Effect of Meteorological Condition during Ripening on the Grain Shattering of Rice Plant

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登熟期 氣象條件이 벼알의 脫粒性에 미치는 影響

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ABSTRACT

Environmental factors are known in general to influence much on the development of abscission layer and thereby on shedding of plant parts. The present study was carried out to determine the effect of meterological condition during ripening on the grain shatterability of rice plants at harvest. Different meteorological conditions were obtained by shifting transplanting timing of 40 days old rice seedlings 4 times with a 15 days-interval.

Grain shatterability was measured as tensile strength of rice grains: it varied within a range of 214g. to 251g. in a practically non-shattering Japonica variety 'Jinheung' and 127.5g. to 204g. in an easy shattering Indica x Japonica progeny variety 'Taeback'. In view of field loss of rice, the variation in tensile strength with time of transplanting and harvest did not matter in Jinheung, but was an important factor in Taeback. In Taeback the tensile strength was significantly correlated positively with mean, maximum and minimum air temperature and relative humidity during a certain period of grain ripening, especially during 30 days period before harvest, but diurnal range of air temperature showed a significant, negative correlation with it. The tensile strength seemed to be more closely related with min. air temperature than max. air temperature, and it was not significantly correlated with radiation amount during any period of pre-harvest. Meteorological effect on grain shatterability may vary with variety, but temperature regime during ripening appears to play major role among the meteorological factors in easy shattering and more thermophilic Indica x Japonica varieties: lower the temperature, greater the shatterability.

INTRODUCTION

Considerable attention has been paid to the shattering of rice grains since the introduction of Indica x Japonica progeny varieties with easy shattering characteristic.[9] In our previous studies[6,7,8] an easy shattering Indica x Japonica variety 'Mil-Yang 23' has shown a field loss of approximately 200kg of grain per hectare in binder harvest.

The average threshold tensile strength for zero field loss of rice was estimated to be 174g. on average in binder harvest[8]. The degree of shattering was determined mainly by variety, but also the variation in the degree of shattering within a variety tended to differ somewhat with variety and harvesting time and year.[6,7,8] These variations may be related much to the influence of climatic variation

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on the grain shattering of rice. Addicott and Lyons[1] reported that abscission process was sensitive in cotton and other crops to climatic factor which include light factors related to photosynthesis and photoperiod, temperature, rainfall, humidity and wind. However, little information is available on the climatic effects on the shattering of rice plants.

In Korea the transplanting time covers from the beginning of May to the end of June. This wide range of transplanting time may expose the rice plants to varied climatic conditions during ripening period as the heading is delayed or expedited with shifted transplanting time. The air temperature begins getting lower rapidly, begining mid August which falls under ripening period of most rice varieties and also the day length decreases. Therefore, the present study was aimed to investigate how the meteorological factors during ripening modified by transplanting and harvesting time influence the grain shattering of rice.

MATERIALS AND METHODS

Field trial was conducted in 1981, a year of normal meteorological condition, as shown in the appendix table in Suweon, Korea. Taeback, an Indica x Japonica progeny variety, and Jinheung, a Japonica variety, were chosen for this study. They have average tensile strength of about 170g and 230g, respectively.[8] The two varieties were transplanted on May 11, May 26, June 10 and June 25 so as to be subjected to different climatic conditions during ripening period. Taeback was headed on July 31, August 3, August 9 and August 24, and Jinheung, August 5, August 11 August 20, and September 1 with their transplanting times, respectively. Tensile strength to estimate grain shedding was measured two times at 40 days after heading (DAH) and 55 DAH by the method described in the previous report.[8]

Data analysis was performed with split plot design method where main plots were two harvesting times and subplots, four transplanting dates. To elucidate the effect of meteorological factors during each period of grain filling correlation coefficients were calculated between tensile strength and meteorological factors such as average, maximum, and minimum air temperature, amount of radiation, relative humidity during various periods of ripening: from 10 days before harvest (DBH) to harvest time, from 20 DBH to 10 DBH, from 30 DBH to 20 DBH, from 40 DBH to 30 DBH, from 20 DBH to harvest, from 30 DBH to harvest and from 40 DBH to harvest.

RESULTS AND DISCUSSION

Variations in Tensile Strength When Exposed to Different Meteorological Conditions during Ripening by Shifting Transplanting and Harvesting Time:

It was recognized in some studies[5, 6, 8] that the tensile strength varies with time of harvesting, showing inconsistent variations with varieties. In Jinheung the tensile strength was significantly different between harvesting time, but not among transplanting times (Table 1). However, Table 2 shows that the tensile strength of Jinheung varied within a relatively narrow range of 214g to 251g as the transplanting and harvesting time was changed. The 15-days delay of harvesting time increased the tensile strength by about 20g, but the delayed transplanting did not change the tensile strength significantly. Taking into account of the fact that the field loss of rice grain became negligible above the tensile of 174g,[8] which was estimated by the extrapolation method, this range of variation in tensile strength of Jinheung practically does not matter with field loss of graims. Table 3 also shows the analysis of variance for tensile strength in Taeback as affected by transplanting time and harvesting time. Tensile strength changed significantly with time of harvesting and transplanting and also the interactive effect between them was found to be significant. As shown in Table 4 the tensile strength was significantly lower at 55 DAH than at 40 DAH when transplanted before May 25, but thereafter no significant difference was found be-

Table 1. Analysis of variance for the tensile strength as affected by transplanting date and harvesting time in a Japonica variety "Jinheung".

Source of variance	D.F.	S.S.	M.S.	F
Total	79	78630.0		
Main plot	19	15420.0	811.6	
Replication	9	4291.0	476.8	
Harvesting time(A)	1	4188.0	4188.0	
Error (1)	9	6941.0	771.2	5.18*
Transplanting date(B)	3	16152.0	1615.2	2.04
Interaction (AxB)	3	4343.0	1447.7	1.83
Error (2)	54	42715.0	791.0[	

Table 3. Analysis of variance for the tensile strength as affected by transplanting date and harvesting time in an I x J variety "Taeback".

Source of variance	D.F.	S.S.	M.S.	F
Total	79	85916.00		
Main plot	19	13259.00	697.84	
Replication	9	5977.50	664.17	
Harvesting time(A)	1	3364.00	3664.00	9.116*
Error (1)	9	3617.50	401.94	
Transplanting date(B)	3	38656.50	3865.65	7.762**
Interaction (AxB)	3	7106.50	2368.83	4.756**
Error (2)	54	26894.00	498.04	

Table 2. Effect of transplanting date and harvesting time on tensile strength(g) in a Japonica variety "Jinheung".

Harvesting time	Transplanting date				Average
	May 11	May 25	June 10	June 25	
40DAH*	214.5	222.7	240.5	239.8	229.4
55DAH	233.6	257.2	250.6	250.9	248.1
Average	224.1	239.9	245.6	245.8	

L.S.D.(0.05) to compare :
Harvesting time means 14.05
Transplanting date means N.S.

*DAH: Days after heading.

Table 4. Effect of transplanting date and harvesting time on the tensile strength(g) in an Indica x Japanica rice variety "Taeback".

Harvesting time	Transplanting date				Average
	May 11	May 25	June 10	June 25	
40DAH	195.6	204.2	160.2	127.5	171.9
55DAH	167.0	168.3	164.9	132.9	158.3
Average	181.3	186.2	162.6	130.2	

L.S.D. (0.05) to compare :
Harvesting time means 10.14
Transplanting date means 14.2
Any two values 20.1

tween both harvestings. At harvesting 40 DAH the tensile strength was lowered drastically at transplanting after June 10 and reached the lowest value of 127.5g, while at harvesting 55 DAH it dropped to 132.9g at transplanting of June 25 and remained unchanged with transplanting time before June 10.

These results of Taeback imply that the variations of tensile strength with time of transplanting and harvesting might have been predominated by the internal factors of development at transplantings before May 25, but at transplantings thereafter by environmental factors. Addicot and Lyons[1] also pointed out the sensitivity of abscission process to climatic factors and Jin and Inouye[4] suggested that in Japonica x Indica hybrid rice the temporal

decrease in tensile strength during ripening was related with its ripening process. In Taeback the tensile strength was lowered below the threshold one, 174g by the 15-days delayed harvest and by delaying the transplanting beyond June 10, suggesting that the delayed harvesting and transplanting beyond a critical period may bring about substantial field loss of rice during harvesting operations due to grain shattering.

Relationships between Tensile Strength and Meteorological Factors during Ripening:

Table 5. Correlation coefficients between tensile strength and meteorological factors during various periods before harvest in the Taeback.

Meteorological variable*	1	2	3	4	5	6	7	8	9
Air temperature									
Mean	0.761	0.838**	0.846**	0.701	0.794**	0.895**	0.864**	0.869**	0.842**
Maximum	0.635	0.656	0.734*	0.686	0.614	0.732*	0.818**	0.859**	0.833*
Minimum	0.759*	0.793*	0.821*	0.670	0.780*	0.866**	0.863**	0.871**	0.845**
Diurnal range	0.632	-0.609	-0.596	-0.452	-0.707	-0.754	-0.792*	-0.855**	-0.827*
Radiation	0.356	0.043	-0.072	-0.143	-0.063	0.188	-0.282	-0.001	0.136
Relative humidity	0.358	0.654	0.642	0.688	0.477	0.788*	0.776	0.619	0.592

*1. Avreage for 10days just before harvest.
2. Average for 10days from 20days before harvest to 10days before harvest.
3. Average for 10days from 30days before harvest to 20days before harvest.
4. Average for 10days from 40days before harvest to 30days before harvest.
5. Average for 15days before harvest.
6. Average for 20days before harvest.
7. Average for 25days before harvest.
8. Average for 30days before harvest.
9. Average for 40days before harvest.

Table 6. Correlation coefficients between tensile strength and meteorological factors during various periods before harvest in the Jinheung.

Meteorological variable*	1	2	3	4	5	6	7	8	9
Air temperature									
Mean	-0.627	-0.748	-0.902**	-0.781*	-0.711	-0.776*	-0.886**	-0.843*	-0.837*
Maximum	-0.559	-0.330	-0.805*	0.877**	-0.467	-0.585	-0.755*	-0.763*	-0.809*
Minimum	-0.530	-0.708	-0.860*	-0.694	-0.675	-0.792*	0.912**	-0.856*	-0.832*
Diurnal range	-0.493	0.825*	0.765*	0.245	0.437	0.716	0.828*	0.915**	0.855*
Radiation	-0.563	0.230	0.699	-0.328	-0.731	-0.586	-0.270	0.091	-0.682
Relative humidity	0.341	-0.365	-0.878**	-0.204	-0.146	-0.144	-0.697	-0.940**	-0.804*

*Denotation for various periods of ripening is the same as in the Table 5.

The correlation coefficients between tensile strength of Taeback and Jinheung and meteorological factors during a certain period of preharvest were presented in Table 5 and 6, repectively. The tensile strength was significantly positively correlated with mean, maximum, and minimum air temperature and relative humidity and negatively with diurnal fluctuation of air temperature, but no significant correlations were found with radiation amount during any period throughout ripening. The tensile strength was sifnificantly positively correlated with minimum, maximum and mean air

temperature during during 20-days period from 30 to 10 days before harvest and minimum air temperature during 10 days before harvest, but not related to the temperature conditions during the preharvest period from 40 to 30 days before harvest. For diurnal range of air temperature during 40-days period of preharvest the tensile strength showed negative, significant correlations with only its periods of 25- and 40-days before harvest. And only the average relative humidity during 20 days before harvest showed significant, positive correlation with tensile strength.

Just on the contrary to Taebackbyeo, in Jinheung tensile strength showed significant negative correlations with air temperature, radiation amont and relative humidity, but positive correlation with diurnal range of air temperature during a certain period of preharvest. But this result of Jinheung is dubious as Table 1 and 2 indicate that the tensile strength was not influenced much by the varied environments by shifting the transplanting time.

The meaningful conclusion about the relation between tensile strength and meteorological factors cannot be elicited from the present results as these are confined only to two specific varieties and as the tensile strength tended to show inconsistent variations when subjected to different harvesting time in previous studies.[5,6,8] The above may suggest that rice varieties show different variations in tensile strength one another when exposed to different environmental conditions. Therefore, to clarify the effects of meteorological factors on the tensile strength further extensive studies should be conducted with more number of varieties under controlled environment. However, it appears certain that the temperature regime during ripening plays a major role in determining shatterability of grains in easy shattering and more thermophilic Indica x Japonica varieties: lower the ripening temperature, greater the shatterability of grains.

摘　　要

移秧期에 따른 登熟氣象條件의 差異가 水稻의 脫粒性에 미치는 影響을 究明하기 위하여 脫粒性이 큰 太白벼와 非脫粒性인 振興을 材料로 40日 苗를 5月 11日부터 15日 간격으로 4回 移秧하고 出穗 後 40日 및 55日의 時期에 各各 벼알의 引張強度를 測定하였으며 作期 및 收穫時期의 影響, 그리고 氣象要因들과 脫粒性과의 關係를 分析하였다.

1. 벼알의 引張強度는 各 處理를 통틀어 振興의 경우 214～251g의 變異幅을 보였고 이 範圍의 引張強度는 벼의 圃場損失에 無關하나 太白벼의 경우 引張強度는 127.5～204g의 變異幅을 보였고 移秧期 및 收穫時期가 脫粒性 및 벼의 圃場損失에 미치는 影響은 매우 컸다.

2. 벼알의 引張強度에 미치는 影響은 太白벼의 경우 收穫時期, 移秧期 및 移秧期와 收穫時期와의 相互作用이 모두 컸으며, 특히 移秧期가 6月 25日일 경우 현저히 脫粒性이 커졌다. 振興의 경우에는 移秧期의 影響은 有意하지 않았고 收穫時期가 늦을수록, 즉 벼알이 乾燥될수록 引張強度가 多少間 커지는 경향이었다.

3. 氣象要因들의 脫粒性에 미치는 影響은 日平均, 最低, 最高氣溫 및 日氣溫較差가 컸고, 특히 收穫前 30日間의 이들의 影響이 컸으며, 太白벼의 경우 日射量과 大氣溫度가 影響하지 않았지만 振興의 경우에는 收穫前 10日間의 日射量과 收穫前 30日間의 大氣 溫度가 影響하였다.

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Appendix. Metheorological condition during ripening of rice grains.

Month Day	Air temperature(°C)			Amount of radiation (cal/cm^2·day)	Relative humidity(%)	Frost	Month Day	Air temperature(°C)			Amount of radiation (cal/cm^2·day)	Relative humidity(%)	Frost
	Average	Max.	Min.					Average	Max.	Min.			
July 31	27.4	31.9	23.7	389	79	–	Sept. 16	16.5	23.8	9.0	350	76	–
August 1	27.7	29.5	25.7	127	76	–	17	18.5	25.4	11.9	329	80	–
2	27.2	30.5	24.8	304	85	–	18	20.4	25.6	16.1	277	83	–
3	26.9	29.2	25.4	209	90	–	19	19.7	25.8	16.3	290	84	–
4	26.2	30.7	22.0	398	70	–	20	20.6	27.7	14.1	413	82	–
5	22.9	27.8	17.4	504	64	–	21	21.0	28.3	13.8	393	80	–
6	22.7	26.9	18.8	349	79	–	22	10.8	28.4	14.2	356	79	–
7	21.8	24.5	19.4	207	85	–	23	21.3	29.5	14.4	363	78	–
8	24.7	28.8	20.4	225	81	–	24	18.8	20.6	15.7	26	85	–
9	25.5	30.0	21.4	465	77	–	25	20.2	24.8	15.5	309	70	–
10	24.2	27.0	20.9	193	85	–	.26	18.0	26.0	11.2	425	81	–
11	23.7	30.0	21.2	492	78	–	27	18.9	25.4	13.8	254	87	–
12	23.7	28.5	20.3	516	80	–	28	17.1	21.8	10.8	321	67	–
13	24.3	30.1	19.2	434	80	–	29	16.5	21.4	12.5	290	73	–
14	26.1	32.2	20.0	493	74	–	30	17.5	22.2	14.3	224	79	–
15	24.4	31.1	17.5	551	64	–	Oct. 1	16.8	23.3	12.0	346	78	–
16	24.8	30.7	18.0	447	72	–	2	15.7	21.5	9.2	431	76	–
17	24.6	25.9	23.6	37	88	–	3	14.7	23.5	6.7	409	79	–
18	25.1	27.4	23.5	172	90	–	4	14.0	17.7	8.6	86	78	–
19	25.7	30.7	21.5	374	83	–	5	15.9	21.0	12.8	294	79	–
20	24.6	27.8	21.6	172	88	–	6	15.3	20.7	11.4	237	77	–
21	23.5	27.2	20.6	332	85	–	7	16.1	21.7	11.1	233	79	–
22	22.7	28.0	20.0	40.1	84	–	8	16.2	20.5	12.6	120	81	–
23	22.7	27.7	17.5	517	79	–	9	12.7	16.3	8.6	346	75	–
24	23.1	27.5	17.5	359	81	–	10	12.6	20.5	5.8	369	72	–
25	21.6	23.3	19.3	33	93	–	11	13.2	21.1	6.3	314	83	–
26	21.6	25.8	18.8	236	87	–	12	14.4	21.9	6.8	364	76	–
27	22.5	29.3	17.9	464	78	–	13	13.3	18.6	7.8	170	80	–
28	22.7	30.0	16.5	443	71	–	14	9.8	16.5	3.3	361	59	frost
29	23.3	28.9	17.0	323	72	–	15	11.1	18.9	4.2	335	73	frost
30	23.7	26.0	22.1	135	84	–	16	13.2	20.4	6.8	264	82	–
31	19.7	22.3	18.1	26	92	–	17	15.1	23.2	7.1	288	78	–
Sept. 1	19.7	20.6	18.3	59	89	–	18	15.0	19.3	10.9	186	84	–
2	23.0	27.1	19.5	231	79	–	19	13.0	18.0	7.9	161	77	–
3	21.3	22.4	18.8	77	82	–	20	11.9	18.8	6.5	308	78	–
4	20.1	25.3	15.5	473	72	–	21	15.4	21.6	6.5	320	76	–
5	19.9	27.0	13.4	470	78	–	22	10.8	14.5	3.0	147	74	frost
6	20.4	28.3	14.6	464	76	–	23	3.3	6.5	-1.3	230	76	frost
7	21.2	27.8	14.8	427	72	–	24	7.0	11.2	3.7	293	78	frost
8	21.2	26.0	17.4	275	78	–	25	7.0	13.3	-1.0	281	78	frost
9	19.8	23.8	16.1	389	79	–	26	7.4	15.1	1.7	321	75	frost
10	19.7	25.6	14.4	420	80	–	27	8.4	15.9	1.1	228	78	frost
11	19.1	23.8	15.0	430	76	–	28	9.3	11.7	6.6	17	78	–
12	16.6	21.1	11.5	455	76	–	29	8.3	14.8	3.5	327	76	frost
13	15.3	22.1	8.6	456	69	–	30	10.3	18.4	3.7	272	80	–
14	14.8	21.8	7.7	494	73	–	31	9.4	13.5	2.8	318	77	frost
15	15.2	23.2	7.5	458	73	–							