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단 보

Adaptation Study of Rice Cultivation in Gangwon Province to Climate Change

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기후변화에 대한 강원지역 벼 재배의 적응

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ABSTRACT

The impact of climate change on rice plants in Gangwon province was examined by comparing the climatic conditions during the recent 10 years (2000~2009) with those of normal (1971~2000) years, and by evaluating the rice plant responses. The daily mean air temperature increased by 0.5°C while the daily range decreased by 0.1°C as compared with the normal years. During the main rice growing period in field (from June to September) precipitation increased from 900 to 1,051mm and sunshine hours decreased from 704 to 619 hours. The respiration consumption effect during the rice growing period increased by 0.07 as a result of increased air temperature and reduced sunshine hours. The optimum heading date (determined by the mean air temperature for 40 days after the heading) was delayed in Chuncheon, Hongcheon, Wonju, and Gangneung compared with the normal. The maximum climatic yield potential based on mean temperature and sunshine hours for 40 days after the rice heading decreased by 94 kg/10a mainly due to the decrease in sunshine. The mean air temperature for 40 days after the rice heading from 1999 to 2009 in Chuncheon, Cheorwon, and Gangneung was generally above 22°C, implying that yield and quality of rice can be reduced. Therefore, it is necessary to delay the heading date by planting mid- to late-maturing varieties or by changing the transplanting date in order to produce high quality rice and to maintain rice productivity. In addition, it is also important to develop or select cultivars suitable to changing climate for each region in Gangwon province.

Key words : **Climate change, Rice, Gangwon province, Heading date**

I. INTRODUCTION

Since the growth and yield of crops are determined by genetic characteristics, environment, and management, understanding of climate variability in a region is necessary for crop adaptation. Especially, the temperature anomaly analysis is known to be a crucial factor in tracing productivity of rice in Japan and Korea (Hayashi *et al.*, 1999; Hayashi, 2000).

In Korea, the mean air temperature has increased about 1.5°C since 1904. The minimum air temperature in winter has clearly increased, and the daily temperature range has been reduced due to comparatively large increase in minimum temperature (Kwon, 2003). Choi

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and Yun (2009) reported that the maximum temperature in summer (June to August) from 1983 to 2007 was greater than the 30-year normal (1971~2000) by 0.1°C because of the increased solar irradiance caused by decreased aerosol concentration including sulfur dioxide and increased atmospheric transmittance. Precipitation has increased in the high latitude region of Northern hemisphere where air temperature has increased. In Korea, the annual precipitation has been generally increasing, especially in recent 20 years (Kwon, 2003). Rainfall intensity (determined by the total precipitation divided by the days of precipitation) also increased, especially in summer. We have more rainfall events greater than 50 mm d^{-1} compared to the past (Kwon, 2003).

The increase in temperature may have positive impacts such as extended crop growing season. On the other hand, rice can become deteriorated in terms of yield and quality due to the higher temperature during the grain filling period than the optimum range. The optimum mean air temperature at the ripening stage (i.e., 40 days after rice heading) for a high yield of Japonica type rice ranged from 21 to 23°C with the maximum yield at 22°C, and rice yield can decrease at a rate of 5% per 1°C increase (Yun and Lee, 2001). For high quality rice, the mean air temperature for 40 days after heading should range from 20 to 22°C (RDA, 2004). Respiration of rice can be accelerated and therefore the production of carbohydrate can be reduced by the increase in temperature and decrease in solar irradiation. Climatic yield potential is determined by the mean air temperature and sunshine hours for 40days after the rice heading (Tsuboy, 1977), and meteorological productivity is determined by the mean air temperature and sunshine hours from 10 days before heading to 30days after heading and the number of spikelets per m^2 (Lee *et al.*, 1988). Therefore, it can be inferred that rice yield increases with the increase in sunshine and decreases with the increase in the difference from the optimum mean air temperature. Accumulation of carbon assimilation products is influenced by daily temperature range in early grain filling period. Kim *et al.* (2002) concluded that the yield prediction model using boundary line analysis based on mean air temperature, sunshine hours, and daily temperature range could be used to predict the yield responses to meteorological conditions during rice growing period. Son *et al.* (2002) reported that daily temperature range at ripening stage had a greater impact on rice yield in Gyeongnam province than sunshine hours and mean air temperature, while sunshine hours more important than temperature in Jeonbuk province.

Climate change is important for rice growing management due to its impact on the rice heading date and rice yield by affecting growth and development of rice and grain filling at ripening stage. This study was conducted to provide information for countermeasure to climate change impact on rice cultivation in Gangwon province by examining the climate condition during recent 10 years, from 2000 to 2009, as compared with the normal, 1971~2000, especially during rice heading and ripening stage and by analyzing the possible impact of climate change on rice cultivation.

II. MATERIALS AND METHODS

Weather data (including mean air temperature, maximum temperature, minimum temperature, daily temperature range, sunshine hours, and annual precipitation) were obtained from nine synoptic meteorological stations in Gangwon province. Agricultural land in Gangwon province is classified to five zones: Northern inland region such as Chuncheon, Cheorwon, Hwacheon, and Yanggu, Southern inland region such as Wonju, Hongcheon, Hoengsung, and Younghwol, Alpine highland including Inje, Pyoungchang, Jeongsun, and Taebaek, Northern coast including Sokcho, Gosung, and Yangyang, and Southern coast including Gangneung, Donghae, and Samcheok. Northern inland has basin topography with large daily temperature range and frequent fog. Southern inland has relatively long spring and autumn and site-specific sudden weather change. Alpine highland has cool summer and heavy fog and snow. Northern coast is characterized by relatively warm winter, long frost-free period, and cool wind from the sea. Southern coast has warm winter, long frost-free period, and strong wind in spring. Northern inland including Cheorwon has 38% of the total paddy rice field in Gangwon province, 43,869 ha in 2009, followed by 31% of Southern inland including Wonju and Hongcheon.

In order to examine the climate change impact on rice cultivation, climate data during the major rice growing period in field (from June to September) for recent 10years were compared with the normal in addition to a whole year comparison. Respiration consumption effect (RCE) was determined using mean air temperature and sunshine hours from June to September (Son *et al.*, 2002).

$$RCE = 10^{0.0301(\text{Mean air temperature}-10)}/(\text{sunshine hours}) \quad (1)$$

Proper heading date was determined by mean air temperature at ripening stage (i.e., 40 days after rice heading) based on optimum temperature range, from 20 to 22°C, for high quality rice production. Climatic yield potential (CYP) in kg/10a was determined using mean air temperature and total sunshine hours for 40 days after rice heading (Tsuboy, 1977).

$$CYP = 4.14\cdot(\text{sunshine hours}) - 0.13\cdot(21.4-\text{mean air temperature})^2 \quad (2)$$

Actual rice heading date and mean air temperature for 40days after heading were obtained from the results of rice regional adaptability trial in Chuncheon, Cheorwon, Gangneung, and Jinbu from 1999 to 2009.

III. RESULTS AND DISCUSSION

3.1. Climate change pattern in Gangwon province

In Gangwon province, mean air temperature from 2000 to 2009 rose to 10.7°C which is 0.5°C higher than the normal (1971~2000) (Table 1). Daily temperature range reduced by 0.1°C, sunshine hours decreased by 151 hours, and annual precipitation increased by 122mm. The increase in mean temperature and precipitation and decrease in daily range and precipitation are consistent with the climate change pattern observed in the whole country (Kwon, 2003). Kim *et al.* (2007) reported that mean air temperature from 1996 to 2005 in the south-eastern part of Korea rose by 0.3°C, daily range reduced by 0.2°C, precipitation increased by 188mm, and sunshine hours reduced by 83 hours compared with normal climate. The clearest anomaly was shown in the southern inland area of Gangwon province, i.e., increases in mean air temperature by 0.9°C and precipitation by 152 mm and reductions of daily range by 0.7°C and sunshine hours by 407 hours.

During the major rice growing period in field (from June to September) mean air temperature for the recent 10 years rose to 21.3°C (0.4°C higher than normal years) and daily temperature range reduced to 9.0°C (0.2°C lower), similar to the climate change pattern for the whole year (Table 2). Increase in temperature may result in reduction of rice yield due to decreased carbohydrate accumulation by enhanced respiration and

Table 1. Recent (2000~2009) climatic characteristics compared with normal (1971~2000) in Gangwon province

Zone		T_{mean} [1)]	T_{max} [1)]	T_{min} [1)]	T_{range} [1)]	h_s [1)]	P_t [1)]
		°C				hr	mm
N.Inland	Normal	10.6	16.6	5.2	11.4	2,134	1,301
	Recent	10.8	16.9	5.4	11.5	2,025	1,396
	Difference	0.3	0.3	0.2	0.1	-109	95
S.Inland	Normal	10.5	17.3	4.9	12.4	2,390	1,291
	Recent	11.3	17.7	6.1	11.7	1,983	1,444
	Difference	0.9	0.4	1.2	-0.7	-407	152
Highland	Normal	8.3	13.9	3.2	10.7	2,202	1,380
	Recent	8.9	14.5	3.9	10.6	2,161	1,489
	Difference	0.6	0.6	0.7	-0.1	-42	109
N.Coast	Normal	12.1	15.8	8.5	7.3	2,178	1,342
	Recent	12.4	16.5	8.5	8.0	2,054	1,460
	Difference	0.3	0.7	0.0	0.7	-123	118
S.Coast	Normal	12.9	17.4	8.9	8.5	2,136	1,402
	Recent	13.4	17.7	9.6	8.1	2,059	1,558
	Difference	0.5	0.3	0.7	-0.4	-77	156
Mean	Normal	10.2	15.9	5.2	10.6	2,219	1,341
	Recent	10.7	16.3	5.9	10.5	2,068	1,463
	Difference	0.5	0.5	0.6	-0.1	-151	122

[1)] T_{mean}; Daily mean air temperature, T_{max}; Maximum air temperature, T_{min}; Minimum air temperature, T_{range}; Daily range of air temperature, h_s; sunshine hours, P_t; total precipitation

Table 2. Recent (2000~2009) climatic characteristics during rice growing period (Jun.~Sep.) compared with normal (1971~2000) in Gangwon province

Zone		T_{mean}[1)]	T_{max}[1)]	T_{min}[1)]	T_{range}[1)]	h_s[1)]	P_t[1)]
		°C				hr	mm
N.Inland	Normal	22.0	27.4	17.7	9.7	709	932
	Recent	22.2	27.5	17.9	9.6	610	1,051
	Difference	0.1	0.1	0.2	-0.1	-99	120
S.Inland	Normal	22.1	28.2	17.5	10.7	819	910
	Recent	22.6	28.3	18.2	10.1	607	1,083
	Difference	0.6	0.1	0.7	-0.6	-212	173
Highland	Normal	18.9	24.0	14.6	9.4	674	926
	Recent	19.3	24.4	15.3	9.1	654	1,058
	Difference	0.5	0.4	0.7	-0.3	-20	132
N.Coast	Normal	21.3	24.5	18.4	6.1	634	823
	Recent	21.5	25.3	18.4	6.9	599	980
	Difference	0.2	0.8	0.0	0.8	-35	156
S.Coast	Normal	22.3	26.3	18.8	7.5	628	814
	Recent	22.6	26.5	19.4	7.1	574	1,039
	Difference	0.3	0.2	0.6	-0.4	-54	225
Mean	Normal	20.9	26.0	16.8	9.2	704	900
	Recent	21.3	26.3	17.3	9.0	619	1,051
	Difference	0.4	0.3	0.5	-0.2	-86	151

[1)]T_{mean}; Daily mean air temperature, T_{max}; Maximum air temperature, T_{min}; Minimum air temperature, T_{range}; Daily range of air temperature, h_s; sunshine hours, P_t; total precipitation

shortened vegetative growth period by earlier flowering and heading (Park *et al*., 2006). One of the reasons for less rice yield in the subtropical zones than in the temperate zones is the lower dry matter production due to shorter growing period (Ying *et al*., 1998). Sunshine hours for the four months decreased by 86 hours, corresponding to 57% of the decrease for the whole year. Precipitation increased by 151mm which is higher than the increase for the whole year, indicating reduced precipitation in the remaining eight months compared with the normal. Kim *et al.* (2007) reported a clear decrease in sunshine hours in August and critical increase in precipitation in August and September in south-eastern part of Korea. Similar to climate change for the whole year, the clearest change during the main rice growing period was observed in southern inland area of Gangwon province; rise of mean temperature by 0.6°C and precipitation by 173 mm and reduction of daily range by 0.6°C and sunshine hours by 212 hours.

3.2. Impact of climate change on rice cultivation

Respiration consumption coefficient, an indicator of dry matter increment by increase in sunshine hours and respiration acceleration at high temperature, during recent 10years increased to 0.46 which is greater than normal years by 0.07 (Table 3). The increment in respiration consumption coefficient was greatest in July, just before rice heading. High temperature and shortage of solar irradiation before heading can cause decreased carbohydrate accumulation in grain due to reduced photosynthesis and enhanced respiration consumption (Yun and Lee, 2001), resulting in negative impact on rice yield and quality. The prolonged poor weather conditions in terms of rice cultivation after heading can cause plant lodging through over-allocation of carbohydrates to grains in addition to reduced yield by hampered photosynthesis (Cock and Yoshida, 1972). The greatest increment in respiration consumption coefficient in Gangwon province was 0.17 in the southern inland area with clear rise in temperature and reduction of sunshine hour, while the least was 0.02 for the highland region.

Table 4 shows the proper heading period for high quality rice production in Gangwon province deter-

Table 3. Respiration consumption effect during rice growing period (Jun.~Sep.) in recent (2000~2009) as compared with normal (1971~2000)

Zone		Jun.	Jul.	Aug.	Sep.	Avg.
N.Inland	Normal	0.34	0.54	0.47	0.30	0.41
	Recent	0.39	0.70	0.55	0.36	0.50
	Difference	0.05	0.16	0.08	0.06	0.09
S.Inland	Normal	0.29	0.43	0.41	0.28	0.35
	Recent	0.41	0.71	0.58	0.38	0.52
	Difference	0.12	0.28	0.17	0.10	0.17
Highland	Normal	0.27	0.44	0.43	0.28	0.36
	Recent	0.28	0.47	0.45	0.32	0.38
	Difference	0.01	0.03	0.02	0.04	0.02
N.Coast	Normal	0.36	0.51	0.52	0.35	0.43
	Recent	0.36	0.59	0.53	0.40	0.47
	Difference	0.00	0.08	0.01	0.05	0.04
S.Coast	Normal	0.39	0.56	0.55	0.38	0.47
	Recent	0.41	0.66	0.62	0.43	0.53
	Difference	0.02	0.10	0.07	0.05	0.06
Mean	Normal	0.31	0.48	0.46	0.30	0.39
	Recent	0.36	0.61	0.53	0.36	0.46
	Difference	0.05	0.13	0.07	0.06	0.07

Table 4. Optimum heading period for high quality rice in Gangwon province

Region		FDMT 22°C[1)]	FDMT 20°C[1)]	Period (Days)
Chuncheon	Normal	Aug. 12	Aug. 21	10
	Recent	Aug. 14	Aug. 25	12
Cheorwon	Normal	Aug. 10	Aug. 19	10
	Recent	Aug. 7	Aug. 19	13
Wonju	Normal	Aug. 13	Aug. 22	10
	Recent	Aug. 16	Aug. 27	12
Hongcheon	Normal	Aug. 10	Aug. 19	10
	Recent	Aug. 11	Aug. 22	12
Inje	Normal	Aug. 5	Aug. 16	12
	Recent	Aug. 5	Aug. 18	14
Taebaek	Normal	-	Aug. 3	-
	Recent	-	Aug. 2	-
Daegwallyeong	Normal	-	-	-
	Recent	-	Jul. 21	-
Sokcho	Normal	Aug. 11	Aug. 25	15
	Recent	Aug. 11	Aug. 26	16
Gangneung	Normal	Aug. 14	Aug. 28	15
	Recent	Aug. 15	Aug. 29	15

[1)]FDMT22°C and FDMT20°C; First date for mean air temperature of 22°C and 20°C for 40 days after flowering, respectively.

mined by the mean air temperature for 40 days after heading. The length of proper heading period in Gangwon province was 12 days for Chuncheon and 16 days for Sokcho, and increased by up to 3 days compared with the normal data. For instance, the proper heading period in Cheorwon was 13 days between 7 and 19 August in 2000~2009 compared with 10days for the normal. The first date of the proper heading period ranged from 5 August in Inje to 16 August in Wonju for the recent climate conditions, which was delayed by 1 to 3days in Chuncheon, Hongcheon, Wonju, and Gangneung compared with the normal. The proper heading period for Taebaek and Daegwallyeong ended before 2 August, implying that only early maturing cultivars can be cultivated in this region.

Sunshine hours for 40 days after rice heading based on the proper heading date are shown in Table 5. Sunshine hours decreased from 235 hours for the normal to 201hours in recent years, which is less than 255 hours for the period from 1961 to 1990 in Korea (Yun and Lee, 2001). The reduction of sunshine hours was greatest in Wonju with 72 hours. The sunshine hours at ripening stage for the recent 10 years ranged from 183 to 220 hours in Gangwon province, which is less than that for Youngnam from 1996 to 2005 being 185~241 hours (Kim *et al*., 2007). Insufficient solar irradiation at rip-

Table 5. Sunshine hours during ripening period for high quality rice in Gangwon province

Region	Normal	Recent	Difference
Chuncheon	231(229~234)	204(197~210)	-27
Cheorwon	239(236~241)	204(201~214)	-35
Wonju	263(262~265)	191(182~199)	-72
Hongcheon	250(248~251)	214(211~220)	-36
Inje	244(243~245)	220(218~222)	-24
Sokcho	211(203~221)	191(185~195)	-20
Gangneung	204(195~214)	183(174~193)	-21
Mean	235(195~265)	201(174~222)	-34

ening stage can increase milky white or immature opaque rice. In addition, since shading treatment at the ripening stage enhances the protein content in rice grains (Guh *et al*., 2003), the lack of sunshine may reduce palatability. Park (2008) reported increased 1000 grain weight with increasing sunshine hours for 30 days after rice heading and reduced protein content in grain with greater daily temperature range. For Inje, the sunshine hours at ripening stage was 220 hours, greater than those for other seven regions in Gangwon province.

Climatic yield potential decreased due to temperature rise and the reduction of sunshine hours during the ripening stage (Table 6). Maximum climatic yield potential in Gangwon province was 817 kg/10a in the recent climate, less than the normal with 913 kg/10a. Especially in Wonju, the climatic yield potential decreased by 290 kg probably due to the greatest reduction of sunshine in Gangwon province. On the other hand, maximum climatic yield potential for Taebaek in highland regions increased because of the increase in temperature to proper range and a little decrease in sunshine hours at ripening stage.

3.3. Mean air temperature at ripening stage in Gangwon province

The actual mean air temperature at ripening stage in Chuncheon, Cheorwon, Gangneung, and Jinbu from 1999 to 2009 is presented in Fig. 1. In Chuncheon, the mean air temperature at ripening stage was above 22°C for early maturing cultivars, while proper temperature range, between 20 and 22°C, was maintained for mid to late maturing cultivars such as Hwaseongbyeo and Ilpumbyeo. The heading date of Odaebyeo, one of the early maturing cultivars, ranged from 30 July to 2 August, earlier than the optimum heading date for high quality rice (i.e., between 14 and 25 August). The heading date ranged from 13 to 16 August for Hwaseongbyeo, a mid-maturing cultivar, and from 17 to 28 August for Ilpumbyeo, a mid-late maturing cultivar. In Cheorwon, the mean air temperature at ripening stage of early maturing cultivars including Jinbubyeo, Odaebyeo, Taebongbyeo, and Unkwangbyeo, was above 22°C, except in 2003. In Gangneung, the mean air temperature was generally above 22°C. The mean air temperature at ripening stage above the proper range may result in damage by high temperature including low grain weight due to rapid growth of the rice kernel and short physiological ripening period. In addition, high temperature at ripening stage can increase protein content in grain, especially in early ripening stage (Guh *et*

Table 6. Maximum climatic yield potential and date for the yield in Gangwon province

Region	MCYP[1](kg/10a)			DMYP[2]		
	Normal	Recent	Difference	Normal	Recent	Difference
Chuncheon	954	857	- 97	Aug. 14	Aug. 21	7
Cheorwon	999	839	-160	Aug. 13	Aug. 19	6
Wonju	1,088	798	-290	Aug. 15	Aug. 24	9
Hongcheon	1,039	879	-160	Aug. 12	Aug. 19	7
Inje	1,011	910	-101	Aug. 8	Aug. 9	1
Taebaek	702	947	245	July 28	July 28	0
Daegwallyeong	704	597	-107	July 25	July 25	0
Sokcho	879	795	- 84	Aug. 22	Aug. 19	- 3
Gangneung	845	760	- 85	Aug. 22	Aug. 21	- 1
Mean	913	819	- 94			

[1]MCYP; Maximum climatic yield potential
[2]DMYP; Date for the maximum climatic yield potential

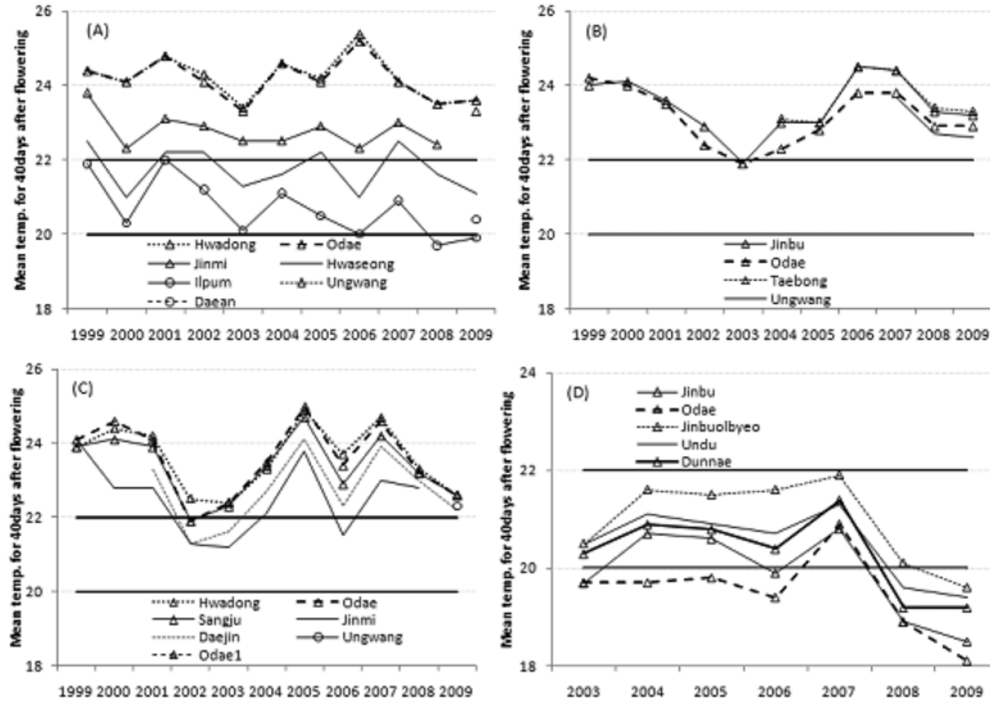

Fig. 1. Daily mean temperature for 40 days after flowering as compared with the optimum temperature range (20~22°C) in Chuncheon (A), Cheorwon (B), Gangneung (C), and Jinbu (D).

al., 2003). Park (2008) reported that the maximum weight of 1000 grain was observed at 22.2°C of mean air temperature for 30 days after rice heading, and the maximum palatability value at 22.7°C. Nampyeong-byeo, Ilpumbyeo, and Junambyeo, mid-late maturing cultivars, had the maximum palatability value from 22.2 to 22.4°C, while Dongjin 1 at 23.5°C. For Jinbu in highland, increase in temperature may have positive impact on yield and quality of rice because mean air temperature at ripening stage was below 22°C or even lower than 20°C in some cases.

3.4. Adaptation of rice cultivation in Gangwon province to climate change

Chung *et al*. (2006) expected that the heading date of rice in Korea would be accelerated by 7days in the near future, from 2011 to 2040, and 20 days for 2071~2100 compared with the current normal (from 1970 to 1999). Early heading date results in high mean air temperature at ripening stage, which is expected to cause rice yield reduction by 3~26% due to short ripening period, decreased ratio of grain fertility, and enhanced respiration consumption by high temperature at night. Yun (1990) expected that rice yield may decrease by 20~37% due to short ripening period after heading by high temperature under the current rice cultivation management, while increase by up to 18% through change in transplanting time. Therefore, yield and quality of rice can be improved in Gangwon province through delayed heading date by growing mid to late maturing varieties rather than early maturing varieties as currently cultivated, shifting transplanting time, and/or direct sowing. Chung *et al*. (2006) projected the increased yield of Hwaseongbyeo (a mid-maturing cultivar) and Dongjin-byeo (a mid-late maturing cultivar) as well as Odaebyeo (an early maturing cultivar) in Taebaek and Pyoung-chang in highland zone under the future climate condition.

Palatability value is in general low for early maturing cultivars due to high protein content (Heu *et al*., 1969; Guh *et al*., 2003). The leaf area index at the heading stage and the number of grain per unit area for early maturing cultivars are less than those for mid-late maturing cultivars due to the early reproductive growth stage with relatively less biomass. The protein content of early maturing cultivars can be high due to relatively small receptor size, less carbohydrate accumulation, and high temperature at ripening stage. Some varieties were selected for high palatability in Gangwon province, for instance Daeanbyeo for Chuncheon, Hwayeongbyeo and Daeanbyeo for Wonju, Munjangbyeo for Gangneung, and Munjangbyeo, Odaebyeo and Unkwangbyeo for Cheronwon (Park, 2008). Rice quality can be improved in Gangwon province by testing elite varieties with high palatability including Samkwangbyeo, Hopumbyeo, and Chilbobyeo for their regional adaptability and by disseminating the seeds to farmers.

Moreover, it is necessary to develop the varieties with medium size and half spindle-shape rather than small size semi-round type in terms of adaptability to high temperature at ripening stage (Yun and Lee, 2001). Yun *et al*. (2001) reported that Daeanbyeo and Donganbyeo maintained grain weight even at above 25°C, and Guh *et al*. (2003) reported that Nihonbarae showed stable ripening characteristics at high temperature. Although air temperature is generally rising, Yun and Lee (2001) reported that it is necessary to develop new varieties with both heat and cold tolerance because the possibility of chilling injury cannot be removed due to greater variation of climate in the future. They also reported that rice varieties with more tillering and smaller grain would be adaptable to reduced solar irradiation at tillering stage and reproductive growth stage. Furthermore, deep root system with everlasting vigor to late ripening stage, flexible stem, and resistance to viviparous germination would be desirable in order to adapt to the decreased sunshine, increased temperature, and enhanced precipitation at ripening stage.

In summary, it is necessary to develop a regional rice cropping system to delay the heading date and select or develop varieties adaptable to the projected climate change for sustainable production of high quality rice in Gangwon province.

적 요

강원 지역에서의 최근 10년간(2000~2009)의 기상 환경을 평년(1971~2000)과 비교하여 벼 재배의 기상 환경 변화 추이를 살펴보고, 고품질 쌀의 안정 생산을 위한 대책을 수립하기 위한 기초 자료를 제공하고자 하였다. 평년에 비해 기온이 0.5°C 올라가고, 일교차는 0.1°C 줄었으며, 강수량은 122mm 많아졌고, 일조시수는 151시간 줄었다. 벼가 본답에서 주로 생육하는 6월부터 9월까지는 연중 기후 변화에 비해 강수량 증가(151mm)와 일조 시간 감소(86시간) 경향이 뚜렷하였는데, 원주 등 남부내륙권에서 가장 큰 폭의 변화를 보였다. 호흡소모계수는 평년에 비해 0.07 높아졌는데, 특히 생식생장기인 7월에 0.13으로 증가폭이 가장 컸다. 이는 고온에서 호흡이 증가하고 일조시간 부족으로 건물 생산량이 낮아질 수 있음을 보여준다. 고품질 벼 생산을 위한 등숙 온도인 20~22°C를 기준으로 산출한 알맞은 출수기는 평년에 비해 춘천, 홍천, 원주, 강릉은 늦어졌으나, 철원은 앞당겨졌다. 알맞은 출수기 후 40일간의 일조시수는 평년에 비해 34시간 줄어 유백미와 사미가 많아질 염려가 있다. 최대 기후등숙량은 원주에서 가장 많이 줄어든 반면, 태백 등 고랭지에서는 등숙 온도 상승으로 높아졌다. 춘천, 철원, 강릉에서의 최근 11년간(1999~2009) 등숙 온도는 대체로 22°C 이상이었다. 향후 기후 전망에 의하면 출수기는 빨라지고 등숙 온도는 올라갈 수 있으므로, 중생종이나 중만생종을 재배하거나, 이앙 시기의 조절이나 직파 재배와 같은 재배 관리를 달리하여 출수기를 늦추면 쌀 수량과 품질의 저하를 막을 수 있을 것으로 보인다. 나아가 등숙 기간의 기온 상승과 일조량 감소, 강수량 증가 등의 변화된 기상 여건에 잘 적응하는 품종을 육성하거나 선발하여 보급 재배함으로써 고품질 쌀의 안정 생산을 이루어야 할 것이다.

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