RACE FORMULAE TO DESIGNATE RACES OF PUCCINIA HELIANTHI ON SUNFLOWER.

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Abstract

A basic concept of the gene-for-gene theory is that the maximum number of races of a pathogen which can be distinguished is 2^n where n is the number of genes for resistance. Four races (race groups) of sunflower rust identified when resistance genes R_1 and R_2 were first described in Canada have been encountered in various parts of the world. Different entities within the groups have been demonstrated from time to time but the differentials necessary to distinguish them proved difficult or impossible to maintain. Three Argentine rust isolates, identified as race 4 on standard differentials, behaved as distinct entities on lines resistant to the four races, developed at Junin, and were confirmed as new races in tests at Macdonald College. The resistance genes in the three new differential lines have not yet been identified but have been maintained through several generations of selfing. If the genes are shown to be independent of R_1 and R_2, theoretically 32 races of sunflower rust could be distinguished. To make such additional information useful to breeders and pathologists breeding for resistance and studying epidemiology and population dynamics we propose that in addition to any local or annual numbers assigned to sunflower rust races, they be designated by avirulence/virulence formulae based on known effective/ineffective host genes for resistance as is now done for cereal rusts in Canada. Critical tests of proposed new differentials and suspected new races could be made initially at the high-level quarantine facility at Macdonald College.

Introduction

The proposal for designation of races of rust (Puccinia helianthi Schw.) on sunflower (Helianthus annuus L.) presented in this paper is directed to pathologists and plant breeders alike. Although not a paper on genetics of the host or the pathogen, it is based on the gene-for-gene concept of host:parasite relationships developed by Flor, working with the flax:rust system. He was the first to study the genetics of both the host and the parasite; he brought together the results of many years of work in classic summary papers in 1955 and 1956. The concepts based on Flor's work were expanded to apply as a general rule in host:parasite systems and were put into elegant geometric form by Person (1959).

A basic property of gene-for-gene systems is that the total number of races which can be distinguished by the reactions of the appropriate series of differential hosts, ~~and the total number of differentials in such a series~~, is 2^n, where n is the number of single genes for resistance.

Historical

The first rust-resistant sunflower plant was observed in a breeding nursery at Altona, Manitoba, in 1949, and a second in 1950 (Putt and Sackston 1957).

The genes responsible for resistance in these two sources were later shown to be distinct and were designated R_1 and R_2 (Putt and Sackston 1963).

The results of tests made in the greenhouse at Winnipeg during the winter of 1954-1955 on seedlings of sunflower lines previously found to be resistant to rust showed that all four races which can be distinguished by two genes for resistance were already present in farm fields or in breeding nurseries in Manitoba. The races were designated:

1 able to attack only the "universal suscept," with no known genes for resistance;
2 able to attack resistance gene R_2, but not R_1;
3 able to attack gene R_1, but not R_2;
4 able to attack both R_1 and R_2 singly or together (Sackston 1962).

Tests with rust collections from various parts of the world showed that most of them could be classified as race 1 on the Canadian differentials, with collections of race 2 from Uruguay, and races 2 and 3 from Mexico (Sackston 1962).

The existence of genes for rust resistance different from R_1 and R_2 but not conferring resistance to race 1 was shown for sunflower lines from Argentina (Sackston 1962) and other areas (Sackston and Miah 1963). As the identity of these genes was not determined genetically and differential lines carrying them were not maintained successfully, they could not continue to be used to identify additional races of rust.

Sunflower lines carrying the R_1 gene have been used to confer rust resistance on varieties and hybrids in many parts of the world. A line derived from the original source of the R_2 gene, developed in the U.S.A. as a female parent for the production of hybrids (Zimmer and Kinman 1972) after the discovery of cytoplasmic male sterility by Leclercq (1969), has been used extensively around the world because it conferred resistance to two races of downy mildew (Plasmopara halstedii (Farlow) Berlese and de Toni).

It could be expected that the widespread distribution of these genes for resistance would sooner or later lead to the occurrence and increase of races capable of attacking them. The probability was particularly high as the rust has its whole life cycle on sunflowers, and in many areas goes through the sexual stage to initiate new infections in the spring. In most areas the expected rust outbreaks did not develop. Rust has become more conspicuous in recent years in Australia (J. Kochman, personal communication). Collections from Australia have been identified and confirmed as races 1 and 3 (Kochman, unpublished, Sackston, unpublished). Rust incidence and severity have also increased in Argentina and all four races have been identified there (Bertero de Romano, unpublished).

Experimental

The breeding program at Junin has utilized various sources of resistance to rust. Three lines resistant to all four races of rust have been developed there. They are designated B66-B100, MP557, and 71-538 respectively (Vazquez and Bertero-Romano, unpublished.

After the lines had been grown for varying numbers of generations in a

breeding nursery, isolated large pustules indicating susceptibility to rust were found on each of them. When single pustule collections were made and increased, it was found that all of them behaved as race 4 on the standard differentials. When inoculated onto the three resistant lines, however, each collection was found to infect only the line from which it was isolated (Bertero-Romano, unpublished).

All three collections were compared with the four standard races in multiple-race inoculations on individual seedlings of the standard differentials and on the three new lines at Macdonald College, using our standard methods (Miah and Sackston 1967). Their status as new races distinct from the four standard races and from each other was confirmed (Sackston, unpublished). If the lines from which they were collected can be maintained in spite of the difficulties inherent in working with an open-pollinated, frequently self-incompatible crop such as sunflower, they will be valuable as new differentials. It is hoped to use them and others which may be developed to compare possible new races under standard conditions in the high-level quarantine facility at Macdonald College.

Genetic studies are being started to determine if each of the three lines has a single new gene or a combination of genes conditioning resistance to rust. Until the results of such studies are known, the new races of rust may be designated A5, A6, and A7, the "A" indicating their Argentine origin, and 5, 6 and 7 referring to the rust isolated from lines B66-B100, MP557, and 71-538 respectively.

Discussion

For many years sunflower breeders in many parts of the world have used the same one or two genes for resistance to rust. The pathogenic characteristics of the four races which these genes could distinguish were not difficult to remember, although local collections sometimes behaved unexpectedly. The addition of three new genes for resistance to the system will change the situation completely. Five genes for resistance can distinguish a theoretical maximum of 2^5 or 32 races of rust, and more new genes are quite likely to be found in the future. The system of assigning numbers in serial order as new races are encountered is not very helpful to breeders selecting appropriate parental material to breed for resistance, nor to pathologists looking for relationships between these and other new races which are bound to appear where resistant sunflowers are grown under conditions suitable for rust development.

To be useful to all those who need to know the significance and the relationships of the rust races in their area and elsewhere in the world, designations of races should indicate their pathogenic potential. A scheme for international nomenclature of genes and races in the potato:late blight system was described by Black et al (1953). A different system has been in use for designating the races of wheat stem rust in Canada since 1965 (Green 1981). It is called the "formula method," and it is the one we propose be adopted for races of sunflower rust.

By the formula method, each new race could be given a local year and serial number identification for record purposes, e.g. A 1985-8, or C 1986-5, if an eighth new race should be identified in Argentina in 1985, and a fifth new

race in Canada in 1986. The important part of the description, however, would be the virulence formula, listing the effective genes, those the race cannot attack, as numerator, and the ineffective genes, those it can attack, as the denominator.

The virulence formulae for the three new Argentine races can only be hypothetical until the resistance genes in the new differential varieties are identified. If each variety is shown to have only one new gene, and if they are tentatively designated R_a, R_b, and R_c respectively, the formulae for the seven races in Argentina would be (omitting the year in which they were identified):

Race and formula number	Effective genes	/	Ineffective genes
A1	1,2,a,b,c	/	
A2	1,a,b,c	/	2
A3	2,a,b,c	/	1
A4	a,b,c	/	1,2
A5	b,c	/	1,2,a
A6	a,c	/	1,2,b
A7	a,b	/	1,2,c

The formulae for Canadian races would be simple:

C1	1,2	/	
C2	1	/	2
C3	2	/	1
C4		/	1,2

North American races have not yet been tested on the new Argentine lines.

The main reason for proposing the adoption of the formula method at this time is not that the current system is already unworkable. It would not be too difficult to learn and remember the characteristics of seven races of rust. As more new races are found in various parts of the world, however, local investigators are likely to develop their own systems for simplifying race designations. As these become entrenched with use, it will become progressively more difficult to obtain agreement on a single internationally acceptable scheme. By putting this proposal forward at this time for discussion and any necessary modification, we hope that it can be adopted and put into use before the situation gets out of hand.

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