〔韓作誌(Korean J. Crop Sci.) 41(6) : 656~664(1996)〕

Relations between Seed Vigor Criteria and Field Performance in Malting Barley

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ABSTRACT : Three malting barley cultivars, Sacheon #6, Doosan #12, and Doosan #22 were collected from Gwangsan, Chinju and Milyang which were artificially aged to provide varying levels of seed quality. Samples were evaluated by the standard germination test (SGT), cold germination test (CT), electroconductivity test and tetrazolium vigor test (TZ). In a multiple regression analysis, percent germination in the SGT accounted for 65% of the variation in field emergence of malting barley. Vigor index of the standard germination and cold germination tests also contributed significantly to the regression equation. Grain yield was predicted by the vigor index of TZ test. Percent standard germination and percent TZ germination prediction were useful for predicting grain yield in nine lots of malting barley.

Key words : Malting barley, Seed lot, Seed vigor, Field emergence, Grain yield.

Many types of tests have been proposed to measure seed and seedling vigor[2,7,17,18,20,22,23,30,31,32]. The standard germination test shows a tendency to overestimate field performance[11,12,33,34]. Scientists have suggested combining physiological and biochemical test indices for improving the accuracy of predicting field performance of a given seed lot[8,10,14,15,18,21]. DasGupta and Austenson[9] concluded that the standard germination test could be supplemented with tests such as early seedling growth rate or root and shoot measurements to assess barley field performance more reliably. Bishnoi and Delouche[5] reported that assays which simulated adverse field conditions such as the cold test and accelerated aging test were adequate for predicting deterioration levels and field performance of cotton. Using six soybean varieties that had been naturally and artificially aged, Burris et al.[6] found that 4-day germination count and seedling growth rate gave the best estimates of soybean vigor, while Tekrony[28] proposed a combination of the standard germination test with one or more vigor tests to provide a broad evaluation of soybean vigor. Don et al.[13] concluded that several test methods were needed for a full evaluation of wheat seed quality and that no single test was in itself adequate in estimating seed vigor.

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In explaining the inadequacy of the germination test as a complete quality test, Yaklich and Kulik[34] showed that high germination percentage was not necessarily correlated with vigorous seedling growth. Scott[26] regarded vigor test as an extension of the standard germination test.

Stand establishment, as influenced by the rate and vigor of germination and emergence, is one of the most critical factors in obtaining maximum grain yield in cereals. In barley, rapid and uniform germination has an additional value to the malting barley. To date, plant breeders have been restricted in selection due to lack of an effective selection criteria.

Field emergence and subsequent stands are known to be affected by seed weight[8], seed maturity[3], seed vigor[14,21,29], seedling elongation rate[24,25], soil temperature[24], soil moisture[24] and their interactions. In addition to the interaction between those factors, there is also genotype-environmental interaction that further impedes the progress in developing rapidly emerging cultivars. Because field conditions are difficult to predict and control, the intrinsic potential of seed vigor is to be highly appreciated.

In this study, emphasis was given to assess aging treatment on vigor test and to find out the relationship between field emergence rate and various seed vigor criteria.

MATERIALS AND METHODS

1. Seeds and aging treatment

Nine lots of malting barley (three each of the cultivar Sacheon 6, Doosan 12 and Doosan 22) were collected from Gwangsan, Chinju and Milyang in 1992. The seeds were artificially aged for 0(control), 2, 4 and 6 days, incubated at 41±1.0℃ in near 100% relative humidity by the 'Wire-mesh tray' procedure with three hundred seeds per tray. Seeds were then placed in a single-seed layer at room temperature and dried up to 12~14% moisture content. All 45 subsamples were stored at 10℃ in 50% relative humidity until completion of the laboratory tests.

Seeds from each of the above treatments (days of aging) were tested by each of the following laboratory tests.

2. Standard germination test

According to the "Rules for Testing Seeds" of the Association of Official Seed Analysts(AOSA)[4], three 100-seed replications of seed were germinated by rolled paper towel method at 20℃ for 7 days, then plumule length of normal seedling was measured.

3. Vigor index

Vigor levels were calculated by multiplying percent normal germination by length of plumule.

4. Cold germination test

A cold test was conducted by exposing the seeds to 5℃ for 3 days, followed by successive 7 days at 20℃. The cold test was performed by three 100-seed replications of seeds in soil medium which was composed of equal parts of vermiculite and soil (v/v). A 3cm thick soil layer was placed on the bottom of each plastic box (9.7cm×8.4cm×9.4cm) on which 100 seeds were placed and covered uniformly with the half amount of soil. Seventy percentage of water holding capacity was maintained. After replacing the lids, the plastic boxes were incubated for 3 day at 5℃ and then removed the boxes from the cold chamber setted at 20℃ in 90% relative humidity for 7 days. The lids were removed from the boxes after 4 days to allow seedlings to grow. Normal seedlings were evaluated after 7 days with the number of emerged seedling above the germination medium, and classified into vigor categories based on plumule lengths of shorter than 2cm, 2~4cm, and longer than 4cm, of which were indiced as 2, 4 and 6, respectively.

5. Tetrazolium vigor test

The AOSA standard procedures[4] were adopted to categorize the vigor into high, medium, and low. A cumulative index of vigor was calculated by the indices.

6. Conductivity test (electroconductivity)

A conductivity test was performed by using the Suntax SC-17 Conductivity Tester. The sample seeds were soaked in tube with 30 ml deionized water at 20℃ for 20 hours. The average microamp per seed was calculated by dividing the sum of all 100 seeds and the values were shown in microsiemens cm/g/seed 30 ml. The details were published in previous paper[19].

7. Field test

Field plots were established at the Gyeongsang National University Experiment Station's Farm at Chinju, Gyeongnam. The seeds were sown at the rate of 12ℓ/10a, plot size was $3.3m^2$. Fertilizer was applied at a rate of $N\text{-}P_2O_5\text{-}K_2O$=12-9-7kg/10a. The sowing date was October 27, 1992. The treatments were arranged in a 3×3×5 factorial experiment in a completely randomized design with three replications. The factors included three cultivars harvested from three locations, Gwangsan, Chinju and Milyang, and five different aging times.

Field emergence counts were made on the 20th day from sowing. The rate of compensation(C) was estimated from the number of seedlings per $3.3m^2$(E) before wintering, the number of tillers at heading per $3.3m^2$(T).

8. The formular used was

$$C = \frac{T}{E}$$

The samples were used for measuring 1 liter weight by using the Brauer's Grain Balance (Kiya, 127). The number of grains per spike and the number of spike per m^2 were estimated. The harvest index values were calculated from the dry weight of grain and straw.

9. Statistic analyses

A stepwise multiple regression analysis described Steel and Torrie[27] was made.

RESULTS

1. Reproducibility

An analysis of variance showed that there were no significant differences between the replicates but the level of reproducibility was low in the coefficients of electro-conductivity, rate of compensation, the number of spikes per m^2 and grain yield as shown in Table 1 and 2. However, the least significant difference for cultivar was not recognized for plumule length and seed vigor parameter in standard germination test.

2. Cultivars

Most of the parameters revealed signifi-

Table 1. Significance for analysis of variance in respect of cultivar, seed lot, aging treatments and their interaction

Variable \ Factors	Variety (A)	Seed lot(B)	Aging treat.(C)	A×B	A×C	B×C	A×B×C
% standard germination	*	***	***	***	NS	***	***
Plumule length (mm, SGT)	***	NS	***	***	NS	***	***
Vigor (SGT)	NS	***	***	**	NS	***	***
% cold germination	NS	***	***	***	**	***	***
Vigor (CT)	***	***	***	***	***	***	***
% TZ germination prediction	***	***	***	***	***	***	***
Vigor (TZ)	***	***	***	***	***	***	***
Electroconductivity	***	***	***	***	NS	NS	NS
% field emergence	NS	***	***	***	NS	**	NS
Yield (kg /10a)	NS	***	***	NS	NS	NS	NS

NS, not significant; *, significant at 5%; **, significant at 1%, ***, significant at 0.1%.

cant difference among the three cultivars though inconsistent. Percent field emergence, standard germination vigor, percent cold germination, and yield showed no significant differences among the cultivars.

3. Seed lots

There was a significant difference between the seed lots though inconsistent. The differences of seed lots, plumule length, the number of grains per spike and harvest index were significantly different among cultivars. Percent field emergence, 1ℓ weight and grain yield were slightly different between cultivars.

4. Aging treatment

High significant differences between aging treatments were shown for all parameters, but not for electroconductivity test for Doosan 12 and Doosan 22 cultivars.

Inter-relationship of results obtained from cultivars, seed lot and aging treatment

The differences between cultivars and seed

Table 2. Correlation coefficient of the results of several laboratory tests in three malting barley cultivars having 3 seed lots and four aging treatments

Variable	Sacheon 6		Doosan 12		Doosan 22	
	Seed lot	Aging treat.	Seed lot	Aging treat.	Seed lot	Aging treat.
% standard germination	.30NS	.83**	.16NS	.88**	.28NS	.85**
Plumule length (mm, SGT)	.04NS	.91**	.03NS	.91**	.02NS	.91**
Vigor (SGT)	.21NS	.88**	.15NS	.90**	.26NS	.87**
% cold germination	.23NS	.86**	.21NS	.87**	.21NS	.89**
Vigor (CT)	.21NS	.79**	.20NS	.88**	.34NS	.84**
% TZ germination prediction	.25NS	.81**	.33NS	.80**	.13NS	.84**
Vigor (TZ)	.24NS	.82**	.19NS	.84**	.12NS	.78**
Erectroconductivity	.49*	.33NS	−.05NS	.22NS	.75**	.10NS
% field emergence	.32NS	.75**	.06NS	.84**	.36*	.73**
Yield (kg /10a)	.30NS	.70**	.13NS	.66**	.19NS	.77**

NS, not signigicant ; *, significant at 5%; **, significant at 1%.

Table 3. Correlation coefficients of several laboratory tests with the field performance of nine seed lots averaged across four aging treatments of three malting barley

Variable	Aging levels							
	Control		2nd day		4th day		6th day	
	FE	Yield	FE	Yield	FE	Yield	FE	Yield
% standard germination	.49*	.50*	.53*	.37NS	.55**	.46*	.12NS	.17NS
Plumule length(mm, SGT)	.02NS	.02NS	.18NS	.15NS	.01NS	.20NS	.04NS	.04NS
Vigor (SGT)	.49*	.51*	.43NS	.39NS	.54*	.39NS	.09NS	.10NS
% cold germination	.45NS	.53*	.57**	.47*	.55**	.22NS	.27NS	.46*
Vigor (CT)	.45NS	.49*	.53*	.43NS	.60**	.11NS	.32NS	.42NS
% TZ germination prediction	.25NS	.54*	.41NS	.25NS	.58**	.48*	.05NS	.20NS
Vigor (TZ)	.13NS	.28NS	.30NS	.16NS	.32NS	.58**	.20NS	.26NS
Electroconductivity	.58**	.53*	.56**	.42NS	.70**	.18NS	.34NS	.19NS
% field emergence (FE)	–	.41NS	–	.43NS	–	.39NS	–	.72*
Yield (kg/10a)	.41NS	–	.43NS	–	.39NS	–	.71**	–

NS, not significant; *, significant at 5%; **, significant at 1%.

lots were recognized in all parameters except yield. The percent field emergence, the number of spikes per m^2 and yield were affected largely by the plumule length, number of grains per spike and harvest index of the different seed lot.

5. Inter-relationship between cultivars, seed lots and aging treatment

An examination of the correlation coefficients in Table 3 indicated that aging treatment had no significant effect on test results. However, higher electroconductivity was obtained in the aged seed.

6. Inter-relationship between parameters

The relationship between the various parameters was summarized in Table 4. Plumule length, percent TZ germination prediction and vigor parameters. Electroconductivity was not related with rate of compensation, the number of grain per spike, 1 ℓ weight, yield and harvest index. Rate of compensation was not correlated with the results for any of the other parameters except plumule length, percent TZ germination prediction, TZ vigor, the number of grain per spike, 1 ℓ weight and harvest index.

Table 4. Interrelationships between the vigor tests carried out for three seed lots and four aging treatments of three malting barley cultivars

Character	Independent from
(1) % field emergence	(10)
(2) % standard germination	(10)
(3) Plumule length (mm, SGT)	–
(4) Vigor (SGT)	(10)
(5) % cold germination	(10)
(6) Vigor (CT)	(10)
(7) % TZ germination prediction	–
(8) Vigor(TZ)	–
(9) Electroconductivity	(10)(11)(13)(14)(15)
(10) Rate of compensation	(1)(2)(4)(5)(6)(9)(12)(14)
(11) No. of grains per spike	(9)
(12) No. of spike per m^2	(10)
(13) Wt. of 1 ℓ	(9)
(14) Yield (kg/10a)	(9)(10)
(15) Harvest index (%)	(9)

DISCUSSION

The data were representing the changes[3,5,7,8,19] that have been reported to occur when seeds lose vigor. All the measured criteria, vigor(CT), % cold germination, vigor(SGT) and % of standard germination parameters were correlated with field stand.

Acceptable levels of reproducibility between replicates and repeated tests were obtained during the investigation.

Establishment of the existence of true varietal effects on these tests requires further investigations on a large number of samples. The differences among the three cultivars in most of our tests may be due to effect of cultivars or simply to the quality of the seed lots used. The yield was not related to the difference between cultivars and seed lots.

The accelerated aging test has been developed to estimate the overall integrity of the seed, which may indicate potential failure when placed in unfavorable environments in the field. With the techniques described here, a number of physiological changes that accompany vigor loss could be determined within a working day.

Anderson[3] concluded that 10-to 20-year old barley seeds differ from 2-to 3-year old barley seeds of the same variety as follows: Older seeds (a) are more sensitive to accelerated aging; (b) have higher rates of CO_2 evolution; and (c) have lower total amylase activity than newer seeds. The older seeds were most sensitive to accelerated aging than newer seeds, even there were no differences in percent germination or shoot growth. After 36hr germination newer seeds showed 46 to 67% greater total amylase activity than older seeds.

Abdul-Baki and Anderson[1] found that barley seeds which were aged for up to 12 days by accelerated aging did not leach sugars, but barley seeds which were aged under normal conditions for 2, 5, and 8 years did leach sugars. They concluded that accelerated aging conditions are not identical to normal aging conductions even through the final result, loss of germination, is the same.

These results do answer some of the questions about the conductivity test but elucidation of differences observed in conductivity and field emergence still remain unanswered.

Seedling emergnce in the field is variable and it can be inferred, without knowledge of the actual biotic or edaphic factors which influence emergence, that when soil conditions were adverse emergence was poor and that when they were favourable emergence approached to the germination capacity.

The vigor test was more consistently related to emergence regardless of the soil condition. Thus the expression of seed vigor differences and the applicability of vigor test to emergence in the field for barley seed followed a similar pattern to those which have been described previously for pea seed[24]. In other papers relating vigor tests to field emergence of soybeans[29] correlations have been used to establish those vigor tests having potential use in estimating field emergence.

Table 5 showes a stepwise multiple regression analysis using various indices of the vigor which were effective in predicting field emergence. Determination coefficient (R^2) analysis showed that 65% of the variation in field emergence could be explained by the percent of the standard germination test in predicting field emergence. The prediction accuracy of field emergence was enhanced when contributions of variables such as vigor index of the standard germination and cold germination tests were added to the equation.

Table 5. Summary of a stepwise multiple regression analysis of emergence rate and seed vigor criteria in malting barley cultivars

Entered variable[a]	R^2	Residual mean squares
% standard germination	.647	117.44
Vigor (SGT)	.669	110.87
Vigor (CT)	.700	101.94
% cold germination	.700	101.16
Electroconductivity	.708	100.20
% TZ germination prediction	.710	100.04
Vigor (TZ)	.710	100.79
Plumule length (mm, SGT)	.711	101.34

[a] Order of variables entered in addition to previous variables.

Table 6. Summary of a stepwise multiple regression analysis of yield and seed vigor criteria in malting barley cultivars

Entered variable[a]	R^2	Residual mean squares
Vigor (TZ)	.537	11,567
% standard germination	.567	10,890
% TZ germination predication	.572	10,849
Vigor (SGT)	.575	10,866
Vigor (CT)	.576	10,924
% cold germination	.576	11,007
Plumule length (mm, SGT)	.577	11,064

[a] Order of variables entered in addition to previous variables.

In Table 6, the coefficient of determination was estimated for prediction of grain yield. It seemed to be more difficult than field emergence. To some extent, however, the vigor index (TZ), percent standard germination and percent TZ germination prediction contributed. It can be explained that the grain yield is influenced by environmental factors for a longer period than field emergence. Therefore, soil and weather conditions should be considered in order to predict the grain yield of malting barley together with the results of various vigor tests.

We conclude that the present approach may serve as a laboratory method for predicting field performance. Field performance differences that are to be measured and evaluated by this approach should be physical and physiological rather than genetic. In comparing seed lots within the same cultivars, and low germinability or seedling growth should be imposed by reduced vigor and not by dormancy.

In conclusion, vigor(CT), % cold germination, vigor(SGT) and % of standard germination parameters had a good association with field stand in decreasing order. The relationship among yield and TZ tests were best for yield prediction. Tests such as CT, TZ and SGT were related to emergence and grain yield. The cold test and TZ test results were also more closely related to grain yield than the germination test results, by showing that both the rate of field emergence and their vigor influenced grain yield.

적 요

광산, 진주와 밀양에서 수확된 사천6호, 두산12호와 두산22호 종자를 인위노화시켜 종자세를 조절하였다. 이들 종자로서 표준발아검사(standard germination test), 저온발아검사(cold germination test), 전기전도도검사(electroconductivity test)와 Tetrazolium 검사(TZ vigor test)를 실시하여 포장출아율및 수량과의 관계를 구명하고자 하였다. 9가지 seed lot을 이용한 맥주보리의 포장출아율 예측에는 표준발아검사에서의 발아율만으로 65%의 예측효과가 인정되었고 표준발아검사에서의 유묘세와 저온발아검사에서의 유묘세와 발아율 parameter 또한 효과적인 방법임을 다중회귀분석으로 알 수 있었다. 수량 예

측에는 TZ검사에서의 종자세 지수와 표준발아검사에서의 발아율과 TZ 검사에서의 예측발아율이 효과적인 parameter임을 알 수 있었다.

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