. K. Kim, E. S. Kim, B. Y. Son, D. J. Kang, Y. J. Choi, and W. S. Kim. 1998. Growth and seed quality of spring-sown barley in response to growth habit and seeding date. *RDA J. Crop Sci.* 40(1):28-33.

Lee, H. S., E. W. Lee, and H. Y. Lee. 1975. Studies on the response of barley varieties to nitrogen application and seeding methods. *Korean J. Crop Sci.* 20:152-162.

MacGregor, A. W. and R. S. Bhatty. 1993. Barley : Chemistry and Technology. Amer. Associ. Creal Ind. Inc. St. Paul. pp. 131-134.

Mactedd, L. B. 1969. Effects of N, P, and K and their interactions on the yield and kernel weight of barley in hydroponic culture. *Agron. J.* 61:26-30.

Mossedaq, E. and D. H. Smith. 1994. Timing nitrogen application to enhance spring wheat yields in a mediterranean climate. *Agron. J.* 86:221-226.

Nam, J. H., E. S. Lee, B. H. Hong, and K. J. Kim. 1990. Quantify and quality of seed protein and its regional variation in barley. *Korean J. Crop Sci.* 35(5):387-392.

Park, C. Y. 1975. Analytical studies on yield and yield components in barley. *Korean J. Crop Sci.* 18:88-123.

Park, N. J., C. S. Lee, I. S. Ryu, C. S. Park, and Y. S. Kim. 1973. The effects of major climatic factors on barley response to NPK fertilizers. *J. Korean Soc. Soil Sci. Fert.* 6(2):129-136.

Park, S. H. and W. S. Han. 1976. Analytical study on predicting conditions of major crops II. Relation of temperature before heading and during ripening to 1,000 grain weight of barley. *RDA J. Crop Sci.* 18:127-131.

Pendleton, J. W., A. L. Lang, and G. H. Dungan. 1953. Response of spring barley varieties to different fertilizer treatment and seasonal growing conditions. *Agron. J.* 45:529-532.

Raun, W. R. and G. V. Johnson. 1999. Improving nitrogen use efficiency for cereal production. *Agron. J.* 91(3):357-363.

Ryu, Y. H., C. D. Lee, and Y. W. Ha. 1992. Effects of sowing date on grain filling and related traits in winter barley. *Korean J. Crop Sci.* 37(1):93-103.

Sinclair, T. R. 1998. Historical change in harvest index and crop nitrogen accumulation. *Crop Sci.* 38:638-643.

Singh, R. D., B. N. Chatterjee, and S. N. Sanyal. 1972. Tillering pattern in tall and dwarf wheat varieties under different levels of nitrogen and spacing. *Indian J. Agri. Sci.* 42:42-47.

Yoon, E. B., Y. H. Yoon, Y. U. Kwon, K. B. Youn, and M. G. Shin. 1991. Studies on fertilizer level, row spacing and seeding rate using the plot drill seeder in winter wheat. *Res. Rept. RDA.* (U&I). 33(2):65-71.