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DIVERSITY OF RUST RESISTANCE OF THE CIMMYT MULTILINE COMPOSITE, ITS YIELD POTENTIAL, AND UTILIZATION

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IN 1952, Jensen proposed that multiline cultivars might be produced through blending of seed of several compatible pure lines of oats. Borlaug and Gibler (1953) and Borlaug (1959) reported on the use of a modified backcross in developing a wheat multiline in 'Yaqui 50'. However, due to the emergence and success of the new semi-dwarf wheats, research on the tall 'Yaqui 50' multiline was suspended, since tall varieties were now commercially unacceptable in Mexico where it was produced.

The first multiline cultivar in wheat which reached commercial production was 'Miramar 63'. This was released from the Colombian Program (Anon., 1963). 'Miramar 63' was a mechanical mixture of ten 'Frocor' backcross lines which carried resistance genes to stripe and stem rust.

In 1957, researchers at Iowa State University initiated a program aimed at developing a multiline in oats. Since then 11 multiline cultivars in two maturity classes have been released for commercial production in the Corn Belt (Frey *et al.*, 1977). Recently a winter wheat multiline cultivar, 'Tumult', has been released in the Netherlands (Groenewegen, 1977).

In the CIMMYT collaborative program with national scientists, many semidwarf wheat cultivars have been developed since 1962. These now cover more than 20 million hectares in lesser developed countries (Dalrymple, 1976). Among these, several were derived from cross 8156 and given different names in different countries. This group of varieties proved to have wide adaptation and achieved wide acceptance. Such broad adaptability is an essential feature of a variety in which a multiline should be produced since the additional expenditure is easily justified if the resultant multiline varieties are widely grown.

In view of this and because the aforementioned group of varieties had succumbed to leaf and stripe rust in most countries, CIMMYT scientists decided to develop a large series of multiline components with this phenotype. The multiline program has had the collaboration of scientists in several countries including a large program in India. It was felt that from these components, developed in collaboration with country programs, a large number of multiline varieties could be assembled differing in composition according to the needs of individual countries.

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Before going into the results of the multiline research, it must be pointed out that this is only one of several approaches CIMMYT has taken in a effort to stabilize yields through maintenance of adequate levels of resistance in high disease hazard areas. Thus, in addition to the multiline, CIMMYT scientists are using the approach advocated by Watson and Singh (1952), wherein they proposed that multiple specific genes should be combined in one cultivar to provide sustained resistance. Rajaram and Luig (1972) demonstrated that a wheat cultivar showing a low coefficient of infection, on the basis of multilocation testing, often carries a number of genes. In the CIMMYT program a wide array of resistance genes is cycled through crosses to increase the multiple-gene effect.

Hooker (1977) and many others have pointed out the value of international testing in the identification of desirable parents with high levels of disease resistance. CIMMYT has been using this approach for many years. Some of the nurseries which have been utilized for this purpose include the USDA International Spring Wheat Rust Nursery (ISWRN), CIMMYT International Spring Wheat Yield Nursery (ISWYN), CIMMYT International Bread Wheat Screening Nursery (IBWSN), CIMMYT Regional Disease and Insect Screening Nursery (RDISN) (Eastern Hemisphere), Latin American Disease and Insect Screening and Observation Nursery (VEOLA), Latin American Rust Nursery (ELAR), Regional Disease Trap Nursery (RDTN) and others. Such nurseries signal changes in pathogen virulence and identify lines with resistance over a wide virulence range. Broad based resistance may result from multiple specific genes and/or non-specific/resistance which may be expected to provide in-depth resistance.

As indicated, CIMMYT scientists cycle these genes through the crossing program on a continuous basis and in this way pyramid resistance genes.

Finally, studies are being made on the "slow rusting" phenomenon as enunciated by Caldwell (1968). This form of resistance has seldom been utilized in a directed fashion. Skovmand *et al.* (1978) are of the opinion that this type of resistance is polygenically controlled. Whether it should be classed as race specific or general resistance has not been adequately determined. It is apparent, however, that it differs from hypersensitive, seedling gene resistance and should be utilized.

Materials and Methods

Derivatives of the cross 8156 made in Mexico demonstrated wide adaptation, and on release gave high yields in many countries. However, although they have retained their resistance to loose smut, bunts and powdery mildew they have become susceptible to one or more of the three rusts in the major areas of production. The white-grained derivatives are commonly known by such names as 'Siete Cerros', 'Kalyansona', and 'Mexipak'. The red-grained sister derivatives have such names as 'Super x', 'PV18' and 'Indus 66'.

In contrast to the Iowa backcross method, CIMMYT utilizes a top and double cross system plus a limited backcross technique. Details of the method have been published (Rajaram and Dubin, 1977). Based on this method a large number of lines of the 8156 phenotype have been selected.

Beginning six years ago, an international multiline components nursery was sent each year to more than 30 cooperators world wide. The nurseries have differed in number from 92 to 300 candidate components. The aims were to test these lines for resistance over a wide variation in virulence; to create interest in the multiline concept, and to provide materials from which cooperators might select components with appropriate agronomic type, rust resistance and yield potential. Selected lines would then be suitable for inclusion in one or more composites for production in the individual country or region.

In this paper, detailed analyses of adult plant reaction at a number of locations for stem, leaf and stripe rust are presented. The data were drawn from the results of the ninth and tenth International Bread Wheat Screening Nursery rather than from the multiline nursery from which the data have not yet been received.

Stem rust notes were taken at 16 locations where adequate epidemics occurred. Similarly, leaf rust notes were taken at 30 locations and stripe rust at 11. Varieties were placed in resistance groups on the basis of their having the same or a similar combination of reactions at the different sites. A conservative approach was employed in data analysis, such that lines grouped as having the same rust resistance genes, may in fact, have some differences in the number of genes for resistance.

Selected components were analysed for seedling reaction to leaf and stem rust races with known virulence genes. In this way, through the use of critical cultures, the likely presence of specific genes was determined.

Results

In the case of stem rust, data were available for 15 components as shown in Table 1. For leaf rust there were 21 components (Table 2) and for stripe rust 21 (Table 3). It is evident from these tables that even these few lines show substantial diversity for resistance to the three rusts.

For stem rust the adult plant reactions at 16 sites show that there are at least ten groups of resistance genes among the 15 components. Seedling reactions to North American stem rust cultures indicated the presence of at least Sr5, 6, 9a, 10, 11, 12 and 17 as well as others not identified.

In a similar fashion analysis of adult plant reaction to leaf rust separated the lines into 16 distinct groups for resistance. It should be noted that in some cases, such as the "Brochis" sib lines, sisters were differentiated into groups because of their gene complement. Turning to the seedling reactions to leaf rust and using genetically diverse culture of rust from Canada, Mexico and Australia, it is evident from Table 2 that, collectively, the lines tested represent a broad range of race specific genes. Critical analysis of the Canadian race reactions, permitted the authors to postulate the presence of Lr1, 2a, 3, 10, 14a, 18 and 23 among the 14 components tested. In addition, at least three, as yet unknown genes were present.

Finally, in Table 3, the adult plant reaction to stripe rust shows a broad diversity of resistance in that the 21 components could be separated into 11 resistance groups. No seedling data were available for stripe rust.

It is important to remember that some of the multiline components carry adult plant genes for resistance to stem and leaf rust in addition to those discussed for seedling resistance.

A multiline yield trial was distributed in 1976 and yield data for three locations—Bahteem, Egypt and two plantings in the Yaqui Valley of Mexico—are shown in Table 4 for whitegrained composites. Data for a similar group of redgrained composites were obtained from four locations—Guelma, Algeria; Njoro, Kenya; and two trials in Yaqui Valley. These are presented in Table 5. While the number of trials is limited and in some cases there is large variability, the yields of the composites are essentially equal to those of 'Siete Cerros' and 'Super X.'

Discussion

A multiline introduces heterogeneity into a self-pollinated crop in contrast to the homogeneity of a pure line variety. In the CIMMYT concept most lines used as components should be resistant to most biotypes in the region. This resistance is maintained, as components are replaced when they are rendered susceptible by changes in virulence within the rust population. Such a multiline would, therefore, act in the same manner as a variety with effective specific resistance and the inoculum entering the field would not survive. However, when shifts from avirulence to virulence occur in the rust population, only a fraction of the plants in the multiline will show susceptibility. Because of limited inoculum and longer build-up time, even these susceptible plants will be less heavily attacked as has been demonstrated in oats with the Iowa multilines.

Population heterogeneity is the essence of the multiline concept. As indicated earlier, in an international sense, only widely adapted high yielding varieties should be used as the recurrent parent if costs are to be justified. In the method used by CIMMYT very diverse donor parents are top–and double-crossed often using recurrent parent-derived genotypes as two of those in the cross. When this is combined with wide geographic testing, it can be expected that components will be produced, differing widely in their genes for resistance.

By this approach it has also been possible to recover the high yield potential and most of the wide adaptability of the recurrent parent as indicated by the yield data of Tables 4 and 5 and the Rajaram and Dubin data of 1977. A further advantage, based on the non-backcross feature of the system, is that the components are likely to differ as well in resistance to other pathogens, thus providing a secondary benefit. This has been observed but has not been throughly investigated.

Finally, the components of the multiline can be treated as pure line varieties in a widely adapted background for those programs where staff shortage precludes the increased breeding work associated with using the multiline. In other cases, e.g., Kenya, where stem rust is extremely severe, several sister lines of 'Brochis' have shown outstanding resistance and are being considered for release as pure line cultivars.

In discussions on the use of multilines, the question is often asked "How many components should be used"? The answer is not simple, but depends on a variety of factors.

In the Iowa multiline in oats, the frequency of virulence genes in the rust population was used as a criterion for number of lines. This is a very reasonable answer but in practice, in many areas, such information is not available. Hence, certain compromises must be made. The general rule, however, should be more,

TABLE 1

Ten genetically different component groups of 8156 Multiline determined by their adult plant reaction at 16 sites[1] in the world; their average C.I. and additionally seedling infection types to stem rust races from USA and Australia

Group	Components	Average CI	REACTION TO PUCCINIA GRAMINIS TRITICI RACES											
			Minnesota[2]											Australia[3]
			TNMK	RPQQ	RTQQ	RTQQ	RKQS	QSHS	HJCS	MMCS	DKCS	RHRS	RTQS	34-1, 2, 3, 4, 5, 6, 7, 8, 9, 11
I	Bolsena"S" CM-8625-G-1M-4Y-1M-1Y-4M-0Y	2·1	2	0;	—	–;	0;1-c	2	0	Tr0;	0	0;	Tr0;	X=
	Brochis"S" CM-5872-C-1Y-1M-3Y-0M	2·2	S	0;	0;	0;	0;1c	2	0;	0;	Tr0;	0;1-c	0;	;2=3=
	Como"S" CM-4756-12Y-1M-1Y-0M	2·2	—	—	—	—	—	—	—	—	—	—	—	—
	Flicker"S" CM-8954-B-7M-1Y-1M-1Y-0M	2·7	2	2	2	2	0;	2	0;	Tr0;	0;	0;	0;+c	;2=3=
II	Bolsena"S" CM-8625-F-1M-4Y-1M-0Y	3·9	2	0;	0;1-cn	0;	0;1-c	2	0	0;	0	0;	Tr0;	X=
III	Flicker"S" CM-8954-B-7M-1Y-1M-0Y	6·2	E	2	2	2=	0;	12	0;	Tr–;	0;	Tr0;	0;+c	2=3=
IV	(Cno-7C×CC-Tob/Cno-No) Kal CM-11377-A-1Y-8M-3Y-0M	7·5	2	0;1-cn	0;	0;	0;	2	Tr0;	Tr0;	0;	0;	0;	33+
V	Bb-Kal CM-9160-11M-5Y-5M-2Y-0M	11·5	2	0;1cn	0;1cn	0;1cn	0;1-c	2	0;	2	0;	0;	0;1-c	;2=3=

TABLE 1—(*Contd.*)

Group	Components	Average CI	REACTION TO PUCCINIA GRAMINIS TRITICI RACES											
			Minnesota[2]											Australia[3]
			TNMK	RPQQ	RTQQ	RTQQ	RKQS	QSHS	HJCS	MMCS	DKCS	RHRS	RTQS	34-1, 2, 3, 4, 5, 6, 7, 8, 9, 11
VI	Como"S" CM-4756-12Y-1M-3Y-0M	11·9	—	—	—	—	—	—	—	—	—	—	—	—
	Nipigon"S" CM-8972-F-9M-1M-1Y-0M-(1-53B)	14·9	—	—	—	—	—	—	—	—	—	—	—	—
VII	Osprey"S" CM-8701-A-1M-2Y-1M-3Y-0M	19·9	2	0;1cn	0;1=cn	0;1−cn	2	2	0	0;	0	2	Tr0;	23=
VIII	Hork"S" CM-8874-K-1M-1Y-0M-(1-356Y)-(1-200B)	21·8	23	0;1cn	0;	0;	0;1c	S	0;	S	0;	0;1=c	0;1−c	3+
IX	Y50-Kal^{3}-5M-II-35188-31Y-0M-8M-0Y	21·9	Tr0;	0;1+cn	0;1cn	0;1−cn	0;1c	S	0;1	2;	0;	0;1=c	Tr0;	3+
X	Hork"S" CM-8874-K-1M-1Y-1M-2Y-0M	30·1	2	0;	0;1−cn	0;	0;1c	S	0;	S	0;	2c	1c	X=33+
	Hork"S" CM-8874-K-1M-1Y-1M-1Y-0M	32·9	—	—	—	—	—	—	—	—	—	—	—	—
	7 Cerros	23·1	2	0;1cn	0;1−cn	0;1−cn	0;	S	0;	2	0;+c	0;+c	1c	3+

1. Bethlehem; South Africa; Salisbury, Rhodesia; Njoro, Kenya; Sahka, Egypt; Yemen; Izmir and Dyarbakir, Turkey; Maharashtra, Indore and Jaipur, India; Islamabad, Pakistan; Afghanistan; Parana, Brazil; Paraguay; Marco Juarez, Argentina and St. Paul, Minnesota, U.S.A.
2. USDA Cereal Rust Laboratory, St. Paul, Minnesota.
3. Sydney University, N.S.W. Australia.

TABLE

Sixteen 8156 *Multiline leaf rust resistant groups as determined by their differential adult average coefficient of infection (C.I.) and seedling infection reaction to*

Group	Components	Average 1976	CI 1977	Seedling reactions to selected			C A
				5	9	11	15 64 158
I	Bb-Kal CM-9160-11M-5Y-5M-2Y-0M	2·3	9·8	2	;	;	;
	Bolsena"S" CM-8625-G-1M-4Y-1M-1Y-4M-0Y	4·2	22·4	;	;	(;)(2)	;
	Bolsena"S" CM-8625-F-1M-4Y-1M-0Y	7·2	15·6	—	—	—	—
II	Hork"S" CM-8874-K-1M-1Y-0M-(1-356Y)-(1-200B)	4·4	2·0	2+	4	2	3+
III	Hork"S" CM-8874-K-1M-1Y-1M-1Y-0M	5·6	8·0	—	—	—	—
	Hork"S" CM-8874-K-1M-1Y-1M-2Y-0M	5·9	3·0	2+	4	2	3+
IV	Nipigon"S" CM-8972-F-9M-1M-1Y-0M(1-53B)	5·8	—	—	—	—	—
V	Brochis"S" CM-5872-C-1Y-1M-3Y-0M	9·6	21·0	1+	;	;	;
VI	Flicker"S" CM-8954-B-7M-1Y-1M-0Y	10·7	17·3	2	;	(;)(2)	2+
VII	Flicker"S" CM-8954-B-7M-1Y-1M-1Y-0M	12·3	22·7	2	;	(;)(2)	2+
VIII	Como"S" CM-4756-12Y-1M-1Y-0M	11·6	14·6	—	—	—	—
	Como"S" CM-4756-12Y-1M-1Y-1M-0Y	—	15·3	4	;	(X)(4)	4
IX	Como"S" CM-4756-12Y-1M-3Y-0M	11·6	13·2	—	—	—	—
X	Orizaba "S" × Cno-No/Kal CM-11377-A-1Y-8M-3Y-0M	13·9	12·5	4	4	4	3+
XI	Osprey"S" CM-8701-A-1M-2Y-1M-3Y-0M	16·7	27·3	4	2+	4	4
	Osprey"S" CM-8701-A-1M-2Y-3M-0M	—	22·5	4	3	4	4
XII	Y50-Kal^3 II-35188-5M(F_1)-31Y-0M-8M-0Y	34·5	—	3+	4	4	3+
XIII	IWP 85=S221-SS^2 72 L178	—	4·6	—	—	—	—
XIV	Brochis"S" CM-5872-C-1Y-1M-1Y-3M-0Y	—	11·7	—	—	—	—
XV	Brochis"S" CM-5872-C-1Y-5M-2Y-2M-0Y	—	12·8	1+	;	;	;
XVI	Brochis"S" CM-5872-C-1Y-1M-1Y-1M-0Y	—	16·3	1+	;	;	;

1. Bethlehem, South Africa; Sakha and Bahteem, Egypt; Yemen, Israel, Afghanistan; Islamabad, Lyallpur and Tandojam, Pakistan; Ludhiana, Delhi, Pantnagar, Jaipur, Pusa, Indor and Niphad, India; Hokkaido, Japan; Cd. Obregon, Los Mochis, Jalisco, Celaya, Rio Bravo, El Batan, Toluca, Mexico; North Dakota, USA; Parana, Brazil; Montevideo Uruguay; Itapua, Paraguay and Pla and Marco Juarez, Argentina.
2. Sensako, Natal and Yugerhoerk, S.A.; Giza, Sakha and Germeiza, Egypt; Izmir, Turkey; Wadiyabis, Jordan; Hazera, Israel; Delhi, Ludhiana, Pusa and Pantnagar, India; Yodedpur, Bangladesh; Cd. Obregon, Los Mochis, Rio Bravo, Monterrey, El Batan and Toluca, Mexico; Nebraska, USA; D.F., Brazil; Buenos Aires, Argentina; and Lima, Peru.

2

plant reaction at 30 sites[1] in 1976 and 24 sites[2] in 1977 in the world, together with their selected leaf rust races from Canada[3], Mexico[4] and Australia[5]

races of P. recondita tritici from Canada, Mexico and Australia[6]

N A D A											MEXICO			AUSTRALIA
15 68 20	30	58	126a	126 K-1	161	76	67×2 S-42	Bulk 175 Trans (4)	Bulk 675 AG (4)	Bulk 471 EG (4)	6a	7c	10a	162-1, 2, 3, GTS (761·1)
;	2	;1+	2	;	;	;	2	;	;	;	;1	1+	;1	x^{n};3
;1-	2	;1	2	;1-	;	;1-	2+	;1-	;1-	;1-	x	21	12	;2-,2
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
;1-	3+	;1	4	3+	3	2	4	2	;1-	;1-	;	21	;	;^{n}
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
;1-	3+	;1	4	3+	3	2	4	2	;1-	;1-	;	21	;	;^{n}
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
;	2+	1+	1+	1+	;	;	2+	;	;	;	2+	2	2	x,$^{=}x^{-n}$
;1-	3	2	2	(;)(2+)	;	1+	2+	2	;1-	;1-	;1	3-2+	;12	2,$x^{=}$,3+
;1-	3	;1+	2	(;)(2+)	;	;1	2+	;1+	;1-	;1-	;1	3-2+	;12	2,$x^{=}$,x+
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
;	3+	;1+	4	;1	4	x	4	x	4	4	3+	3-	3±	x,3+
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
;	2+	3+	2+	2++3	3	4	2+	4	4	4	3+	3	3+	—
;1	3+	2+	4	4	4	4	4	4	;1	;1	;	3-2+	;1	2,$x^{=}$
;1-	3	1+	4	4	4	4	4	4	;1	;1	;1	3-2+	;1	2,$x^{=}$
;1-	3+	3	4	4	4	2	4	2	;1-	;1-	;1	3	x	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
;	2+	;1	2	;1-	;	;	2+	;	;	;	32+	2±	2+1	;,x
;	2+	1+	1+	;1	;	;	2+	;	;	;	;	2±	;1	$x^{=}x^{-n}$

3. Agriculture Canada, Rust Laboratory, Winnipeg, Manitoba.
4. CIMMYT.
5. Sydney University, Australia.
6. Race designations are those used by the respective cooperators. Avirulence/virulence formulae have been determined for each race.

TABLE 3

Eleven genetically different component groups of 8156 Multiline determined by their adult plant reaction to stripe rust at 11 sites[1] in 1976 and 10 sites[2] in 1977 in the world together with their average coefficient of infection

Group	Components	Average C.I.	
		1976	1977
I	Brochis "S" CM–5872–C–1Y–1M–1Y–3M–0Y	—	1·2
	Brochis "S" CM–5872–C–1Y–1M–1Y–1M–0Y	—	1·5
	Brochis "S" CM–5872–C–1Y–5M–2Y–2M–0Y	—	2·4
	Brochis "S" CM–5872–C–1Y–1M–3Y–0M	2·5	5·3
II	Bb-Kal CM–9160–11M–5Y–5M–2Y–0M	5·5	2·8
III	Como "S" CM–4756–12Y–1M–1Y–0M	—	10·6
	Como "S" CM–4756–12Y–1M–3Y–0M	0·7	15·0
IV	Orizaba "S" × Cno-No/Kal CM–11377–A–1Y–8M–3Y–0M	4·9	13·0
V	Bolsena "S" CM–8625–F–1M–4Y–1M–0Y	6·9	15·7
	Bolsena "S" CM–8625–G–1M–4Y–1M–1Y–4M–0Y	5·9	17·4
VI	IWP 85–5221–S6[2] 72L–178	—	18·0
VII	Hork "S" CM–8874–K–1M–1Y–0M	—	18·1
	Hork "S" CM–8874–K–1M–1Y–1M–1Y–0M	23·3	22·3
	Hork "S" CM–8874–K–1M–1Y–1M–2Y–0M	16·7	26·7
	Hork "S" CM–8874–K–1M–1Y–0M–(1–356Y)–(1–200B)	27·6	22·8
	Osprey "S" CM-8701–A–1M–2Y–3Y–0M	—	26·6
	Osprey "S" CM–8701–A–1M–2Y–1M–3Y–0M	11·4	27·9
VIII	Flicker "S" CM–8954–B–7M–1Y–1M–1Y–0M	13·3	26·0
IX	Flicker "S" CM–8954–B–7M–1Y–1M–0Y	18·1	30·6

TABLE 3—(*Contd.*)

Group	Components	Average C.I.	
		1976	1977
X	$Y50_E$–Kal^3 II–35188–5M (F1)–31Y–0M–8M–0Y	9·8	—
XI	Nipigon "S" CM–8972–F–9M–1M–1Y–0M–(1–53B)	25·5	—
	Siete Cerros (Check variety)	38·5	56·0

1. Beja, Tunisia; Njoro, Kenya; Diarbakir, Turkey; Ludhiana, India; Toluca and El Batan, Mexico; Tibaitata, Colombia; Huencayo, Peru; Chillan, Chile; Platina, Argen ina and Quito, Ecuador.
2. Njoro, Kenya; Izmir, Turkey; Hazera, Israel; Lelystad and Wageningen, The Netherlands; Hyslop, Oregon; Toluca and El Batan, Mexico; Quito, Ecuador; and Chillan, Chile.

TABLE 4

Yields of nine multiline, white-grain, composites of 8156 compared with Siete Cerros *66 at Bahteem, Egypt and Yaqui Valley, Mexico*

Composite	Yield in kg/ha		
	Bahteem	Yaqui Valley	
		Exp 1	Exp 2
1/B1 B1	3840	6104	5453
B2	3750	7034	6313
B3	4254	6964	6974
B4	4239	6865	6682
B5	4053	7245	6928
B6	3837	7339	6484
B7	4347	7219	7089
B8	3921	7303	6344
B9	4212	7365	6620
7C	4308	7505	6385
SE (47 df)	391	211	137

1/B (Blanco) indicates white grain color composite.

TABLE 5

Yield of the 8156 composite multiline red grain color type, and of Super X at Guelma, Algeria; Njoro, Kenya; and Yaqui Valley, Mexico.

Composite	Yield in kg/ha			
	Guelma	Njoro	Yaqui Valley	
			Exp 1	Exp 2
1				
R/1	3330	2141	6898	6585
R2	3222	2230	6964	7042
R3	3141	1877	6713	6516
R4	2748	605	6932	6156
R5	2544	2146	7099	6505
SX	3144	1116	6953	6495
SE (47 df)	427	271	342	200

1/ R(Rojo) indicates red grain color composite.

rather than fewer components. Again many programs of the LDC's cannot manage a large number of components because of weak seed organizations or limited research personnel. The answer must, therefore, be empirical. Five to six components which differ in resistance may be entirely adequate to buffer against a disease epidemic. Should this be too difficult, two are better than one, three are better than two and so forth.

Thus the ideal is to base the number on the pathogen stability. As practicality permits in areas where rust races are complex and unstable, the numbers of components may be maximized, whereas in areas of simpler and more stable rust populations the number of components may be minimized.

A second question often asked is when should the mechanical mxture be made? Again circumstances will govern the answer. Where facilitiesi are well developed, individual lines are raised separately and combined later in multiplication. Where this is not possible, the mixture of lines can be multiplied directly. The only problem of the latter course is that competition and genetic drift may lower the proportion of one or more components. However if the components are carefully selected for essential quality of yield, height, maturity and agronomic type, the competition factor should be minimal.

Probably the greatest problem of all will be to convince the purist seed producing agency that a variety which is not homogeneous is truly a variety to be accepted in the interest of crop protection.

Summary

The diversity of resistance to stem, leaf, and stripe rust among 8156 multiline components has been investigated. Adult plant reactions, taken by CIMMYT cooperators, from 16 locations for stem rust, 30 for leaf rust, and 11 for stripe rust were analyzed. The data showed that 15 component candidates studied for stem rust could be separated into 10 resistance groups; twenty one into 16 resistance groups for leaf rust; and twenty one into 11 groups for stripe rust. Seedling reactions to stem and leaf rust cultures with known virulence genes indicate that Sr5, 6, 9a, 10, 11, 12 and 17 plus other unidentified genes are present among the components analyzed for stem rust resistance. The presence of Lr1, 2a, 3, 10, 14a, 18, 23 and three unknown seedling genes was postulated among the components analyzed for leaf rust resistance. A possible seed multiplication system is presented.

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