Korean J. Crop Sci. 48(5): 397~401(2003)

Varietal Characteristics of Kernel Growth of Rice influenced by Different Temperature Regimes During Grain Filling

Deog-Su Kim*, Jin-Chul Shin*, Kyung-Jin Choi*, Chung-Kuen Lee*, and Je-Kyu Kim

*National Crop Experiment Station, RDA, Suwon 441-857, Korea

ABSTRACT: This experiment was conducted to know the characteristics of kernel growth as affected by various temperature regimes during grain filling using the varieties Hwaseongbyeo, Ilpumbyeo and Chucheongbyeo. The rice plants tested were grown in the natural condition at 1/5000a Wagner pots until flowering. After flowering, the rice plants were moved to controlled temperature conditions in a phytotron. The minimum/maximum daily temperature in the phytotron was controlled by 12/18, 15/21, 18/24, 21/27, and 24/30°C, respectively. The grain weights were measured every three days after treatment. The mean daily kernel growth rate during active grain filling period showed different responses among varieties under various temperature regimes. The kernel growth rate of Chucheongbyeo was seriously reduced as temperature regimes were decreased. However, that of Ilpumbyeo was not influenced so critically. Ilpumbyeo showed some advantages in grain filling under low temperature regimes compared to Chucheongbyeo. The lag phase in grain filling of Chucheongbyeo was the longest among tested varieties, followed by Hwaseongbyeo under daily mean temperature regime of 15°C. Kernel weight of Ilpumbyeo increased fast in early grain filling phase under low temperature. This characteristic may be favorable for grain filling in temperate zone where the daily mean temperature is drastically dropped during grain filling period. Regression analysis with kernel growth rate and temperature showed the estimated critical low temperature for grain filling among varieties were 9°C, 12°C, 13°C in Ilpumbyeo, Hwaseongbyeo and Chucheongbyeo, respectively. Under moderate temperature the duration of grain filling of Ilpumbyeo was longer than that of Chucheongbyeo. However, Under low temperature that of Ilpumbyeo was more favorable than Chucheongbyeo.

***Keywords*:** rice, critical temperature, grain-filling

Characteristics of grain or spikelets filling of rice is one of important factors determining grain yield and quality. In temperate region, especially in Korea, low temperature gives a severe damage on the growth and yield of rice, occasionally. Low temperature induces impeding of the growth, resulting in the delay of heading. Starch granules start to accumulate in the caryopsis 3 days after pollination and the most fast accumulation is attained from 5 to 9 days after pollination, and the accumulation is finished at about 20 days after pollination(Rangie and Juliano, 1977). In this period of grain filling, many factors such as temperature(Zakaria *et al.*, 2002; Huang & Sheng, 2000), sunshine hours(Kobata *et al.*, 2000), plant nutrition and soil moisture regime(Jianchang *et al.*, 2002, 2001), and genetical background(Lee *et al.*, 1996; Seo & Chamura, 1980) affect the yield determination and grain quality. Among these factors temperature controls the duration of grain filling of rice. The process of grain growth can be quantified by the increase in dry weight and the decrease in water content. The rate of grain growth is faster and the grain filling period is shorter at higher temperature. Low temperature in late fall reduces the grain filling speed as well as grain weight, while moderate low temperature induces slow grain filling which has good effect on carbohydrates accumulation and grain quality. High temperature also influence grain filling adversely, and induce the immatured grain to increase. Rice grains matured under 32~40°C conditions can be characterized as immatured and white cored grains. Zakaria *et al.*(2002) reported the genetic diversities in the response of grain filling characteristics to high temperature. The high temperature in night more severely affects grain filling than the day time temperature(Morita, *et al.*, 2002). The optimum temperature for grain filling in japonica cultivars are 25°C in day and 20°C in night and 30/20°C in indica cultivars(Huang & Sheng, 2000). There are various reports on the optimum temperature for grain filling around 20~22°C (Matsushima, 1957 ; Murata, 1964; Lee & Oh, 1996). The final grain weights attained at both high and low temperatures are about the same for IR20, a indica cultivar, suggesting that IR20 is well adapted to high temperature during ripening. However, in some japonica cultivars, the final grain weight at 28°C is about 15% less than that at 16°C. The temperature appears to have some detrimental effect on japonica cultivars (Yoshida, 1981).

The adverse environments for grain filling, especially temperature conditions during grain filling, would be of detriment to be worse rice quality. This study aimed to clarify

†Corresponding author: (Phone) +82-31-290-6647 (E-mail) kim0dus @ rda.go.kr <Received November 2, 2003>

the temperature response of grain filling of typical cultivars and to find out the basic criterion of characteristics for rice quality determining factors.

MATERIALS AND METHODS

The cultivars used in this study are all japonica varieties, Chucheongbyeo, Hwaseongbyeo and Ilpumbyeo. Chucheongbyeo is an old cultivar which is adapted as a high quality variety for long period and Hwaseongbyeo and Ilpumbyeo are newly developed high quality varieties. Plant materials were grown under natural conditions during summer season until heading stage and transferred to phytotron where the temperatures were controlled precisely. Five regimes were set, as 12 to 18°C, 15 to 21°C, 18 to 24°C, 21 to 27°C and 24 to 30°C, which were controlled daily by following sine curves where minimum and maximum temperature appeared at 05:00 and 14:00, respectively. Humidity were controlled as 75% during day time and 80% night, and light and day length condition were the same as the natural condition during ripening season in 2002.

Soaked 16 seeds were sown on the surface of a 1/5000a Wagner pot which suppressed to produce tiller formation. Panicles from main culms were used for the evaluation of grain filling in this experiment. Fertilizers were applied at the rates of 0.44-0.28-0.32 g(N-P_2O_5-K_2O) per pot. Nitrogen was splitted 40% as basal, 30% at the active tillering stage and 30% as top dressing at the panicle initiation stage. Phosphorous was incorporated in the pot soil as basal and potassium was applied 70% as basal and 30% as top dressing at panicle initiation stage with nitrogen.

At flowering stage of rice plant the flowering spikelets were tagged and subjected to 5 different temperature regimes until maturation and the tagged spikelets were sampled at 7, 11, 14, 16, 19, 21, 26, 31, 41 and 51 days after treatment of temperature and the spikelets weight measured. Mature grain was identified as the brown rice which did not contain chlorophyll on the surface.

RESULTS AND DISCUSSION

Fig. 1 shows the growth rate of grain during rapid filling stage in relation to grain filling temperature conditions in the three rice cultivars tested. Daily mean grain growth rate during rapid grain filling stage of Hwaseongbyeo increased gradually as increasing the grain filling temperature up to average daily mean temperature of 27°C. Under the grain filling temperature condition around 15°C, daily mean grain growth rate was quite different among cultivars. The grain filling speed was slowest in Chucheongbyeo among the three cultivars tested, and Ilpumbyeo had some advantageous characteristics of grain filling rate under low temperature. Under the high temperature conditions, Chucheongbyeo showed typical characteristics in grain growth rate. The grain filling rate was rather reduced under the temperature higher than 24°C. This implied that high temperature during grain filling period was not favorable in Chucheongbyeo compared to the other ones. It suggests that too early heading accompanied by early transplanting may have some disadvantage for grain filling in Chucheongbyeo. Early transplanting accelerates the development of rice growth rate and induces early heading date resulting that grain filling is conducted under high temperature regime. On the contrary, Ilpumbyeo had better advantageous characteristics of rapid grain filling under low temperature and high temperature than Chucheongbyeo. This indicates that Ilpumbyeo has more adaptable characteristics under reversed conditions than Chucheongbyeo.

It was reported that there were big differences in grain filling period among cutivars(Cho, *et al.*, 1987, Sasahara, 1982, Lee, *et al.*, 1996). This results are in consistency with our results that the daily mean grain growth rates showed different responses among cultivars at the same grain filling temperature and there were interactions between temperatures and cultivars. Kim *et al.*(1988) reported that daily grain growth rate was accelerated until temperature was going up to 30 (Natago, 1952; Yoshida & Hara, 1977; Tanaka, 1962).

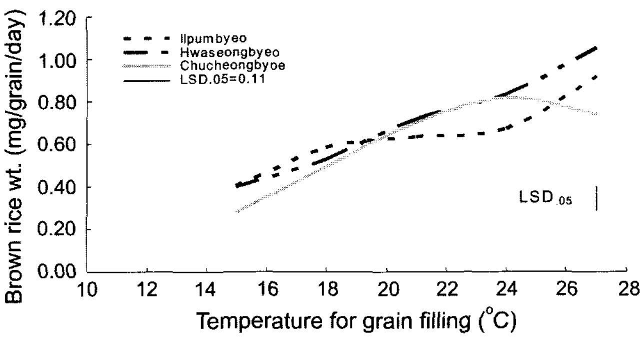

Fig. 1. Relationship between grain filling rate influenced by temperature in rice cultivars.

Table 1. Mean temperature during various ripening stage of daily average temperature of normal year (1971-2000) in Suwon according to heading date of rice.

Days after heading date	Mean temperature according to heading date (°C)			
	Aug. 1	Aug. 10	Aug. 20	Sep. 1
1~10	26.0	25.7	24.2	22.5
11~20	25.7	24.2	22.9	20.1
21~30	24.0	22.9	20.5	18.0
31~40	22.7	20.5	18.4	16.0
41~50	20.3	18.4	16.4	13.7

This inconsistency with our results means that the responses of grain filling rate to temperature are different among cultivars tested.

Table 1 shows the ripening temperature after the heading date calculated with 30-year-normal meteorological data in Suwon. Normally, rice plant shows rapid grain filling period from 10 days after heading. The temperature condition during the rapid grain filling period will greatly affect the grain quality. Normal heading date of Ilpumbyeo and Chucheongbyeo is around the 20th August. In this case, grain filling rate of Chucheongbyeo will be more rapid than that of Ilpumbyeo. However, the grain filling rate of Chucheongbyeo was more sensitive to low and high temperature regimes than Ilpumbyeo. This implies that the more early heading date, the higher temperature be subjected to grain filling period, resulting the worse condition for grain filling in Chucheongbyeo. On the other hand, since Ilpumbyeo is less sensitive to the temperature changes during grain filling the heading date would not affect greatly on grain filling characteristics.

The changes in the condition of rapid grain filling period largely affect the appearance of white belly and core, unmatured grain etc. due to competition of carbohydrates among grains(Kim *et al.*, 1988; Natago, 1952; Zakaria *et al.*, 2002). If the heading date of Ilpumbyeo is on 20th Aug., the temperature regime during 40 days after heading is 18.24°C. In this temperature regime the grain filling rate of Ilpumbyeo changed a little compared to that of Hwaseongbyeo and Chucheongbyeo.

Fig. 2 shows the trends of grain filling under low temperature after flowering. There are reports showing that the grain filling proceeds below 15 conditions(Tanaka, 1962; Sato & Takahashi, 1971; Sasahara *et al.*, 1982) and the grain filling rates under the low temperature have some varietal differences(Cho *et al.*, 1987). There were big differences in grain filling pattern among the three cultivars tested. The grain weight of brown rice of Ilpumbyeo increased fast at early phase of grain filling and maintained certain amount of increment after the fast increasing until 50 days after heading. In Hwaseongbyeo, rapid filling of grain maintained from 25 days after flowering to 40 days after flowering, but it stopped after 45 days after flowering. The leg phase of grain filling in Chucheongbyeo was extremely prolonged under 15 condition. Rapid grain filling started from 30 days after flowering and maintained continuously after 50 days after flowering.

Table 2 represents the relationship between kernel weight at 31 days after flowering and the grain filling temperatures for 31 days from flowering. Daily mean temperature during grain filling were 15, 18, 21, 24 and 27°C. Quadratic equation was fitted on each cultivar and extrapolation of the equations was used to estimate the threshold low tempera-

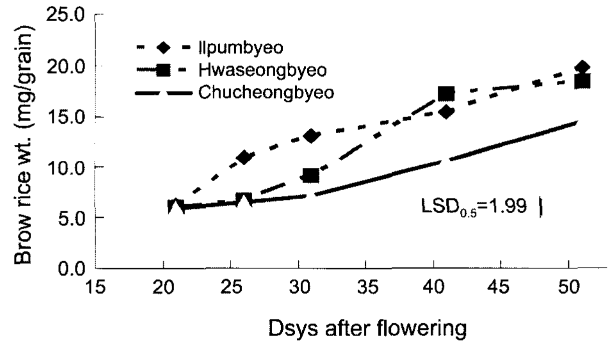

Fig. 2. Time course changes in brown rice weight under daily mean temperature of 15°C.

Table 2. Relationship between kernel weight at 31 days(y) after flowering and temperature(x) and extrapolation of threshold temperature for grain filling.

Cultivar	Regression equation	R^2	Threshold temp. for ripening (°C)
Ilpumbyeo	$y=-0.0866x^2+4.0893x-28.557$	0.942	9
Chucheongbyeo	$y=-0.1803x^2+8.3978x-78.461$	0.995	13
Hwaseongbyeo	$y=-0.1429x^2+6.9261x-62.495$	0.974	12

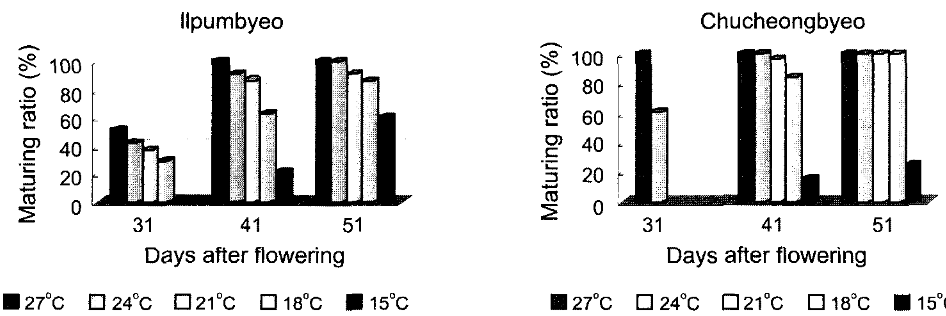

Fig. 3. Matured grain ratio at various grain filling periods under different temperature regimes during grain filling in rice plant.

ture under which no more dry matter accumulation in grain occurred. The estimated critical temperature for grain filling were 9, 12 and 13°C in Ilpumbyeo, Hwaseongbyeo and Chucheongbyeo, respectively. The optimum temperatures for grain filling calculated by the regression equations were 23.6, 23.3 and 24.2°C in Ilpumbyeo, Hwaseongbyeo and Chucheongbyeo, respectively. Chucheongbyeo showed a bit high temperature for optimum grain filling compared to Ilpumbyeo and Hwaseongbyeo.

Takekawa & Shimazaki(1973) reported grain filling process had continued for 3 weeks at the grain filling temperature of 10°C and Tanaka(1962) reported the grain filling process ceased completely by frost.

Fig. 3 shows the varietal differences in the completely matured grain ratio during certain period of grain filling from flowering under different temperature regimes. At the 31 days after flowering Chucheongbyeo had more completely matured grains than Ilpumbyeo at 24 and 27°C. Because Chucheongbyeo has smaller grain than Ilpumbyeo, matured grain ratio was higher than Ilpumbyeo at high temperature regimes. However, Ilpumbyeo had more matured grain ratio at low temperatures of 21, 18 and 15°C. This implies that Ilpumbyeo have more favorable property of dry matter accumulation in grain under low temperature regimes.

Rice quality is determined by various factors during grain filling. In Korea, grain filling conditions are largely changed year by year depending on the heading date and cultivars to be grown. Especially, temperature condition during grain filling period drastically changed year by year, site by site. Temperature plays an important role for grain filling property. The responses of ripening properties of grain to temperature were investigated using three cultivars, Ilpumbyeo, Hwaseongbyeo, and Chucheongbyeo. Clear differences in the responses of grain filling rate to temperature among tested cultivars were observed. Ilpumbyeo has a good property of grain filling rate under low temperature regimes, 15, 18 and 21°C. However, Chucheongbyeo is favorable for the grain filling in relatively high temperature conditions. The property of Ilpumbyeo would be advantageous in autumn climate conditions in Korea.

REFFRENCES

Ahn, S.B. 1973. Studies on the varietal difference in the physiology of ripening in rice with special reference to raising the percentage of ripened grains. *J. Korean Soc. Crop Sci.*, 14 : 1-40.

Cho, D.S., S.K. Jong, Y.K. Park and S.Y. Son. 1988. Studies on the duration and rate of grain filling in rice(*Oryza sativa* L.) I. varietal difference and effects of nitrogen. *Korean J. Crop Sci.* 32(1) : 103-111.

Huang, J.J. and L.H. Sheng. 2000. Effects of temperature on yield components, milling quality, and grain physico chemical properties. *Journal of the Agricultural Association of China.* 1(4) : 370-389.

Jianchang Yang, Jianhua Zhang, Lijun Lin, Zhiqing Wang, and QingsenZhu. 2002. Carbon remobilization and grain filling in Japonica/Indica hybrid rice subjected to postanthesis water deficits. *Published in Agron. J.* 94 : 102-109.

Jianchang Yang, Jianhua Zhang, Zhiging Wang, Qingsen Zhu, Wei Wang. 2001. Remobilizaition of carbon reserves in response to water deficit during grain filling of rice. *Field Crops Research.* 71 : 47-55.

Kim, K.H., J.C. Chae, M.S. Lim, S.Y. Cho and R.K. Park. 1988. Research status and prospects in rice quality. *J. Korean Soc. Crop Sci.(quality research 1).* 1-17.

Kobata, T., S. Makoto, and S. Takatu. 2000. Shading during the early grain filling period does not affect potential grain dry matter increase in rice. *Published in Agron. J.* 92 : 411-417.

Lee, J.I., J.K. Kim, J.C. Shin, E.H. Kim, M.H. Lee and Y.J. Oh. 1996. Effects of ripening temperature on quality appearance and chemical quality characteristics of rice grain. *RDA. J. Agri. Sci.* 38(1) : 1-9.

Lee, J.H. and Y.J. Oh. 1996. Food crop science I, Rice Culture. 600 pp.

Matsushima, S. 1957. Analyses of developmental factors determining yield and yield prediction in lowland rice. Bull. Nat. Inst. Agri. Sci., Series. A.5 : 89-91.

Morita, S. 2000. Effects of high air temperature on ripening in rice plants-Analysis of ripening performance in growth chamber experiments. *Japanese Journal of Crop Science* 69(33) : 391-399.

Morita, S., H. Shiratsuchi , J.I. Takanashi, and K. Fujita. 2002. Effect of high temperature on ripening in temperatures and high day temperatures. *Japanese Journal of Crop Science.* 71(1) : 102-109.

Murata, Y. 1964. Influence of radiation and air temperatures upon the localization of paddy in Japan. *Proc. Crop Sci. Soc. Japan.* 33(1) : 59-63.

Natago, K. 1952. The occurrence of white core, milk-white, and white belly grains in rice plants. *Proc. Crops Sci. Soc. Japan.* 21 : 26-27.

Rangie Singh and Bienvenido O. Juliano. 1977. Free sugars in relation to starch accumulation in developing rice grain. *Plant Physiol.* 59 : 417-421.

Sasahara, T., M. Takahashi and M. Kambayashi. 1982. Studies on structure and function of the rice ear. III. Final ear weight, and increasing rate of ear weight and decreasing rate of staw weight at the maximum increasing period of ear weight. *Japan J. Crop Sci.* 51(1) : 18-25.

Seo, S.W. and S. Chamura. 1980. Occurrence of varietal differences in protein, phosphorus, and potassium content in brown rice, and influence of temperatures and shading the ripening period on it. *Japan. Jour. Crop Sci.* 49(2) : 199-204.

Takekawa. M. and Shimazaki 1973. Ripending characteristics of rice plant in highland after heading date. *Japan. Jour. Crop Sci.* 42 (Extra 1) : 197-198.

Tanaka. M. 1962. Studies on damage to rice plants caused by cool irrigation water and delayed deading. Bull. Aomori Pref. Agri. Exp. Sta. 7 : 1-107.

Yoshida, S. and T. Hara. 1977. Effects of air temperature and light on grain filling of an Indica and Japonica rice(*Oryza Sativa* L,) under controlled environmental conditions. *Soil Sci. Plant Nutr.* 23(1) : 93-107.

Zakaria S., T. Matsuda, S. Tajima, and Y. Nitta. 2002. Effect of high temperature at ripening stage on the reserve accumulation in seed in some rice cultivars. *Plant Production Science.* 5(2) : 160-168.