REACTION OF RICE VARIETIES TO WINTER HARDINESS

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INTRODUCTION

Winter injury of rice seedlings in the nursery and young rice plants in the paddy field can be frequently observed in the first crop during the coldest months of January and February in the northern and central parts of Taiwan. Rice injury ranges from slight chlorosis to complete killing. Although the amount of injury suffered by rice plants may be influenced by many factors, the role played by inherent resistance of rice variety seems important. Rice plants, unless completely killed, usually recover from injury when weather becomes warm and the damage caused by winter injury is generally slight in comparison with those of other natural adversities. For this reason, winter injury of rice has never been taken very seriously in Taiwan. However, recent emphasis on the development of indica type varieties has brought into focus the problem of winter injury which has to be solved before there can be any significant extension of indica varieties in the first crop season. The improvement of winter hardiness of rice varieties appears to be a logical solution to this problem. This paper presents the results obtained at this station on the reaction of rice varieties to winter hardiness in the first crop of 1970.

MATERIALS AND METHODS

The experimental materials consisted of two sets of rice populations. Set 1 included 50 rice varieties coming from different sources. Half of these varieties were of indica type and the others, japonica type. Seeds were sown on the dry nursery constructed in the screenhouse on the 24th of December, 1969. The plots consisted of one row, 1 m long with 20 cm spacing between rows. Planting was made at a rate of 50 seeds per rows. A randomized block design with two replications was employed.

Temperature during the months of January and February was unusually 10w (Table 1) and sufficient winter injury was obtaind to differentiate between the varieties being tested. Comparison of winter hardiness was made by the percentage of winter survival. Varieties with more plants survived in proportion to the total emerged plants were considered to be more resistant to winter killing.

The number of seedlings emerged were counted every day to the last and the number of surviving plants was counted on April 10, 1970.

Table 1. Temperature during the period of the experiment at Chiayi Agricultural Experiment Station.

Temperature (°C)	Dec. 21–31 1969	Jan. 1–10 1970	Jan. 11–20 1970	Jan. 21–31 1970	Feb. 1–10 1970	Feb. 11–20 1970	Feb. 21–28 1970	March 1–10 1970	March 11–20 1970	March 21–31 1970	April 1–10 1970
Maximum	23.3	21.9	17.3	20.9	21.8	23.4	27.9	24.8	22.7	22.9	26.1
Minimum	13.8	13.6	9.4	13.6	11.2	12.3	16.6	14.5	13.8	15.7	15.9
Average	18.5	17.8	13.3	17.3	16.5	17.9	22.3	19.6	18.3	19.3	21.1

Set 2 consisted of three distinct levels of genetic diversity namely, homogeneous varieties, simple mechanical mixtures, and complex mixtures or bulk hybrids. There were 9 pureline varieties, all indica type; 8 simple mechanical mixtures, and 12 bulk hybrids in F_2 and F_3 generations. The simple mechanical mixtures were obtained by mixing equal quantities of seed of two varieties. The bulk hybrids were obtained by crossing the varieties and increasing the seed from each cross in successive generations without intentional selection.

Sowing was made on the ordinary wet nursery on the 30th of December, 1969 at the rate of 100 grams of seed per m^2. The area of the nursery occupied by each population was about 1 m^2. The nursery was not covered with polyethylene film so that rice seedlings could be exposed to low air temperature. When sufficient amount of injury was evident about 4 weeks after sowing, each population was graded for the resistance by visual estimates of chlorosis developed on rice seedlings according to the following system:

1. No apparent chlorosis, rice seedlings green to pale green.
2. Slight chlorosis on rice seedlings.
3. Moderate chlorosis with yellowish white color on rice seedlings.
4. Severe chlorosis with slight wilting of rice seedlings.

This experiment was conducted in the first crop of 1970 at the Chiayi Agricultural Experiment Station.

RESULTS AND DISCUSSION

Winter Survival of Rice Plants

Rate of winter survival of rice plants for each variety tested is given in Table 2.

The average rate of survival for japonica varieties was 67.0% whereas that for indica varieties, 36.8%, showing that as a group, the former appeared more resistant to winter injury than the latter. Among japonica varieties, average rates of survival were 71.6, 64.4 and 38.4% for those coming from Taiwan, Japan, and the United States, respectively. For indica rice, improved varieties of Taiwan gave the highest survival rate of 46.4% which was followed by 39.8, 34.8, 29.2, 7.1 and 3.3% for varieties of Taiwan natives, the United States, Philippines, Mainland China, and India, respectively. It was obvious, therefore, that winter hardiness of rice appears a genetically controlled character. The nature of inheritance for this trait is still not well understood, although the tolerance of rice plants to low air temperature during the period between panicle formation and flowering was reported by Toriyama (1962) to be controlled by 5 to 7 independent genes with additive effect.

It was observed that, in both indica and japonica types, varieties developed here were more resistant to winter injury, indicating that genotypes of greater winter hardiness have been unconsciously selected from the hybrid progenies. It was also observed that varieties from the tropical regions were generally more susceptible to winter killing. IR8, the world-famous variety developed by the International Rice Research Institute (IRRI) in Phi lippine, had survival rate of only 16.3% which was the fourth lowest of the varieties tested. The poor winter survival of IR 8 seems to be the major limiting factor for its suc

cessful establishment in the first crop, especially in the northern and central parts of Taiwan. Since these varieties have become increasingly important as breeding materials in our rice breeding program, special attention should be paid on the elimination of less hardy individuals or lines in the hybrid populations crossed with these tropical varieties. With increased planting of nonhardy indica varieties as well as the extension of early planting and direct-seeding methods of rice culture in the coming days, winter hardiness is likely to become an important objective in our rice breeding program.

Direct seeding on dry nursery as employed in this experiment appeared to be an effective means of testing rice varieties for winter hardiness. As dry nursery is not irrigated, the amount of winter killing will be much greater than the ordinary wet nursery. Thus, differentiation between hardy and non-hardy genotypes will be much easier when materials are grown on dry nursery. In Japan, cold water irrigation method was used to induce sterility in breeding rice for cold resistance (Kondo, 1952). Since unusually low temperature may not occur every winter for effective selection of winter hardiness, artificial freezing test appears necessary as an aid to selection.

Table 2. Rate of winter survival of rice plants direct-seeded on dry nursery.

Japonica type					Indica type				
Source	Variety	Plants emerged	Plants survived	Rate of survival(%)	Source	Variety	Plants emerged	Plants survived	Rate of survival (%)
Taiwan	C220	93	74	79.6	Mainland China	Chian-hsi 3613	99	7	7.1
	C223	97	66	68.0	Taian native	Pai-mi-fen	77	21	27.3
	C233	93	67	72.0		Wu-ko-ching-yu	92	32	34.8
	C236	95	63	66.3		I-kung-pao	86	35	40.7
	Chianung 242	94	59	62.8		Ya-lun	90	16	17.8
	Taichung 65	99	69	69.7		Tsai-yuan-chung	92	32	34.8
	Taichung 186	95	72	75.8		Hsinchu-ai-chueh-chien	51	51	100.0
	Tainan 3	95	56	59.0		Ai-chueh	89	46	51.7
	Tainan 5	100	80	80.0		Pai-ko-hua-lou	89	33	37.1
	Chianan 8	100	59	59.0		Mean	83	33	39.8
	Kaohsiung 64	98	69	70.4	Taiwan improved	C229	87	41	47.1
	Kaohsiung 135	81	80	98.8		C235	59	39	66.1
	Mean	95	68	71.6		Taichung native 1	89	44	49.4
Japan	Pi No. 1	81	53	65.4		Taichung shien 2	84	60	71.4
	Pi No. 4	85	57	67.1		Taichung shien yu 28	86	17	19.8
	Fuku-nishiki	90	71	78.9		Yien shin 2	93	27	29.0
	Hatsu-nishiki	89	50	56.2		Kaohsiung shien 2	92	48	52.2
	Hoyoku	89	47	52.8		Mean	84	39	46.4
	Kinmaze	92	63	68.5	U.S.A.	Blue belle	94	26	27.7

	Nohrin 124	92	62	67.4		Saturn	86	10	11.6
	Kogane Senbon	91	54	59.3		Nova 66	91	25	27.5
	Aichi Asahi	80	44	55.0		CI 9416	94	41	43.6
	Br No. 1	79	63	79.8		CI 9534	99	50	50.5
	Fujisaka 5	91	69	75.8		CP 231	87	38	43.7
	Hoki Asahi	86	35	40.7		Mean	92	32	34.8
	Mean	87	53	64.4	Philip-pines	IR8	86	14	16.3
U.S.A.	Zenith	86	33	38.4		IR9-60	92	37	40.2
Mean (Japonica)		91	61	67.0		Mean	89	26	29.2
					India	TKM-6	90	3	3.3
					Mean (Indica)		87	32	36.8

Chlorosis of Rice Seedlings

Visual estimates of chlorosis developed in homogeneous and heterogenes populations of rice are shown in Table 3. In homogeneous varieties, Ti-chueh-.wu-chien and Hsinchu-ai-chueh-chien showed no apparent chlorosis whereas IR 8, severe with slight wilting. It was observed that rice varieties with heavier chlorosis were generally associated with lower rate of survival, showing that winter injury evaluated by survival rate and chlorosis rating agreed very closely. In heterogeneous populations, chlorosis rating of each simple mechanical mixture is superior to the susceptible parent but inferior to resistant parent. For example, Hsinchu-ai-chueh-chien (P_6) showed no apparent chlorosis (class 1) whereas IR 8, severe chlorosis with slight wilting (class 4), and the mixture of P_6+P_8 developed slight chlorosis (class 2.) The performance of complex mixtures or bulk hybrids was quite similar to that of simple mixtures of the same varietal combination. No difference was also detected in the degree of chlorosis in F_2 and F_3 populations of the same cross. Hanson et al. (1964) also reported that reactions of crosses and mixtures to the pathogens and insect were mostly intermediate between the reactions of the parents or components involved.

Table 3. Chlorosis rating of homogeneous and heterogenous population of rice

Varieties	Classes of* chlorosis	Simple mixtures	Classes of chlorosis	Bulk hybrids	Classes of chlorosis
C229 (P_1)	2	P_1+P_8	2	$P_1\times P_8,F_2$	2
C230 (P_2)	2	P_2+P_4	2	$P_2\times P_4,F_2$	2
C235 (P_3)	3	P_2+P_6	2	$P_2\times P_6,F_2$	1
Ti-chueh-wu-chien (P_4)	1	P_3+P_9	2	$P_3\times P_9,F_2$	2
Kaohsiung shien 2 (P_5)	2	P_5+P_4	1	$P_5\times P_4,F_2$	1
Hsinchu-ai-chueh-chien (P_6)	1	P_6+P_7	2	$P_6\times P_7,F_2$	2
Taichung native 1 (P_7)	3	P_6+P_8	2	$P_6\times P_8,F_2$	2
IR 8 (P_8)	4	P_7+P_8	3	$P_7\times P_8,F_2$	3

IR 9-60 (P_9)	2			$P_1 \times P_8, F_3$	2
				$P_6 \times P_7, F_3$	2
				$P_6 \times P_8, F_3$	2
				$P_8 \times P_7, F_3$	2

* Chlorosis of rice seedlings in 4 classes. Class 4=heaviest chlorosis.

It appears highly probable that winter injury of rice can be overcome through a plant breeding approach. However, the problem sometimes demands a solution within a shorter period than even the minimum time required to develop a new resistant variety. The result of this experiment seems to indicate that heterogeneous populations of rice produced by mixing varieties of different winter hardiness may provide an interim solution to this problem while breeding rice for winter hardiness is in progress. There was no apparent relationship between residual heterosis and the resistance of winter injury to justify the utilization of hybrid populations. Further investigation on the possible utilization of heterogeneous population appears worthwhile.

SUMMARY

The reaction of rice varieties to winter hardiness was evaluated in the first crop of 1970 at the Chiayi Agricultural Experiment Station. The winter survival of young rice plants in the dry nursery indicated that japonica varieties were more resistant to winter injury than indica varieties. Varieties developed at or native of Taiwan showed better survival from winter killing than those from tropical regions of the United States, Philippines, and India. Visual estimates of chlorosis on rice seedlings in the ordinary wet nursery showed that varieties of poor winter survival generally developed severe chlorosis. Reaction of heterogenous populations were usually intermediate between those of the parents or components involved.

LITERATURE CITED

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水稻品種之耐寒性反應

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摘 要

嘉義農業試驗分所於民國五十九年第一期作就水稻品種之耐寒性反應做初步之觀察。旱田直播區之幼小稻株越冬生存率顯示日本型水稻品種之耐寒性一般均較印度型爲强，臺灣在來品種或在臺灣育成之水稻品種，其生存率均較來自美國、菲律賓及印度等熱帶地區之水稻品種爲高。以目測方法所得秧苗葉色之黃化程度顯示越冬生存率低之品種，其葉色黃化現象亦較嚴重。雜質水稻集團之耐寒性反應大致位居兩純系親本或構成分子之中間。