Effects of Rain in Ripening Period on the Grain Quality of Wheat

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Deterioration of grain quality of wheat due to rain, such as damaged grains or viviparous germination, often occurs in the south-eastern region of Japan, because the ripening stage falls into the rainy season. Of the rain damages of wheat grains, the viviparous germination has been studied from an early days in many countries of the world. Varietal differences, relation to seed dormancy, etc., have been made clear, and the information is being utilized in breeding programmes. However, not much is known about the actual state and mode of occurrence of grain quality deterioration. Therefore, the author carried out a study in the southeastern part of Japan, when he was in the Chugoku National Agricultural Experiment Station in Fukuyama City, Hiroshima Prefecture. Results of the study will be described briefly in this paper.

Grain quality as affected by a long spell of rainy weather

In 1963, wheat production in the south-eastern Japan suffered seriously from an extraordinarily long spell of rain days, which occurred from the heading stage to maturity, with marked reductions in yields and severe damages in grain quality. Grain samples were collected from fields of the Station as well as of neighboring prefectures, and they were compared to the grains harvested in the normal year, 1962.

In Fig. 1, quality of grains harvested in 1963 is expressed in percentage of that of 1962 grains. The affected grains of 1963 showed decreases in weight of 1000 grains and weight of 1 litre of grains, increased ash contents, slightly decreased flour yields, but apparently decreased milling scores (for which ash content was taken in consideration), higher ash contents of flour, and inferior flour colors.

Elasticity of dough determined by the Brabender's test was found very low, with reduced valorimeter values in the farinogram, reduced areas in the extensogram, increased elongation, reduced resistance and consequently remarkable reduction in R/E values, although water absorption was almost unchanged. Remarkable decreases in viscosity were also found in the amylogram. Examples shown in Fig. 2 illustrate clearly these changes.

Thus, it becomes apparent that the long spell of rainy weather at the ripening stage is very detrimental not only to quantitative characters such as grain filling and resultant milling recovery but also to qualitative characters such as the elasticity and viscosity of dough.

Effects of rain at different stages of ripening

As the materials used in the above study were grains exposed to rain during a whole period of ripening, effects of rain at different stages of ripening on grains were examined by treating plants growing in pots or in fields with artificial rain at different ripening stages. Grains were harvested at the time of maturity and their quality was examined.

Results with plants in pots are shown in Table 1. The treatment at 16–19 days and at

Table 1. Effect of rain at different time of ripening on the quality of grains and flour

Time of rainfall (*)	Yield per pot g	Small thin grains %	Viviparous germination %	1000 grains weight g	Grain ash %	Flour yield %	Milling score (**)	Flour ash %	Flour color %	Sedimentation value ml
Control	17.9	2.0	0.2	33.6	1.41	61.7	79.2	0.35	52.8	19.5
16—19 days	14.8	11.0	0.1	30.2	1.73	59.4	73.9	0.41	51.9	24.8
23—26 days	14.4	15.8	0.3	28.9	1.65	59.1	71.6	0.45	49.6	24.3
30—33 days	17.4	3.6	0.5	29.5	1.44	60.8	75.8	0.40	51.5	15.4
37—40 days	17.0	2.5	1.5	33.9	1.39	61.6	79.6	0.34	51.9	17.3

(*) Days after heading
(**) 100—[(80—flour yield)÷50 (straight flour ash—0.30)]

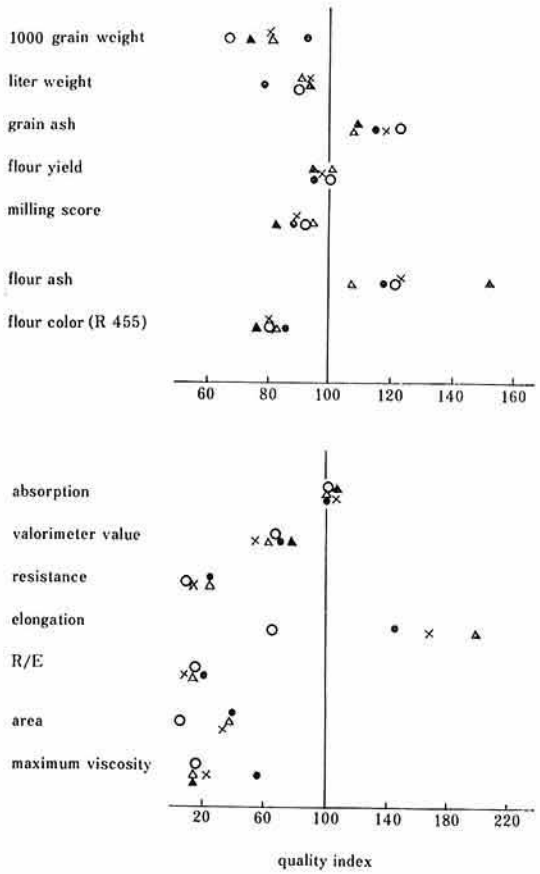

Fig. 1. Quality of grains and flour as affected by a long spell of rainy weather during the whole period of ripening in 1963. Values of 1963 are expressed in percentage of those of 1962, a normal year.

23–26 days after heading gave an increased screenings, decreased yield, increased ash content of grains, and low milling scores with high ash content of flour and rather increased sedimentation values. On the other hand, the treatment given at the later stage of ripening, 37–40 days after heading, caused no appreciable effect on grain filling, ash content, and milling scores, but an increased viviparous germination and decreased sedimentation values.

Results with plants in fields were almost similar to the above. The Brabender's values are given in Table 2, which shows a decrease in the values, particularly with the extensogram, by the treatment at 35–38 days after heading, although no definite effect is observed by the treatment at 27–30 days after heading.

These results indicate that the treatment at the early stage of ripening affects mainly quantitative characters of grain whereas the treatment at the later stage of ripening causes the deterioration of qualitative characters related to the processing.

Rain pattern and grain quality deterioration

Even with the rain at the same ripening stage, its effect might be different with the difference in its pattern such as number of rain days and time of rain in a day, etc. Therefore, effects of rain pattern were examined with the rain at the later ripening period.

1) Number of rain days: Plants grown in pots and in the field were exposed to artificial

Table 2. Effect of the time of rain on Brabender's values

Time of rainfall (*)	Farinogram		Extensogram				Amylogram
	Absorption %	Valorimeter value	Area cm^2	Resistance BU	Elongation mm	R/E	Maximum viscosity BU
Control	53.7	31	71	552	102	5.5	917
27—30 days	53.7	33	71	591	96	6.2	899
31—34 days	53.0	30	67	542	101	5.4	906
35—38 days	53.7	30	59	494	95	5.2	865

(*) Days after heading

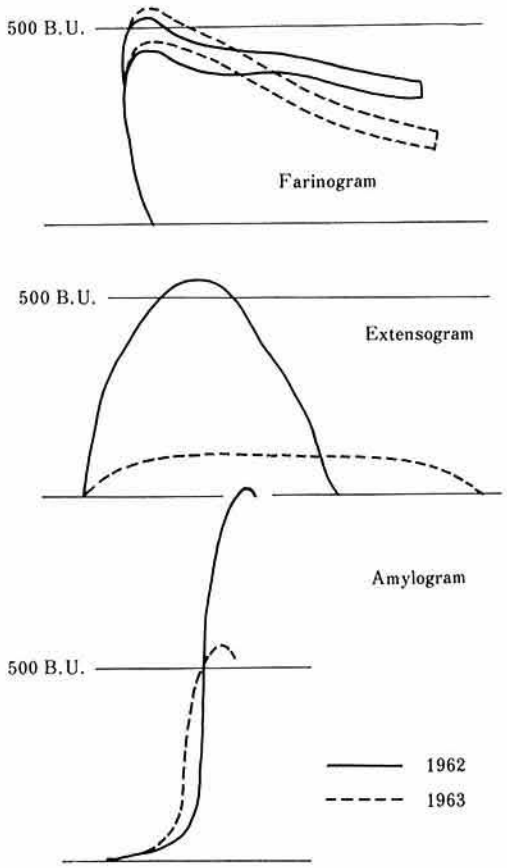

Fig. 2. Values determined by the Brabender's test

rain treatment for 1–5 days at the time of maturity. No adverse effect was observed with 1 day treatment, but some qualitative characters were affected by 2 day—treatment, and almost all of the character examined were affected by the treatment for more than 3 days.

2) Time of rain in a day and intermittent rain: Plants grown in pots were exposed to the rain treatment in the daytime or in the night, every day or every other day, or at different frequencies, during the stage from 3 to 9 days prior to the maturity. Total hours of rain was the same for each treatment. Results showed that daytime, every other day and frequent treatments were more detrimental than night, every day, and less frequent treatments, respectively. The results indicate that the longer the duration of wet condition of grains the more is the adverse effect. Particularly the daytime treatment causes a reduced photosynthesis and long lasted wet condition of grains even in the untreated night time.

Climatic condition of rain day and response of plants

In rain days, solar radiation was only about 10% of that of fine days, with almost no diurnal variation in air temperature and almost saturated humidity in a whole day. Shading treatment with reed screens lowered the leaf temperature by 2–3°C, and with rain treatment added the leaf temperature was further lowered by 10–11°C. Soil temperature at a 5 cm depth lowered by 3–4°C by the shading treatment and by about 7°C by the rain treatment. Absorption of water by detached panicles at 7–8 days prior to the maturity was reduced to about 60% under a 80–90% shading, and to only about 10% under

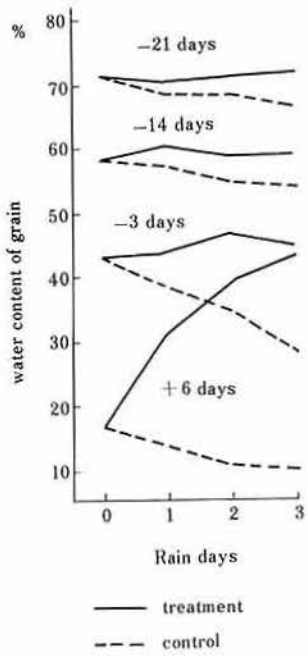

Fig. 3. Water content of grains affected by rain treatment given at different stages of ripening (indicated by number of days before (−) or after (+) the maturity)

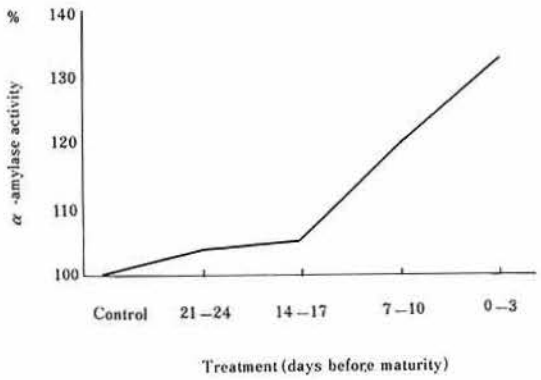

Fig. 4. Relation between time of rain treatment and α-amylase activity

the shading and rain treatment. Based on these results, it can be considered that photosynthesis and nutrient absorption by plants might be reduced markedly in rain days, due to the reduced solar radiation, lowered leaf temperature and retarded water absorption.

Water content of grains affected by the rain is given in Fig. 3. At the stage more than 2 weeks prior to the maturity, grains showed a high water content, and which did not change so much by the continuous rain days. However, when grains were close to the maturity and at the process of dehydration, the rain treatment for 2–3 days caused a remarkable increase in water content to as high as 45–47%.

With the water absorption of grains, the activity of hydrolytic enzymes was increased. In Fig. 4, changes of α-amylase activity caused by the rain treatment for 4 days applied at different ripening stages are shown. At an early stage, more than 2 weeks prior to the maturity, when grains had high water content, an increase of α-amylase activity was not much, whereas at the stage after 7–10 days prior to the maturity α-amylase activity was increased linearly with the advancement of grain ripening. The similar result was obtained with protease activity, which was measured only with a part of the materials.

High correlations were found between the activities of these hydrolytic enzymes and the lowering of grain quality. Application of α-NAA or MH30 reduced the activity of these enzymes and alleviated the grain quality deterioration. Apparently the activation of these enzymes is involved in the grain quality deterioration caused by rain at the later stage of ripening.

Mechanism of grain quality deterioration due to rain

Based on these results and that of related experiments not shown here, the mechanism of grain quality deterioration due to rain at the ripening stage is considered as follows:

1) Time of rain as related to grain quality deterioration

As the effect of rain differs with the stage of ripening, the ripening period is divided into three stages (Fig. 5).

The first stage: An early stage of ripening, more than 10 days prior to the maturity.

Water content of grain is higher than 51–52%. Only quantitative characters are affected by rain.

The second stage: 3–10 days prior to the maturity, with 41–51% water content of grains. Both quantitative and qualitative characters are affected.

The third stage: After 3 days prior to the maturity, with less than 40–41% water content of grains. Qualitative characters are seriously affected by rain.

2) Grain quality deterioration at different stages

Grain quality deterioration caused by rain at these different stages is summarized in Table 3.

At the first stage: Rain decreases grain filling with a resultant increase in ash content and crude protein content of grains. This is due to the reduced dry matter accumulation into grains because of reduced photosynthesis and nutrient absorption. Grains become slender, and litre weight is reduced. Relative proportion of outer layer of grains is increased, resulting in low milling quality and inferior flour color. As the enzymes are not activated at this stage, qualitative characters of grains are not affected, and in some cases the dough is rather strengthened due to an increased protein content of grains.

At the second stage: As a transition stage from the first to the third stage, grain filling is still continued, but the activation of enzymes begins. Therefore, quantitative as well as qualitative characters are affected: in an early half mostly quantitative characters while in a later half mainly qualitative characters. Mechanism of the deterioration of quantitative and qualitative characters is the same as in the first and third stage, respectively.

At the third stage: Although the quantitative characters are hardly affected, qualitative characters such as elasticity and viscosity of the dough are affected remarkably. Grains exposed to rain absorb water and swell. The swelling and rapid drying make the seed coat of grains fragile, and as a result the seed coat is more included in the flour, giving high ash content and inferior color. Activated enzymes are also included in the flour, and starch and

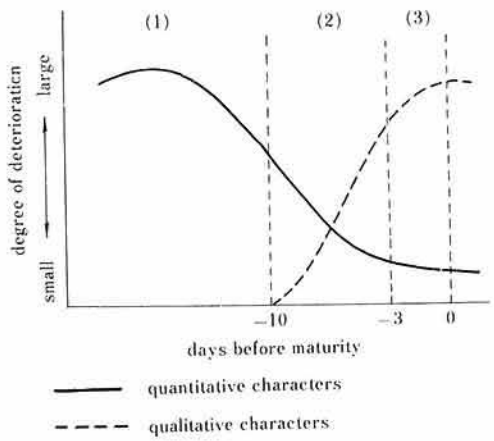

Fig. 5. Three stages of ripening period, (1), (2) and (3), as divided by their response to rain

Table 3. Summary of grain quality deterioration caused by rain at three different stages of ripening

Quality characteristics	Stages of ripening		
	1	2	3
1000 grains weight	−	−	(−)
Liter weight	−	−	−
Hardness of grain	±	(−)	−
Grain ash	+	+~(−)	(−)
Grain protein	+	+~(−)	(−)
Flour yield	−	−~+	+
Milling score	−	−	−
Flour ash	+	+	+
Flour color	−	−	−
Sedimentation value	+	(+)~−	−
Valorimeter value	(+)	±~−	−
Area of extensogram	±	−	−
R/E of extensogram	(+)	−	−
Maximum viscosity	±	−	−
Enzym activity	±	+	+
Viviparous germination	±	(+)	+

\+ increase (+) slightly increase
− decrease (−) slightly decrease

protein of the flour are decomposed or degenerated, thus lowering the elasticity and viscosity of the dough. In addition, the leaching of nutrients from grains and an increased respiratory consumption may occur to some extent.

The number of rain days, time and pattern of rain fall influence the extent of deterioration but the mechanism of deterioration may not vary with these factors.

References

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