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Monosomic Analysis of Genes for Resistance Against Stem Rust Races in Bread Wheat

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Summary. Using monosomic analysis genes governing resistance in one wheat variety, 'E5883', against stem rust races 15C and 122, were located on specific chromosomes. Against race 15C, a major dominant gene, *Sr6*, was located on chromosome 2D of 'E5883' with minor modifiers found on chromosomes 4A and 6D. Against race 122, the presence of a recessive hemizygous ineffective gene, *Sr8*, was identified, located on chromosome 6A of variety 'E5883'.

Key words: *Triticum aestivum* – Wheat – *Puccinia graminis* – Stem rust resistance – Monosomic analysis

Introduction

Up until 1954, when Sears reported the production of a complete series of 21 monosomic lines in the hexaploid wheat variety 'Chinese Spring', all studies regarding the inheritance of rust resistance were confined to conventional genetic analyses. To date a total of 34 stem rust resistance genes have been identified in wheat.

By aneuploid analyses 29 different *Sr* genes (Sr = stem rust = black rust = *Puccinia graminis* Pers.f.sp. 'tritici' Eriks and Henn) have been located on specific chromosomes of hexaploid wheat by various workers. In the present investigation, an attempt has been made to locate rust resistance genes on specific chromosomes of one exotic wheat variety against races 15C and 122 of stem rust.

Material and Methods

One exotic resistant variety of *Triticum aestivum* (**2n** = 42), from the International Spring Wheat Nurseries, with Indian Agricultural Research Institute accession number 'E5883', was selected for locating genes conditioning seedling resistance against stem rust. For this purpose monosomic analysis was employed. The 21 monosomic lines of wheat variety 'Chinese Spring' used were obtained from Dr. E.R. Sears.

The salient features of varieties 'E5883' and 'Chinese Spring' are:

'E5883': Pedigree – 'Norin 10', 'Yaqui 53', 'Kentana 54'. This variety is characterized by full awning, single dwarf, early maturing and possesses seedling resistance to all the groups of races of stem rust except group IV (groups of stem rust races : I = 15 and 15C; II = 117 and 117A, III = 21 and 21A-1; IV = 34 and 34A; V = 42, 42B and 42-B-3; VI = 122 and 295; VII = 184 and 222 and VIII = 14,40 and 194). The intensity of infection at adult plant stage in epiphytotic condition with mixture of all the available races of stem rust is restricted to 'traces' only.

'Chinese Spring': An awnless and hooded spring variety susceptible to all the races of stem rust, both in the seedling and adult plant stage.

Two races of stem rust, 15C and 122, were used to infect the seedlings. Race 15C was first isolated by Gokhale (1950). Race 122 is one of the most virulent races of stem rust first identified by Gokhale and Patil (1952). Earlier, this race was confined to Southern India but has spread now practically throughout the country.

Monosomic (**2n** = 41) plants were identified cytologically in all the 21 aneuploid lines and were crossed with 'E5883'. F_1 progenies were grown and monosomic F_1 hybrids were identified in all 21 lines. F_2 seeds were collected from the monosomic F_1 hybrids and grown in the glass house for testing against the two races of stem rust. – To serve as control, 'Chinese Spring' (disome) was crossed with 'E5883', the F_1 progeny grown and F_2 seeds collected for testing against stem rust races. – The F_2 seedlings were raised and inoculations were carried out with the races of stem rust according to the technique described by Stakman et al. (1944). Observations were recorded on the infection type 15 to 25 days after inoculation and classified according to the scale devised by Stakman et al. (1962). The tests were conducted at a temperature ranging from 8°C to 22°C.

A chi-square test was applied to the segregation ratios of both the resistant and susceptible plants obtained in the F_2 generation of the control cross and after selfing the monosomic F_1 hybrids, after infecting with the rust race. The control cross provided the data of the conventional genetic analysis and among the F_2, derived from monosomic F_1's, only those lines which deviated from the expected ratios were considered to be the critical lines (chromosomes on which the resistance genes are located).

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Results

The inheritance of resistance in 'E5883' to races 15C and 122 was studied in crosses of 'Chinese Spring' monosomic lines with 'E5883'. 'E5883' produced '0' type reaction to race 15C, whereas to race 122, a '2' type of reaction was observed. 'Chinese Spring' produced a highly susceptible reaction of the '4' type to both these races.

The F_2 data for race 15C, showing the mode of segregation in different monosomic F_2 families, including 'Chinese Spring' (disome) X 'E5883', are presented in Table 1. A good fit to a ratio of 3R:1S was obtained in the F_2 of the disomic cross (control) as well as in the 17 families of the monosomic F_2's (F_2 of monosomic 6B X 'E5883' could not be studied). In crosses involving chromosomes 4A, 2D and 6D expected monogenic segregation was not obtained.

49 plants out of 50, from the progeny of monosomic 2D F_1 showed a resistant type of reaction, which is to be expected if the resistance gene is located on this chromosome of 'E5883'. Minor deviations from the monogenic segregation was also observed in the F_2 of mono 4A and 6D hybrids. The number of resistant plants observed in both these families were more than expected, suggesting the presence of modifiers located on chromosomes 4A and 6D of 'E5883'.

Against race 122, F_2 of monosomic F_1 hybrids in all the 21 families and disomic F_2 (control) segregated in a ratio of 1R:3S, the normal monogenic segregation with resistance as recessive (Table 2). On the basis of monogenic segregation obtained in the disomic cross, one critical line is expected in which the monosomics as well as the disomics (which are approximately 97 percent of the population) exhibit resistance. Alternatively, in case the recessive resistance gene under study is hemizygous ineffective, it is to be expected that approximately 24 percent (disomes only) of the seedlings are resistant and 76 percent (monosomes and nullisomes) are susceptible.

This ratio of resistant and susceptible seedlings is very close to the 1R:3S ratio which has been obtained in all the families of the monosomic F_1 hybrids. An additional F_2 population of monosomic 6A X E5883 was tested with race 122. Out of a total of 159 seedlings tested against race 122, 133 were observed to be susceptible and 26 to be resistant. The χ^2 value, on the basis of 1R:3S, was found to be 6.33, which significantly deviated from the expected Mendelian Ratio. However, when the observed segregation was subjected to the expected ratio of 24R:76S, it gave a

Table 1. Segregation of F2 seedlings (from 41 chromosome F1 hybrids) from crosses between variety 'E5883' and the monosomic lines of 'Chinese Spring' inoculated with race 15C of stem rust

	Resistant		Susceptible				
Chromosome	Observed	Expected	Observed	Expected	Total	χ^2 3R: 1S	P value
1A	36.00	36.00	12.00	12.00	48	0	>0.99
1B	65.00	64.50	21.00	21.50	86	0.02	0.99–0.95
1D	29.00	33.75	16.00	11.25	45	2.67	0.20–0.10
2A	61.00	64.50	25.00	21.50	86	0.76	0.95–0.50
2B	31.00	34.50	15.00	11.50	46	1.42	0.50–0.20
2D[a]	49.00	37.50	1.00	12.50	50	14.11	<0.01
3A	43.00	42.75	14.00	14.25	57	0.005	0.95–0.50
3B	46.00	45.75	15.00	15.25	61	0.005	0.95–0.50
3D	32.00	36.00	16.00	12.00	48	1.77	0.20–0.10
4A[a]	42.00	33.75	3.00	11.25	45	8.07	<0.01
4B	34.00	33.75	11.00	11.25	45	0.007	0.95–0.50
4D	18.00	22.50	12.00	7.50	30	3.60	0.10–0.05
5A	32.00	36.00	16.00	12.00	48	1.77	0.20–0.10
5B	21.00	20.25	6.00	6.75	27	0.11	0.50–0.20
5D	26.00	28.50	12.00	9.50	38	0.88	0.50–0.20
6A	104.00	100.50	30.00	33.50	134	0.49	0.50–0.20
6B	Not tested						
6D[a]	49.00	39.00	3.00	13.00	52	10.25	<0.01
7A	36.00	40.50	18.00	13.50	54	2.00	0.20–0.10
7B	20.00	22.50	10.00	7.50	30	1.01	0.50–0.20
7D	44.00	48.00	20.00	16.00	64	1.33	0.50–0.20
D X D	69.00	66.00	19.00	22.00	88	0.55	0.50–0.20

[a] Critical lines; D X D = Disome X Disome (control)

Table 2. Segregation of F2 seedlings (from 41 chromosome F1 hybrids) from crosses between variety 'E 5883' and the 21 monosomic lines of 'Chinese Spring' inoculated with race 122 of stem rust

Chromosome	Resistant		Susceptible		Total	χ^2 3S: 1R	P value
	Observed	Expected	Observed	Expected			
1A	8.00	11.50	38.00	34.50	46	1.45	0.50–0.20
1B	3.00	4.50	15.00	13.50	18	0.67	0.50–0.20
1D	8.00	11.00	36.00	33.00	44	1.09	0.50–0.20
2A	9.00	11.75	38.00	35.25	47	0.85	0.50–0.20
2B	8.00	11.50	38.00	34.50	46	1.45	0.50–0.20
2D	12.00	15.50	50.00	46.50	62	1.05	0.50–0.20
3A	10.00	14.25	47.00	42.75	57	1.69	0.20–0.10
3B	9.00	14.25	48.00	42.75	57	2.57	0.20–0.10
3D	8.00	12.25	41.00	36.75	49	1.96	0.20–0.10
4A	9.00	14.25	48.00	42.75	57	2.57	0.20–0.10
4B	8.00	11.25	37.00	33.75	45	1.25	0.50–0.20
4D	5.00	7.00	23.00	21.00	28	0.76	0.50–0.20
5A	10.00	12.00	38.00	36.00	48	0.44	0.95–0.50
5B	4.00	6.25	21.00	18.75	25	1.08	0.50–0.20
5D	9.00	12.50	41.00	37.50	50	1.31	0.50–0.20
6A[a]	26.00	39.75	133.00	119.25	159	6.33	0.02–0.01
6B	12.00	12.00	36.00	36.00	48	0.00	> 0.99
6D	9.00	13.25	44.00	39.75	53	1.81	0.20–0.10
7A	9.00	13.50	45.00	40.50	54	2.00	0.20–0.10
7B	5.00	7.25	24.00	21.75	29	0.93	0.50–0.20
7D	6.00	7.25	23.00	21.75	29	0.28	0.95–0.50
D X D	40.00	37.00	108.00	111.00	148	0.32	0.95–0.50

[a] Critical line; D X D = Disome X Disome (control)

good fit, supporting the assumption that the recessive hemizygous ineffective gene conferring resistance to race 122 is located on chromosome 6A of 'E5883'.

Discussion

The parents involved in the pedigree of 'E5883' are 'Norin 10', 'Yaqui 53' and 'Kentana 54B'. The parents of 'Yaqui 53' are 'Kenya 58' and 'New Thatcher' and that of 'Kentana 54B' are 'Kenya RF 324' and 'Mentana'.

Monosomic analysis has revealed the presence of a dominant major gene for resistance on chromosome 2D of 'E5883' and minor modifiers on chromsomes 4A and 6D against race 15C (Table 1). The modifiers were for increased resistance. The dominant gene for resistance against race 15C has been shown from crosses with effective *Sr*-genelines to be *Sr6* (Sawhney et al. 1979). This gene in 'E5883' has been derived from 'Kenya RF324'. The presence of *Sr6* in 'Kenya RF 324' has been reported by Knott and Anderson (1956).

The susceptible disome ('Chinese Spring' X E5883) gave an F_2 segregation against race 122 of 3S:1R (Table 2) suggesting thereby the operation of a recessive gene for resistance. Monosomic analysis did not reveal a critical line indicating the possibility that the resistance gene involved was hemizygous ineffective, which will simulate the segregation pattern of the control cross because 3 monosome : 1 disome are approximately produced when a monosomic plant is selfed (Sears 1954).

The recessive gene conditioning rust resistance in 'E5883' against 122 has been identified as being *Sr8* by Sawhney et al. (1979), with the help of seedling reaction of the F_2 progenies of the crosses between 'E5883' and single gene testers. Since *Sr8* is known to be located on chromosome 6A (Sears et al. 1957), an additional population of the cross mono 6A X 'E5883' was tested and it was found that the ratio observed confirms satisfactorily to that expected for segregation of a hemizygous ineffective gene. It is thus concluded that the recessive gene *Sr8* operative against race 122 in 'E5883' is located on chromosome 6A.

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Note Added in Proof

In the case of monosomics × 'E5883' tested against race 122 (Table 2), cytology of ten resistant plants from the F2 of monosomic 6A × 'E5883' was done. All the ten plants were found to be disomes (2n = 42) thereby confirming that chromosome 6A of variety 'E5883' possesses the hemizygous ineffective resistance gene.