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A RELATIONSHIP BETWEEN COMPETITION AND VIRULENCE IN RACES OF STEM RUST OF WHEAT.

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Abstract

The phenomenon of competition among races of *Puccinia graminis tritici* Eriks & E. Henn. was studied. Pairs of races differing on one or more of the four differential varieties; Kanred, Yalta, Eureka and C. I. 12632 were mixed and mixtures were cultured on Little Club for 11 generations. The avirulent race 21A predominated in all mixtures with races 126-C, 222-C or 222D and eliminated the associated race in six to seven generations. Races with more genes for virulence were poor competitors and avirulent races were better competitors. The phenomenon of competition seemed in some way associated with the genes for virulence in the pathogen.

Introduction

The survival of the fittest forms the basis of natural selection of the fit and stamping out of the unfit in the evolutionary system of life. The competitive ability of a genotype in a population decides to a great extent its survival. There is enough scientific evidence to support that the competitive ability of a genotype has a genetic basis. Gustaffson (1953) studied this phenomenon in both monohybrid and dihybrid erectoid mutants in Barley. He tried to explore what is called "Montgommary effect" (after Montgommary-1912) which implies that a genotype, although inferior in maximal productive capacity, nevertheless, might be superior in competition. He found that this has a genetic basis, because he observed that mixtures of genotypes AABB, AaBB and aaBB produced 4% more than each of these genotypes alone. Black (1952) tested survival values of six races of *Phytophthora infestans* (Mont.) de Bary in competition. He suggested that the survival value of a race is correlated with its host range. The wider the host range of a race, the less prolific it is on varieties with recessive genes for virulence and lower is its survival value in competition. Flor (1956) also indicated that the ability to survive in nature was associated with absence of recessive genes for virulence in *Melampsora lini.* (Pers) Lev. This was supported by a study by Watson and Singh (1952) who indicated that races of *Puccinia graminis tritici* Eriks. and E. Henn. with a wider host range were unable to maintain themselves in competition with those races having a narrower host range.

In order to verify and establish some relationship of survival in competition with virulence, six races of *Puccinia graminis tritici*, stem rust of wheat were studied in mixtures of different proportions.

Material and Methods

The material for this study consisted of six races of *Puccinia graminis tritici* Eriks. and E. Henn. namely 21A, 21B, 126A, 126C, 222C and 222D. Single spore cultures were prepared, built up on Little Club and their purity checked on the standard differential set used to differentiate races of stem rust of wheat. Uredospore

mixtures of fixed proportions of different races were prepared and grown on Little Club for 11 generations in the green house where the temperature was kept between 60° to 75°F. The following mixtures were studied :-

Mixture No.	*Races*	*Proportion*
I	21A and 222D	50:50
II	21A and 222D	25:75
III	21A and 222C	50:50
IV	126A and 222D	50:50
V	21A and 126C	50:50
VI	21A and 21B	50:50
VII	21A and 21B	25:75

The percentage of each race in a mixture was estimated in each uredial generation according to the methods developed by Stakman, Popham and Cassell (1940) and later used by Watson (1942) and Loegerring (1951). For example, on Yalta, race 21A gives;1 (flecks and 1) reaction (resistant) and race 222D gives 3+ reaction (susceptible). The total number of resistant (;1) reaction type and susceptible (3+) type pustules counted on 40 leaves of Yalta was used to estimate the percentage of each race in a mixture. The selection of components of each mixture was based on the number of varieties namely Kanred, Yalta, Eureka and C. I. 12632 that were susceptible to rustraces. The reaction types of rust produced on these varieties is given in table-1.

Table 1: Reaction Types of six races of Puccinia graminis tritici on Little Club and critical differential varieties.

Race	*Little Club*	*Kanred*	*Yalta*	*Eureka*	*C.I.*12632
21A	4*	0	;1	;	x—
21B	4	0	3+	;	x—
126A	4	3	;	;	x—
126C	4	3	3+	;	x—
222C	3c	3	3+	3+	x—
222D	4	3	3+	3+	3+

* ; 1, x =Resistant. 3, 3c, 3+, 4=Susceptible.

Experimental Results

Mixture I:- This mixture comprises 50% each of races 21A and 222D which differ on 4 varieties. All the four varieties are resistant to 21A and susceptible to 222D. The results given in table 2 show that race 21A increased rapidly to 79.06% and race 222D fell to 20.94% in second generation. Race 21A continued to increase until race 222D was completely eliminated after five uredial generations.

Table 2. Competition of Races 21A and 222D mixed in equal proportions.

Race	Percentage in the Original Mixture	Percentage of each Race in generations:										
		1	2	3	4	5	6	7	8	9	10	11
21A	50.0	50.75	79.06	90.86	96.90	97.00	100	100	100	100	100	100
222D	50.0	49.25	20.94	9.14	3.10	3.00	—	—	—	—	—	—

Mixture II– :This mixture was made up of 25% 21A and 75% 222D. The results given in table 3 reveal that inspite of having three times more inoculum in the original mixture, the race 222D could not compete with race 21A and was eliminated in the sixth generation. It appears that even higher proportion of inoculum of race 222D did not help its survival in competition with race 21A.

Table 3. Competition of Races 21A and 222D with 25% and 75% uredospores respectively.

Race	Percentage in the original Mixture	Percentage of each race in generations:										
		1	2	3	4	5	6	7	8	9	10	11
21A	25.00	24.55	61.45	96.10	98.46	99.33	100	100	100	100	100	100
222D	75.00	75.45	38.55	3.90	1.54	0.67	—	—	—	—	—	—

Mixture III—:Uredospores of Races 21A and 222C were mixed in equal proportions and studied for 11 generations. The results given in table 4 show that race 21A predominated and after six generations only traces of race 222C were left. The type of competition was exactly the same as between races 21A and 222D. Despite its narrow host range race 222C was no more effective than 222D in competing with race 21A and was quickly eliminated from the mixture.

Table 4. Competition of Races 21A and 222C mixed in equal proportions.

Race	Original Mixture	Percentage of each race in generation:										
		1	2	3	4	5	6	7	8	9	10	11
21A	50.00	50.40	74.12	81.45	90.70	95.20	98.69	100	100	100	100	100
222C	50.00	49.60	25.88	18.55	9.30	4.80	1.31	—	—	—	—	

Mixture IV– :This mixture consists of 50% each of races 126A and 222D. The results of this mixture are given in table 5. The proportion of race 126 A increased to 72.15% in the second generation and then gradually rose to 100% in the 7th generation. The race 126A appeared to be as good a competitor with race 222D as was race 21A.

Table 5. Competition of Races 126A and 222D mixed in equal proportions.

Race	Original Mixture	Percentage of each race in generation:										
		1	2	3	4	5	6	7	8	9	10	11
126A	50.00	50.73	72.15	82.19	91.02	96.90	98.76	100	100	100	100	100
222D	50.00	49.27	27.85	17.81	8.98	3.10	1.24	—	—	—	—	—

Mixture V– :In this mixture competition among races 21A and 126C was studied. Uredospores of each race were mixed in equal proportion and the mixture studied for 11 generations. The results of this mixture given in table 6, revealed that race 21A increased gradually and after seven generations, race 126C was eliminated.

Table 6. Competition of races 21A and 126C mixed in equal proportions.

Race	Original Mixture	Percentage of each race in generations:										
		1	2	3	4	5	6	7	8	9	10	11
21A	50.00	48.91	61.53	67.00	81.63	83.05	93.31	98.34	100	100	100	100
126C	50.00	51.09	38.47	33.00	18.37	16.95	6.69	1.66	—	—	—	—

Mixture VI—:The races 21A and 21B were mixed in equal proportions. These races differ on only one of the varieties namely Kanred, Yalta, Eureka and C. I. 12632. The results of this mixture given in table 7 show that the increase in the percentage of race 21A was slow and it took six generations to rise from 50% to 76.74% in 11th generation. The observed proportions from 6th generation to 11th generation remained nearly constant: and the weaker race 21B was not eliminated even after 11 generations of culturing.

Table 7. Competition of races 21A and 21B in equal proportions.

Race	Original Mxiture	Percentage of each race in generations:										
		1	2	3	4	5	6	7	8	9	10	11
21A	50.00	50.63	58.42	65.86	68.51	68.30	72.82	75.55	74.24	73.63	74.10	76.74
21B	50.00	49.37	41.58	34.14	31.49	31.70	27.18	24.45	25.76	26.37	25.90	23.26

Mixture VII—:In order to study the behaviour of the weaker race with higher proportion in the original mixture, races 21A and 21B were mixed in 25% and 75% proportions respectively. The results are given in table 8. Inspite of giving an additional advantage to the weaker race 21B in the original mixture, the later decreased in percentage though gradually from 75.12% in the first generation to 25.08% in the 9th generation; and on the other hand, the percentage of race 21A increased from 24.88% to 74.92%. From 9th to 11th generations, the composition of the mixture did not differ significantly from the ratio of 75% 21A and 25% 21B.

Table 8. Competition of races 21A and 21B mixed in proportion of 25% and 75% respectively.

Race	Original Mixture	Percentage of each race in generation:										
		1	2	3	4	5	6	7	8	9	10	11
21A	25.00	24.88	32.74	37.08	39.39	44.77	53.84	60.19	66.11	74.92	74.76	75.58
21B	75.00	75.12	67.26	62.92	60.61	55.23	46.16	39.81	33.89	25.08	25.24	24.42

Discussion

The results of these studies present an interesting genetic evidence on the phenomenon of competition. A race with wider host range and more number of genes for virulence is a poor competitor with a race with less number of genes for virulence. The study of table 1 reveals that race 21A has no gene for virtulence.

Each of the races 21B and 126A is virulent on yalta or Kanred. Race 126C is virulent on two varieties namely Kanred and Yalta; race 222C is virulent on three varieties namely Kanred, Yalta, and Eureka; and race 222D is virulent on all the four differential varieties.

Races which differed on *four* varieties for virulence when in competition, the avirulent race dominated. In mixture I, avirulent race 21A eliminated rapidly in *five* generations only its associate 222D which has maximum number of genes for virulence (tables 2 and 3). Races which differed on *three* varieties are races 21A and 222C (Mixture III). The avirulent race 21A took *six* generations to eliminate the virulent race 222C (table 4). Races 126A and 222D which also differed on *three* varieties, when in competition (Mixture IV) behaved similar to Mixture III. Races 21A and 126C which differed on *two* varieties, when in competition, the avirulent race 21A eliminated its associate race 126C in *seven* generations (table 6). Races 21A and 21B which differed on *one* variety only, were found to be hard competitors. The avirulent race 21A *could not* eliminate its competitor race 21B. However the proportion of avirulent race increased from 50% to 76.74% in mixture VI (table 7) and from 25% to 75.58% in mixture VII (table 8) in 11 generations of culturing .This analysis of these data reveals that the higher the number of genes for virulence or wider the host range of race, poorer it is in competition. The races which have narrow host range and less number of genes for virulence are better competitors. Other observation is that more the difference in number of genes for virulence, lesser is the time taken by the avirulent race to eliminate its associate and vice-versa. Where this difference was *four*, elimination of the weaker race was completed in five uredial generations; where it was *three*, it took six generations; where it was *two*, it took seven generations; and where it was *one*, the virulent race gradually decreased in proportion but was not eliminated even after 11 generations. From these observations, the indication is that there may be relationship between virulence and survival of a race in competition. The genes for virulence are generally recessive; and it has been postulated by Watson and Singh (1952) and Watson (1958) that acumulation of recessive genes for virulence in a race makes it a poor competitor.

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