

## PRELIMINARY REPORT ON WHEAT BREEDING FOR RUST RESISTANCE IN TAIWAN

KEH-MING LIN and CHAO-JAN TSENG<sup>(1)</sup>

### Wheat Rust in Taiwan

The leaf rust caused by *Puccinia rubigo-vera tritici* is the most destructive wheat disease in Taiwan. The damage is usually more than twice as much as that of the stem rust caused by *Puccinia graminis* which is of second importance in Taichung Area. Though the annual loss caused by the rusts differs from year to year depending upon the degree of its development which is affected greatly by the climatic conditions, it is estimated to be no less than 10% of the total production in average.

When hot and windless weather lasts for a considerable number of days after the middle of December and very foggy nights follow it, serious damage on wheat by the leaf rust may be expected. In such years approximately twenty to forty percent of the total production may be lost.

The measures for rust control now being recommended by the government in Taiwan are: (1) Sowing at proper time, especially not too late; (2) Refraining from over-application of nitrogen, proper quantity of potassium should be used; (3) Do not irrigate at the last stage of growing period; (4) Avoid too dense planting and keep good ventilation of wheat field; (5) Apply proper fungicides such as "dithiite" or "limesulphur mixture" whenever there is indication of its outbreak.

Though these recommended controlling methods are effective to some extent, their efficacies are not satisfactory when the rust is very prevalent. Some of the control measures are not quite economical owing to the high cost of the chemicals.

Therefore, developing wheat varieties immune from or highly resistant to rust is no doubt the most reasonable approach towards a solution of the problem, though it may take a long time because of the wide physiological specialization of rust races.

In analyzing wheat varieties in Taiwan, they have proved themselves to be good varieties of having most of desired agronomic characters, such as high productivity, good quality and especially early maturity to suit our special

(1) Senior Specialist and former Specialist of Taichung Agricultural Improvement Station.

cultivating system, since wheat is planted as a winter crop during the short period after the harvest of 2nd crop paddy and before the transplanting of the first crop paddy on paddy fields of Thichung Area. But none of these is resistant to rust.

The authors started the studies on this particular problem in 1953 and have put their effort on the improvement of rust-resistant varieties.

The authors desire to acknowledge their indebtedness to Dr. S. H. Ou and Dr. C. F. Cheng of JCRR for their valuable suggestions and criticisms in connection with this work as well as on preparation of this paper.

### Varietal Resistance to Rust

#### *Material and Method*

Observational tests of the rust resistance on a total of 346 varieties and strains introduced from different localities of the world, mostly from the U. S. A. and Japan and some from Canada, Australia, Russia, China Mainland, and Taiwan, were carried out at Taichung, Taiwan in 1952 and 1953.

To make the tests easier, these varieties were sown and observed at the fields located near sea-coast, where the environmental conditions are favorable for rust development. Then the following means were employed to accelerate the development of the pathogen: (1) Seeds were sown 15 days later than the regular sowing time. (2) Heavy nitrogen was applied by using twice as much as the standard amount of ammonium sulphate as basic dressing and top dressing during the vegetable growing period. (3) The test field was kept as wet as possible by frequent irrigation.

Twenty plants were planted in a row with two replicates for each variety and the rust infection was observed on row basis on March 1 and 10, 1954 and 1955.

#### *Classification of Rust Resistance*

The following five classes were used to classify the degree of resistance to rust.

(1) HR-Highly Resistant

No uredinia formed, small flecks, chlorotic or necrotic areas frequent.

(2) R-Resistant

Uredinia few, small, always in small necrotic spots, also many necrotic areas without development of uredinia.

(3) MR-Moderately Resistant

Uredinia of moderate size, fairly abundant, always in necrotic or chlorotic spots.

(4) MS-Moderately Susceptible

Uredinia of moderate size, fairly abundant, no necrosis produced, sometimes slight chlorosis immediately surrounding the uredinia.

(5) HS-Highly Susceptible

Uredinia abundant, large size, no necrosis or chlorosis immediately surrounding the uredinia.

*Experimental Results*

The results of two years' observation are presented in the following tables:

Table 1. Number of Wheat Varieties in Different Classes of Resistance

	HR	R	MR	MS	HS	TOTAL
Leaf Rust	36	42	87	66	115	346
Stem Rust	22	18	152	76	78	346

The result shows that there are wide varietal differences in rust-resistance among those 346 varieties tested.

Table 2. Highly Rust-Resistant Varieties in Taichung, Taiwan

Resistant to	Varieties
Leaf and Stem Rust	HsH <sub>p</sub> 4603, SH <sub>p</sub> S 607, (Frontana X Thatcher), (Timstein X New Thatcher), Selkirk, Towner, Yuma
Leaf Rust Only	Kinai No. 2, No-lin No. 60, No-lin No. 61, Gabo, Chabo, Wheat e13, Stanhalsor, KP 4108, KGP 4508, KGP 4521, Lawrence, Isaria, Anrore, Extralation, Shie-non No. 5, No. 24, and No. 56, KP K4614
Stem Rust Only	Kinai No. 63, Kis 4608, Wheat P. B. 591, Sea Poam, SHSW 4610

As shown in Table 2, varieties resistant to both leaf and stem rust are all those introduced from foreign countries, and none of the local varieties shows any resistance to rusts.

**Some Studies on Rust**

*Physiologic Specialization of Puccinia rubigo-vera tritici*

Leaf-rust reaction of 20 varieties was observed in Taichung and reported in Table 3. Comparison was made with the results tested at five different localities in Wheat Region of U. S. A. (Ausemus, 1951).

It can be seen from Table 3 that a same variety may show different reaction to leaf rust at different localities and it is considered to be due to the different composition of leaf rust races.

The distribution of physiologic races of leaf rust, *Puccinia rubigo-vera tritici*, in Taichung Area of Taiwan has been observed by using several spring wheat varieties whose reactions to 45 physiologic races of leaf rust was studied by Levine *et al* (1951).

Table 3. Leaf-rust resistance of wheat varieties in different localities in U. S. A. and Taichung

Varieties	Madison Wisconsin	Rose- mount Minnesota	Langdon N. Dakota	Highmore S. Dakota	Linclon Nebraska	Taichung Taiwan
Lee	R	R	R	—	3%	R
Rival	30%	32%	40%	25%	70%	S
Rushmore	40%	45%	—	30%	63%	R*
Henry	20%	1%	—	—	84%	S
Thatcher	70%	100%	40%	40%	75%	S
Henry X <sub>1</sub> 1907	—	0%	—	—	—	S*
Henry X Cadet	R	R	—	0%	—	S
Lee X 3175	—	1%	5%	—	—	S*
Thatcher X Surpresa	—	R	R	0%	—	R
Hope X Timstein	—	—	—	0%	—	S*
A. M. 10 X New Thatcher (N. S. 3780)	—	—	R	—	—	S*
Timstein X New Thatcher Frontana X Thatcher	—	1%	—	—	—	HR
(II-46-3)	—	HR	—	—	—	HR
(II-46-5)	—	HR	—	—	—	HR
(II-46-13)	—	HR	—	—	—	HR
Carleton	—	R	—	—	—	S*
Mindum	—	R	0%	0%	R	HR
Stewart	—	0%	0%	0%	—	S*
Nugget	—	R	0%	0%	—	R
Taichung Wheat No. 31	—	—	—	—	—	S

Remarks: (%) the percentage of leaf rust infection.

(\*) indicating the variety showing different reaction to leaf rust at spring wheat region of U. S. A. and Taichung, Taiwan.

The observation results indicate that a part of the physiologic races of leaf rust found in Taichung Area, Taiwan, may consist of some races which do not exist in the Spring Wheat Region of the U. S. A.

#### *Inheritance of Rust Resistance*

According to the test of varietal resistance to rust reported in former paragraph, the strain of "Timstein X Newthatch" was recognized as the most suitable rust-resistant material for the wheat breeding program of Taiwan because of its high resistance to both leaf and stem rusts and its relatively early heading time which makes the cross with wheat varieties of Taiwan highly possible.

The cross combination of "Taichung Wheat No. 31 X (Timstein X Newthatch)" was used as the material for genetical study.

The F<sub>1</sub> plants obtained from the above mentioned cross showed complete resistant to leaf rust but susceptible to stem rust.

80  $F_2$  plants were tested for their rust reactions at the diseased field under favorable environmental conditions for rust development. Observation was made and the degree of rust infection on each plant was recorded according to the classification of rust resistance described above. The result is shown in the following table:

Reaction	Number of Plants
Resistant to leaf rust but susceptible to stem rust	43
Resistant to both leaf and stem rusts	23
Susceptible to both leaf and stem rust	11
Susceptible to leaf rust but resistant to stem rust	3

The result shows evidently that the resistance to leaf rust is governed by one pair of dominant genes, then another pair of independent recessive gene controls the resistance to stem rust. Resistance to leaf rust showed 3:1 ratio to susceptible with 30-50% probability of  $X^2$  (1.06), and on the contrary, 1:3 ratio was obtained for resistant against susceptible to stem rust with 30-50% probability of  $X^2$  (2.40). The result of further study in  $F_3$  conforms this conclusion.

### Breeding of Rust Resistance

#### *Material and Method*

(Timstein X Newthatch) has been used as the resistant parent to cross with the local wheat varieties, Taichung No. 31 and No. 32 since 1953. The methods of testing resistance and its classification used were the same as explained above.

Pedigree and back-cross methods have been used in this breeding program.

In pedigree method, 1,500 individuals were planted in  $F_2$  generation in 1955, then lines were established after  $F_3$  generation. Thereafter, the plants which showed high rust-resistance and possessing desirable agronomic characters were selected from each generation.

Back-cross method, in which Taichung No. 31 was used as the recurrent parent, was employed alternately with selfing. At least more than fifty seeds were obtained from each back cross. Three times of back-cross was completed in the year of 1958 and the progenies were tested for resistance.

#### *Strain Selection*

Two strains from pedigree program and ten from back-cross program have been selected in their homozygous. They are all of high rust-resistance with excellent agronomic characters.

*Regional Test at Taichung Area*

Local test, in which five-row plots with three replicates design was used, was carried out in 1959 in order to study the local adaptability and rust-resistance of 4 newly established strains, the progenies of (Timestone X Newthatch), in different localities. The results are given in Table 5.

Table 5. Test of adaptability and rust-resistance in different localities of Taichung Area, Taiwan

Variety	Lung-ching		Neipu		Fuhsing		Hsilo		Yuanli		% of Yield in Average
	L(c)	S(d)	L	S	L	S	L	S	L	S	
Taichung Strains											
No. 137(a)	HR	HR	HR	HR	HR	HR	HR	HR	HR	HR	100.4
No. 138(a)	HR	HR	HR	HR	HR	HR	HR	HR	HR	HR	104.6
No. 140(a)	HR	HR	HR	HR	HR	HR	HR	HR	HR	HR	95.9
No. 141(a)	HR	HR	HR	HR	HR	HR	HR	HR	HR	HR	108.4
Taichung Wheat											
No. 23(b)	MS	MS	HS	MR	HS	MS	MS	MR	MS	MS	87.0
No. 31(b)	MR	MR	MS	MR	HS	MS	MS	MR	MS	MS	100.0
No. 32(b)	MR	MR	HS	MR	HS	MS	MS	MR	MS	MS	90.6

Remarks: (a) Newly established resistant strains from pedigree method.  
 (b) Common commercial varieties in Taichung Area, Taiwan.  
 (c) Reaction to leaf-rust.  
 (d) Reaction to stem-rust.

The above table indicates that these newly established strains are highly resistant to both leaf and stem rust at all tested localities in Taichung Area, and consequently the yield was higher than local commercial varieties compared.

**Summary**

- (1) Great difference in resistance to leaf and stem rust was found among the 346 wheat varieties introduced from the United States and other countries in Taichung area of Taiwan. Among the introduced resistant varieties, Timestone X Newthatch, which has a relatively early heading date, was selected to cross with two local leading wheat varieties, Taichung No. 31 and No. 32 to develop new resistant wheat for growing in Taichung area, Taiwan.
- (2) Resistance to rusts was tested under natural condition. Rust epidemics were induced by planting in a special locality where rust outbreaks were most frequent and by late sowing, heavy nitrogen fertilizer application and frequent irrigation.
- (3) Through pedigree selection and selfing and back crossing of the progenies of the crosses, four new strains in homozygous state were selected. The

four strains were highly resistant to both leaf and stem rust in 5 localities tested in Taichung area. The four new strains are stable, early maturing to suit local rotation system and yield better than old varieties.

- (4) Reaction of the test varieties used in spring wheat region of America in Taichung indicated that some physiological races exist in Taichung area are absent in the States.
- (5) Genetical analysis of the resistance in the progenies indicated that resistance to leaf rust is governed by a single pair of dominant genes and to stem rust, by a single pair of recessive genes. Combination of back crossing and selfing of the progenies is therefore employed to introduce the rust resistance to established varieties.

## 小 麥 抗 銹 病 育 種

林 克 明 曾 昭 然

- 1) 將自美國及其他國家引進之小麥 246 品系，在臺中試行其抗銹病性檢定試驗結果，證實小麥對葉銹病及莖銹病之抵抗力品種間表現差異極大。並由引進品種中選擇抽穗期較早之一系統“Timstein X Newthatch”與原有優良品種臺中小麥 31 號及 32 號舉行雜交，以圖育成適合臺中地區栽培之新優良抗病性品種。
- 2) 抗銹病性之檢定在自然條件下進行，除選擇容易發病之特殊地帶設置病圃之外，將播種日期儘量延晚，並多用氮肥，常行灌水等，以促進銹病之普遍發生。
- 3) 經系譜選擇法，自交法及回交法等處理雜交後代而由 Homozygous state 中選出四個新系統，該新系統在臺中區六個不同地方檢定結果，發現具有高度之抗銹病性，且早熟，並較在來品種多產等優良特性。
- 4) 美國春播小麥地區之檢定品種在臺中之抗病反應結果，得知有些在美國春播小麥地區所未曾發現之葉銹病生理系却在臺中地區出現。
- 5) 經遺傳的分析雜交後代之抗病性結果，證實小麥抗莖銹病性為由一對顯性遺傳因子所控制，而抗葉銹病性乃為一對隱性遺傳因子所控制。雜交後代以回交及自交之混合法處理，即容易導入抗病因子於既成優良品種內。(摘要)

### Literature Cited

- AUSEMUS, E. R.: Results on Spring Wheat Varieties Grown in Cooperative Plot and Nursery Experiments in the Spring Wheat Region in 1951. Division of Cereal Crops and Disease Report, USDA, 1951.
- CHESTER, K. S.: The Cereal Rusts. Weltham, Mass. U. S. A., 1946.
- JOHNSTON, C. O. and E. M. MAINS.: Studies on Physiologic Specialization in *Puccinia triticina* US Dept. Agr. Tech. Bul. 313, 1932.
- LEVINE, M. N., E. R. AUSEMUS and E. C. STAKMAN.: Wheat Leaf-rust Studies at St. Paul, Minn. Plant Disease Reporter, USDA 199, 1951.
- NEWTON, M. and T. JOHNSON.: Environmental Reaction of Physiologic Races of *Puccinia triticina* and their Distribution in Canada. Can. Jour. Res. C. 19; 121-133, 1941.
- Taichung District Agricultural Improvement Station Annual Report, 1956.