Varietal Differences in Agronomic Characters under Different Altitudinal Locations with Equal Latitude in Paddy Rice

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同一緯度上 標高의 差異에 따른 水稻品種의 收量形質變異

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ABSTRACT

The present study was conducted to investigate the variations in morphological traits, yield and yield-related components of rice cultivars exposed to different weather conditions by growing at the locations with different altitude but with equal latitude. Three Japonica varieties (Daegoldo, Jinheung, Shin #2) and three Tongil type semi-dwarf varieties(Josaengtongil, Suweon 287, wx 817-65-2-3) were seeded at Suweon on April 21 and transplanted at Suweon (127°, N37° 20', altitude 37m) and Jechun (128.2°, N37° 10', altitude 280-300m) on June 1 with the spacing of 30 X 15 cm. The morphological traits, yield and yield-related components were measured. Culm length, paincle length and 1000-grain weight showed a little increase in Japonica varieties in Jechun as compared to those in Suweon and vice versa in semi-dwarf varieties, showing no significant differences. Number of panicles per hill and number of spikelets per panicle among yield-related components showed remarkable increase in all varieties in Jechun as compared to those in Suweon but such inter-locational differences differed with varieties within varietal group and between varietal groups. On the contrary, grain fertility was higher in Suweon than that in Jechun and in Japonica varieties than that in semi-dwarf varieites , showing greater inter-locational difference in semi-dwarf varieties. Among Japonica varieties Jinheung and Shin #2 showed remarkable increase in yield in Jechun as compared to that in Suweon but in semidwarf varieties it was just the opposite. The importance of each of the yield-related component contributing to yield showed similar tendency regardless of locations in Japonica varieties. However, it was evidently different between locations in semidwarf varieties, where number of spikelets per panicle showed greatest direct effect on yield in Suweon but in Jechun so did grain fertility followed by the number of spikelets per panicle.

INTRODUCTION

The crop production is largely dependent upon the weather conditions which influence the crop growth and yield through the direct effects on the physiological process. As rice was originated from the sub-tropical climate region, it requires

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relatively higher optimum temperature. Therefore, suboptimal temperature used to impair the growth and yield of rice according to years and regions in Korea. In particular, with the introduction of Tongil type semi-dwarf varieties vulnerable to low temperature the cool weather damage stood out as most serious problem to be solved for stable and higher yield of rice in Korea.

The weather conditions vary in day-length and temperature with latitude and in temperature with altitude with same day-length. Therefore, not only the high-latitude area but also high-altitude areas even in low latitude are limited in temperature resource for rice growing. The mountainous area above 250m from the sea level covers about 6.2% of total rice cultivated area(O.R.D. 1981), which is very prone to cool weather damage depending on the year. The establishment of safe rice culture to decrease the year to year variation in these regions will contribute to the increased rice production in Korea.

The present study aimed at investigating the variations in morphological traits, yield and its components of rice cultivars exposed to different weather conditions by growing them under different altitudinal locations with equal latitude, and providing with basic informations for the improvement of cultural methods and for the development of safe and high yielding rice varieties.

MATERIALS AND METHODS

Bilocational field experiments were conducted in Suweon and Jechun, which are located at almost same latitude with quite different altitude as shown in table. And the former is only 15 km away from the west sea coast but the latter belongs to inland area 130 km away from it.

Place	Lingitude	Latitude	Altitude
Suweon	127°E	37°20'N	37m
Jechun	128°E	37°10'N	280-300m

The experiment year, 1980, was characterized by the abnormally low temperature throughout the rice growing season, especially at the early part of August. The rice varieties used were three Japonica varieties (Daegoldo, Jinheung, Shin #2) and three Tongil type semi-dwarf varieties (Josaeng-tongil, *Suweon 287, wx 817-1-65-2-3), which* were seeded on April 21 at Suweon and transplanted on June 1 with the spacing of 30 x 15cm at both locations with same seedlings reared at Suweon.

The rates of nitrogen, phosphorus and potassium were 15, 10 and 15kg/10a of their ingredient amounts, respectively. Nitrogen was split 40% at transplanting, 30% at tillering and 30% at panicle initiation stage, and phosphorus and potassium were applied all at transplanting.

Randomized block layout was applied with three replications in both locations, and statistical analysis was done by combining the ANOVA's for both locations.

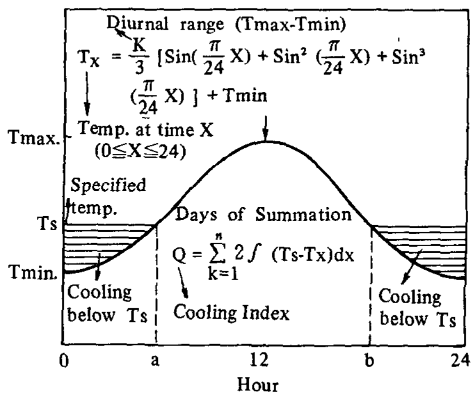

Fig. 1. Calculation of cooling index from the approximate equation of diurnal changes in temperature.

Cooling index [Yoshida's English version (1981) of Reigyakuryo proposed by Uchijima (1976)] was calculated, as shown in Fig. 1, by employing the sine function which Seino et al.(1981) applied to estimating the hour of low temperature duration below specified temperature only from maximum and minimum temperature in Fukuoka prefecture. However, that function is needed to be tested for fitness in those experimental locations in Korea.

RESULTS

Wheather Conditions During the Rice Growing Season

In 1980, the weather condition during the rice growing season was characterized by the chilly air temperature and the reduced solar radiation resulted from the frequent rainfall and the shortage of sunshine-hours, as compared with that in the normal year.

Maximum, Minimum and Mean Temperature: Suweon appeared to be lower in maximum temperature than Jechun by 1-3°C during the period of May to June but during the subsequent rice growing season little differences were noted between the two locations.

The minimum air temperature was lower in Jechun than in Suweon by 1-2°C throughout the rice growing season. In particular, the air temperature was dropped drastically at the beginning of August, recording 7-day duration of lower temperature than 17°C in Jechun and of lower temperature than 19°C in Suweon. However, the temperature below 17°C was not recorded in Suweon during that period.

Daily mean temperature was recorded to be higher in Suweon than in Jechun by about 2°C from the mid-part of June to the mid-part of July and vice versa during August. But beginning with September, its difference between the two locations became negligible. However, the diurnal range of air temperature appeared to be wider in Jechun than in Suweon by more than 2°C.

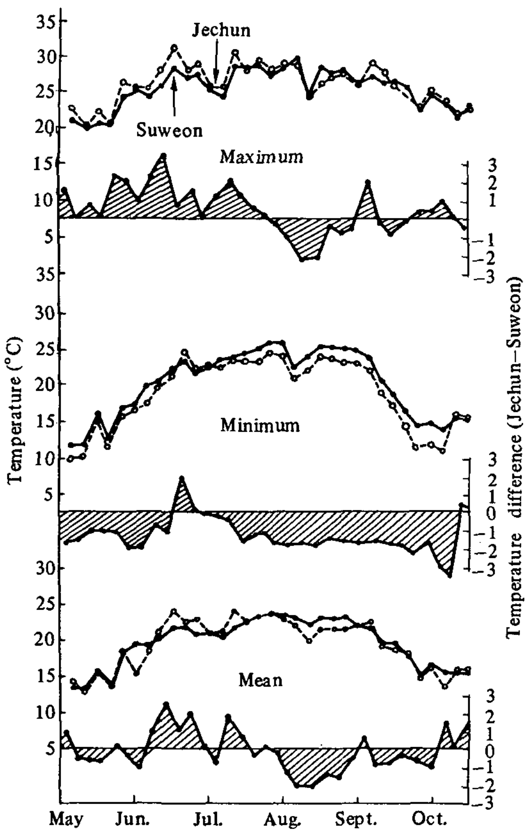

Fig. 2. Changes in maximum, minimum and mean air temperature during rice growing season.

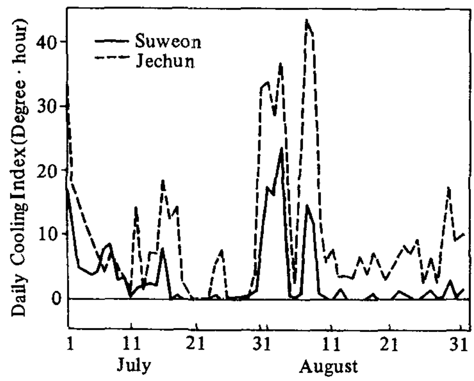

Fig. 3. Seasonal changes in daily Cooling Index at Suweon and Jechun

Cooling Index: The daily Cooling Index was displayed in Fig. 3 temporally during July to August including the sensitive periods to cool weather injury of all tested varieties. Suweon showed much lower Cooling Index throughout those periods than Jechun. In particular, Cooling index showed drastic rise at the early part of August in both locations, exposing the varieties to cooling in different growth stage depending on their heading dates.

Heading Date, Culm Length and Panicle Length

Heading Date: The heading dates of tested varieties in the experimental locations were presented in table 1. The heading date in 1980 varied with varieties and locations. Semi-dwarf varieties among the tested cultivars showed the delayed heading of 2-4 days in Jechun as compared to that in Suweon, marking the greatest delay of 4 days in Josaengtongil. However, tall-statured Daegoldo among tested Japonica varieties headed seven days earlier in Jechun rather than in Suweon, and also Jinheung and Shin #2 showed a little delay of heading in Jechun but slighter delay than semi-dwarf varieties. The duration from the beginning to the end of heading ranged from five to eight days within the tested cultivars and was shorter in Jechun than in Suweon by 1 day in Japonica varieties and by one or three days in semi-dwarf varieties.

Table 1. Responses of heading to experimental locations in the tested cultivars.

Varietal group	Variety	Location		Difference
		Suweon (A)	Jechun (B)	(A-B)
Japonica	Daegoldo	Aug. 12	Aug. 5	−7
	Jinheung	" 25	" 27	2
	Shin #2	" 13	" 13	0
Semi-dwarf	Josaengtongil	" 10	" 14	4
	Suweon 287	" 12	" 14	2
	wx 817	" 6	" 8	2

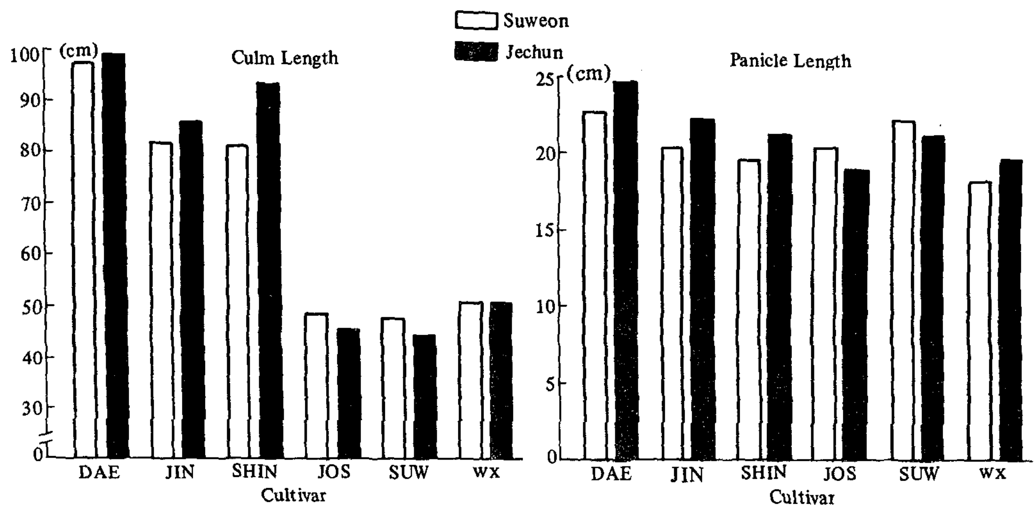

Fig. 4. Culm and panicle length of rice cultivars grown at different altitudinal locations with equal latitude. (DAE: Daegoldo, JIN: Jinheung, SHIN: Shin #2, JOS: Josaengtongil, SUW: Suweon 287, wx : wx817-65-2-3).

Culm and Panicle Length: Figure 4 shows the responses of the culm and panicle elongation under two different altitude locations. The culm of Japonica varieties tended to be somewhat longer in Jechun than in Suweon and vice versa in those of semidwarf varieties. However, its differences between locations showed no significance except Shin #2 among tested varieties. And also the two locations varied in panicle length with similar tendency to the culm length. Its variations with location showed somewhat wider range of 1.5-2cm in Japonica varieties than that of 0.9-1.4cm in semi-dwarf varieties.

Yield and Yield-Related Components

Number of Panicles per hill: The number of panicles per hill varied greatly with locations. All the cultivars tested produced much more tillers in Jechun than in Suweon, showing greater inter-locational difference of 6-10 tillers per hill in Semi-dwarf varieties than that of 5-6 tillers per hill in Japonica varieties.

Number of Spikelets per panicle: Greatly influenced was the number of spikelets per panicle by the location. All the cultivars tested showed significant increase in the total number of spikelets per panicle in Jechun as compared with that in Suweon.

Table 2. Variations in yield and its components of rice cultivars grown under different altitudinal locations with equal latitude.

Varietal group	Variety	Pan. No./hill		Spik.No./pani		Fertility		1000-Grain wt.		Yield/24hill	
		S+	J+	S	J	S	J	S	J	S	J
Japonica	Daegoldo	10.9	15.9	115.3	155.1	86.6%	76.9%	21.4%	21.9%	575.8%	530.8%
	Jinheung	13.2	19.1	137.6	160.6	86.0	71.5	20.9	22.2	750.2	845.3
	Shin #2	14.6	20.4	110.9	125.3	91.9	84.5	21.9	22.3	742.5	1201.2
Sub-average		12.9	18.5	121.2	147.0	88.2	77.6	21.4	21.8	689.5	859.1
Semi-dwarf	Josaengtonil	13.1	23.7	124.5	145.7	75.5	39.8	24.6	24.1	669.1	594.2
	Suweon 287	12.1	19.7	120.0	127.7	86.7	68.2	24.2	22.9	665.7	607.0
	wx 817	11.2	17.1	144.3	146.4	76.6	55.3	27.1	26.3	596.6	483.4
Sub-average		12.1	20.2	129.6	139.9	79.6	54.4	25.3	25.3	643.8	561.5

S.V.	Mean Square				
	Pan. No./hill	Spik.No./pani	Fertility	1000-Grain wt.	Yield/24hill
Location	419.57**	2923.20**	3059.93**	0.25	10622.64**
Variety	21.79*	4281.29**	4281.29**	23.50**	8104.00**
Varietal group	2.10	15672.53**	25672.53**	84.30**	5365.10*
GxL	13.57*	141.53	141.53	5.50	3250.53**
VxL	6.2	265.71*	265.71*	1.25	3050.53*

+ : S and J stand for Suweon and Jechun, respectively.
* and ** : indicate significance at 5 and 1% level, respectively.

Its interlocational differences varied significantly not only within varietal groups but also between varietal groups. In Japonica varieties were shown greater inter-locational variations of 15 to 40 spikelets per panicle than those of 2 to 20 spikelets per panicle in semi-dwarf varieties.

1,000-Grain Weight: 1,000-grain weight of semi-dwarf varieties was shown to be heavier than that of Japonica varieties regardless of locations. However, its difference between varietal groups became narrower in Jechun than in Suweon. The 1,000-grain weight tended to respond to location reversely with varietal groups. Semi-dwarf varieties showed somewhat lighter 1,000-grain weight in Jechun than in Suweon but Japonica varieties were just the opposite. However, its inter-locational differences were not significant.

Fertility: All the tested varieties showed remarkable decrease in percentile fertility in Jechun as compared to that in Suweon but showed variations in its severity with varieties within varietal group and between varietal groups. Japonica varieties exhibited much smaller inter-locational difference of average 10.6% than semi-dwarf varieties that showed that of average 25.2%. Among Japonica varieties Jinheung showed greatest variations with location, follwed by Daegoldo and Shin #2. And among semi-dwarf varieties the interlocational difference was greatest in Josaengtongil followed by Suweon 287 and wx 817-65-2-3.

Grain Yield: The yield responese to experimental location was quite different among varieties and between varietal groups. Japonica varieties except Daegoldo produced higher yield in Jechun rather than in Suweon, on the contrary all the semi-dwarf varieties showed inferior yield performances in Jechun to those in Suweon.

Contribution of Yield-Related Components to the Grain Yield

Fig. 5 displays the direct and indirect effects of yield-related components on grain yield by varietal groups and experimental locations.

The importance of each yield-related components on grain yield showed a considerable difference between varietal groups and between locations. When grown in Jechun, grain fertility exerted greatest direct effect on grain yield without regard to varietal groups but its importance was somewhat greater in semi-dwarf variety than Japonica one. Next to grain fertility, 1,000 grain weight and number of panicles per hill had relatively high direct effect on yield in Japonica and number of spikelets per panicle in semi-dwarf variety, and the other components were almost negligible in direct effect. However, in Suweon, 1,000 grain weight exerted greatest direct effect on yield in Japonica variety but number of spikelets per panicle in semi-dwarf varieties. The other components within varietal group had similar direct effects except for number of panicles per hill which showed negative direct effect on yield.

DISCUSSION

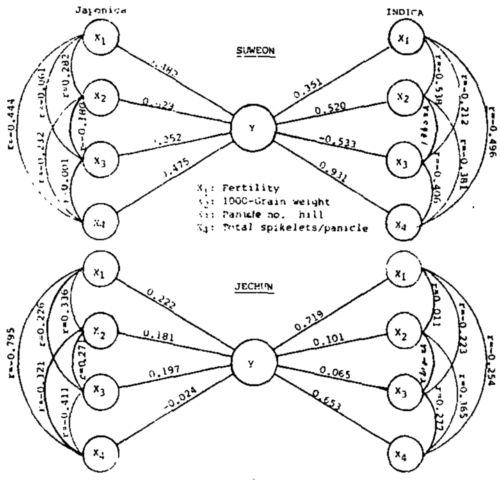

Fig. 5. Diagramatic expression of path analysis between yield and its components.

Heading and yields except for morphological traits such as culm and panicle length of tested varieties were significantly differred when exposed to different environmental conditions by growing rice in different altitude locations with similar latitude. Such variations with location supposed to be resulted mainly from the inter-locational difference in temperature as it is the predominant environmental factor changing with the altitude and the day-length is equal at the same latitude.

All the tested varieties except Daegoldo showed delayed heading of 2 to 4 days in Jechun as compared to that in Suweon (table1). As Matsushima et al (1964) and Oh (1981) observed that the low temperature treatment at meiotic division stage and panicle initiation stage had greatest effect on delay of heading, the average mean air temperature during the 30-day period

Table 3. Average mean air temperature during 30 days before heading.

Variety	Location		Variety	Location	
	Suweon	Jechun		Suweon	Jechun
Daegoldo	23.0	23.7	Josaengtongil	22.9	22.2
Jinheung	22.9	21.4	Suweon 287	22.9	22.2
Shin #2	22.9	22.2	wx 817	23.1	22.5

Table 4. Temperature condition during 40-day period at tillering stage.

Location	Mean temp.	Max. temp.	Min. temp.	Diurnal Range
Suweon	20.94	25.96	17.13	8.47
Jechun	21.72	27.55	16.63	10.92

before heading was compared between locations in table 3. The inter-locational differences in heading dates of all the tested cultivars seemed to be explained by the different temperature regime before heading in the light of the previous pertinent reports (Oh 1981, Matsushima et al 1964a, CES 1978, Ahn et al 1977)

There are some disagreements among reports about the effects of temperature on tillering. Many workers (Matsushima et al 1964, Yoshida 1973, Ahn et al 1977) reported that tillering increased with the rising temperature in a range between approximatly 15°c to 33°C. On the contrary other workers (Oh 1981, Oda and Honda 1963) observed that the number of tillers increased with decreasing temperature in the same range as mentioned above. However, another workers (Oh 1981, Ahn et al 1977, Matsushima et al 1959) reported the consistent results that the number of tillers increased with the increasing diurnal range at the same mean temperature. The temperature regime during the tillering stage was quite different between locations as shown in table 4. During that period, Jechun showed higher mean temperature than Suweon by 0.8°C, and greater diurnal range of temperature by 2.5°C which might be the most important causal factor to the remarkably increased number of panicles per hill in Jechun as compared to that in Suweon.

The panicle differentiation begins at 30 days before heading and finishes at 13 to 15 days before heading (Lee, 1979). Temperature condition during that period was reported to influence the number of spikelets per panicle (Oh, 1981). The significant increase in the number of spikelets in Jechun as compared to that in Suweon might suggest that some-what lower temperature above minimum temperature for growth and greater diurnal range (table 3) be favoralbe conditions for spikelets differentiation. And it was differently affected by temperature conditions with varieties and varietal groups in agreement with the report by Oh (1981).

Rice is most sensitive to low temperatures (15°C-20°C)at the young microspore stage after reduction division and is less sensitive just before and at the leptotene stage of reduction division, about 10-11 days before anthesis (Satake 1976). Spikelet sterility appears to be affected by both night and day temperature. The Cooling Index concept proposed by Uchijima (1976) can demonstrate this. All the cultivars showed the increased sterility with the increase in Cooling Index in Jechun (Fig. 6) coinciding with Uchijima (1976) who reported the close correlation between the Cooling Index and percentage of sterility. The increase in sterility showed

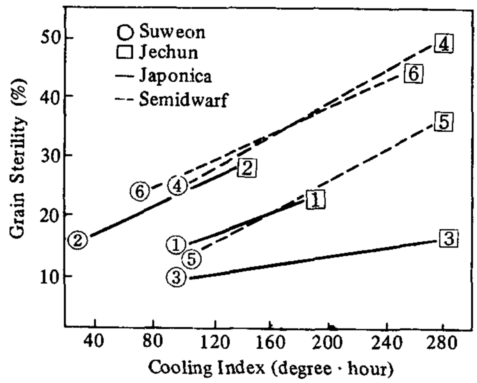

Fig. 6. Relationship between cooling index and sterile percentage at Suweon and Jechun. (1 : Daegoldo, 2 : Jinheung, 3 : Shin #2, 4 : Josaengtongil, 5: Suweon 287, 6: wx 817-65-2-3)

similar increasing tendency with increasing Cooling Index in all varieties tested except Shin #2 that showed most gentle slope. However, the initial Cooling Index causing sterility seemed to be different among varieties.

The grain fertility of rice was predominant factor affecting rice yield in Jechun regardless of varietal groups but quite different tendency was found in Suweon (Fig. 5). This might result from the varietal difference in sensitivity to low temperature and the higher Cooling Index in Jechun because of the characterized *cool air* temperature in 1980. And the weather condition of Jechun characterized by the wide diurnal range of temperature seemed to be more farvorable for higher yield in tolerent varieties to low temperature than that of Suweon. Such weather condition contributed positively to rice yield by increasing the number of panicles per hill and the number of spikelets per panicle significantly.

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摘　　要

水稻 生育期間中 異常低温이 내습하였던 1980年에 同一緯度上의 標高가 다른 두 개 地域, 水原(127°, N 37°20′ 標高 37m)과 提川(128.2°, N37°10′, 標高 280-300m)에다 Japonica 品種인 대골도, 진흥, 신2호와 統一型品種 조생통일, 수원 287호(태백벼), wx 817-1-65-2-3(서울大 農大育成) 等을 4月 21日 播種 6月 1日 移秧하고 出穗期, 稈長, 穗長 및 收量關聯形質들을 調査 比較 檢討하였다.

1. 稈長, 穗長 및 1,000粒重은 Japonica品種의 경우는 提川에서 統一型 品種의 경우는 水原에서 약간 작아지는 경향이었으나 有意的인 差異는 아니었다.

2. 收量構成要素中 株當 穗數는 提川에서 현저히 증가되었는데 그 程度는 品種에 따라서 달랐으며, 稔實率은 水原이 提川보다, Japonica 品種이 統一型 品

種보다 높았는데 지역간 差異는 統一型 品種에서 현저하였다.

3. 地域에 따른 品種들의 收量은 品種群에 따라 달라 Japonica 品種들(대골도 제외)은 提川에서 월등히 높았으나 統一型 品種들은 提川에서 모두 減收되었다.

4. 收量構成要素들이 收量에 기여하는 程度는 Japonica 品種의 경우 地域間에 類似하였으나 統一型 品種은 地域間에 差異가 분명하여 수원에서는 穗當粒數가 提川에서는 稔實率과 穗當粒數의 기여도가 가장 크게 表現되었다.