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# Resistance to Leaf Rust in Pakistani Wheat Lines

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**Abstract:** About 57 Pakistani wheat lines including 49 NUWYT lines (National Uniform What Yield Trial) were analyzed for the identification of leaf rust resistant genes by using twelve Mexican *Puccinia recondita tritici* pathotypes. Postulation showed the presence of leaf rust resistant *genes Lr3, Lr10,Lr16,, Lr17, Lr21, Lr23, Lr26, Lr27+31, Lr13* and *Lr1*. One line Sarsabz was found resistant to all Mexican pathotypes used and had other unidentified genes in addition to Lr16. Most of the Veery derived lines had *Lr26*, which is associated with 1B1R translocation. *Lr13*, closely associated with *Lr23*, was also postulated in some lines. The lines were also evaluated for adult plant resistance and area under the disease progress curve (AUDPC) showed varying behavior. AUDPC ranged from 0%, for highly resistant to 100%, for the most susceptible one. Analysis indicated presence of good adult plant resistance in the lines.

**Key words:**

## Introduction

Leaf rust caused by *Puccinia recondita* Roberge ex Desmaz. f. sp. *tritici* Eriks. and E. Henn., is one of the most important rust diseases of wheat through the world. The most important and environmentally safe method to reduce losses due to this devastating disease is throughout cultivation of resistant varieties. The ability to diversify genetic basis of resistance depends on the availability of resistant genes in the onhand germplasm. Known genes imparting resistance against disease can be postulated in a cultivar if pathogen possess diverse avirulence/virulence combination. This method which is based on gene-for-gene hypothesis has been described and used by several researchers (Modawi *et al*. 1985). The postulation can further be confirmed if necessary, by genetic analysis.

The objective of the current study were to postulate genes for leaf rust resistance in 57 Pakistani cultivars/advanced lines including 49 NUWYT (National Uniform Wheat Yield Trial) lines. These lines are the candidate lines developed by the wheat breeders, tested for yielding ability, adaptation and other agronomic characters. The wheat varietal evaluation committee places a great weightage on the disease resistance of these lines and the rust data for these lines form basis of recommendation.

## Materials and Methods

About 57 Pakistani cultivars/advance lines were evaluated for the postulation of leaf rust resistant genes. Thacher near-isogenic lines, carrying specific genes, were used as a check (Table 1). Thirteen Mexican pathotypes of *P. recondita tritici*, named after Long and Kolmer (1989), were used to identify infection types produced on the check and cultivars/advance lines to be analyzed (Table 2 and 3).

The material to be analyzed and checks were cultivated in 30x23x7 cm plastic trays having pasteurized mixture of soil and compost. Thirteen sets, each consist of a subset of cultivars/advance lines and a subset of near-isogenic lines, as check, were sown in separate trays. Seedlings were grown in green house with temperature maintained at 18-22°C. After ten days when the second seedling leaf was just emerging each of the thirteen sets were inoculated separately with each of the thirteen Mexican pathotypes of *P. recondita. tritici.* Inoculum in the form of uredial suspension in soltor-170 (lightweight non-phytotoxic mineral oil), was sprayed uniformly with a fine atomizer. The seedlings were left in open air for 1-2 hours to evaporate mineral oil and were shifted afterwards to a humidity chamber set at 18°C for overnight, after which they were transferred to greenhouse at 25°C day and 23oC night temperature. After ten days infection types were recorded at 0-4 scale following method described by Stakman *et al.* (1962). For the postulation of *Lr13,* infection types for the sets inoculated with *Lr13* avirulent races were recorded on the 14th day of inoculation. The genes were postulated by comparing infection types produced on the lines to be tested with those on near-isogenic checks.

Field evaluations were carried out at El-Batan Mexico during 1998 crop cycle. Cultivars were planted in plots consist of 1.5 m rows seeded 20 cm apart with 70 cm between the plots. susceptible spreaders , consisting of cultivar >Morocco was planted as clumps on one end of the plots. A leaf rust epidemic was initiated by injecting urediospore-water-tween 20 suspension in leaf sheath of spreader plants at growth stage 34-37 (Zadoks *et al*., 1974). Mexican pathotype MCJ/SP (avirulence/virulence formula *2a, 2c, 9, 16, 24, 3ka, 30, 18, 19/ 1, 3, 26, 11,17, 3bg,13 15 10, 23)* was used to evaluate adult plants. Rust severity and response were recorded thrice on flag leaves with 7 day interval between 1st and 2nd reading and 9 day interval between 2nd and 3rd reading, beginning with the appearance of first symptom (1 month from inoculation), when most cultivars were in late flowering stage. Severity estimations were based on modified Cobb scale (Peterson *et al.,* 1948). The host response to infection was scored using: R = resistant, miniature uredia surrounded by necrotic tissues; M = intermediate, variable sized uredia, some with chlorosis, necrosis or both; MS = moderately susceptible, moderate sized uredia without necrotic tissues and S = susceptible, large sized uredia without necrotic tissues. AUDPC was calculated by using AUDPC computer program developed by CIMMYT (AUDPC version 1) and it was taken as %age of the susceptible check WL-711. Adult plants were also classified for gene *Ltn* conferring leaf tip necrosis, as Dyck (1991) indicated that *Lr34* linked with *Ltn* and Singh (1992) failed to recover recombinants for *Ltn* and *Lr34.*

## Results and Discussion

Host material analyzed is given along with their pedigrees in Table 1. Infection types displayed by 48 near-isogenic differential lines with 13 Mexican pathotypes at 25°C are given in Table 2 and those of 57 Pakistani lines/varieties are given in Table 3. Genes *Lr12, Lr22a* and *Lr22b* are known to confer low infection types only in adult plant stage, therefore these genes could not be postulated at seedling stage. Genes *Lr25, Lr9, Lr29* and *Lr34* could not be postulated because of their low reactions to all the

Table 1: List of Pakistani Cultivars/advance Lines Analyzed for Leaf Rust Resistance

| Accession | Pedigree |
|---|---|
| DW-1 | BOWS"S"/3/CAR853/COC//VEE"S" |
| NR-51 | MILAN |
| PR-65 | DOVE'S'/INIA/4/4777(2)//FN/GB/3/PVN'S' |
| NR-102 | FCTT3/SNI/NKT |
| 93CO65 | COO/VEE//SERI/3/BJY/COC |
| V-94195 | ALTAR84/AE/SQUAROSA(224)2*ESDA |
| BWP-949549 | BOWS'S'/5/BR'S'/ANZA/3/KVZ |
| 95R48 | BJY/COC/PRL/BOW |
| 95CO22 | PSN/BOW'S'//SERI |
| 95202 | KASYON/GLENNSON81 |
| V-4 | URES/BOW'S' |
| V-7002 | BUC'S'/4/TZPP//IRN46/CNO67/3/PRIC M56744 |
| V-7012 | WL58 X LU26S |
| V-93BTO22 | V-84133/V-83150 |
| V-93032 | RL6043/4*NAC/4/ZA75/3/LD35.7E/TC-3//GU"S" |
| V-93118 | HAR"S"//BLS/KLT |
| V-94042 | INQALAB 91//TTR 'S'/VEE 'S' |
| V-94091 | BURGUS/SORT-12-13//KAL/BB/3/PAK-81 |
| V-94105 | CROW 'S'/NAC//BOW 'S' |
| V-94654 | WULP 'S'//CHEN 'S'/ALTAR 84 |
| V-95219 | CBRD |
| 93B2707 | PB 85/NKT 'S' |
| 93B2779 | VEE 'S'/4/GOLDEN VALLEY/AZ 67// MUS /3/ BWP 24 |
| AUP9701 | JUP/BJY 'S'//URES |
| DW-2 | F12-71/COC/CNOCNO 79 |
| WS94012 | PLOUDAN/3/BB/7C*2//Y50E/KAL*3 |
| WS94130 | KEA/TOW///LIRA |
| S-190157 | BUC"S"/FLK"S"/MYNA"S"/BUL"S" |
| BLUE SILVER | 1153-388 /AN /3/YT54 /N10B// LR64/AN //YT54/N10B/3/LR864/4/B4946.A.4.18 .2.1Y -Y53//3/Y50 |
| WL-711 | S308/CHRIS//KAL |
| ZARDANA | C[CNO67/8156*TOB66-CN067/NOR66/II 12300 *LR64-8156]PVN76'S; |
| SARSABZ | M20/79 |
| PAK-81 | KVZ//BUHO//KALBB |
| KOHINOOR-83 | OREF1158/FDL/MFN/2*TIBA63/3/COC |
| FAISALABAD-83 | FURY/KAL/BB |
| FAISALABAD-85 | MAYA/MON//KVZ/TRM |
| CHAKWAL-86 | F1N/ACS//ANA |
| RAWAL-87 | MAYA/MON//KVZ/TRM |
| SOGHAT-90 | PAVON MUTANT-3 |
| INQALAB-91 | WL711/CROW 'S' |
| PIRSABAK-91 | KVZ//BUHO//KALBB |
| KAGHAN-93 | TTR/JUN |
| BAKHTAWAR-93 | JUP/BJY 'S'//URES |
| PARWAZ-94 | V.5648/PRL |
| WATAN-94 | LU26/HD2179 |
| SHAHEEN-94 | MLT"S" |
| SHAHKAR-95 | WL711//F3.71/TRM |
| KIRAN-95 | |
| PUNJAB-96 | SA42*2/4CC/INIA//BB/3/INIA/HD832 |
| V-92128 | BOW/PRL/BUC |
| V93001 | V1562//CHRC"S"/HORK/3/KUFRA-I/4/CARP "S" /BJY "S" |
| V95042 | INQ91/TTR'S'/VEE'S' |
| V-95069 | WL-711/HD-2169//VRES/VEE"S" |
| V92145 | BLS//F3.71/TRM |
| V92145 | (SISTER LINE) SAME AS ABOVE |
| V-93108 | OPATA/TRAP#1 |
| V-94091 | BURGUS/SORT-12-13//KAL/BB/3/PAK. 81 |

races (Table 2). *Lr14, Lr18, Lr20, Lr22a* and *LrB* on the other hand gave high reaction with all the races and thus could not be postulated (Table 2). Postulation could not be made in two badly mixed lines NR15 and 95CO22 and a durum line.

Ten leaf rust resistant genes, *Lr1, Lr3, Lr10, Lr13, Lr16, Lr27+31, Lr17, Lr21, Lr23* and *Lr26*, were postulated in the tested material among which *Lr26* was the most frequent one while *Lr21* was the least frequent. *Lr1* which is gave low infection type (LIT) 0; to ; with pathotypes BBB/BB, CBJ/QB, CBJ/QL, CBJ/QQ and CCJ/SP (Table 2) was postulated in ten lines, including three commercial varieties Zardana, Faisalabad-83 and Soghat-90 (Table 3). *Lr1* in V94195 is inherited from *T. tauchii* accession in its pedigree. This gene had a high virulence frequency in past and thus is of little or no use if diploid alone. 13 lines were postulated to have gene *Lr3* with LIT ranging from ; to ;1 with pathotypes BBB/B, LCJBN and NCJBN (Table 2). This gene had also high frequency of virulent isolates in past and should not be deployed alone. Pathotype NCJ/BN gave ;1 reaction with *Lr13* in Thacher background and $X^-$ type of reaction with WL711 (having *Lr13*) at 25 C° on 14th day of inoculation. Similarly Pathotype LCJBN gave X type of reaction with WL711 and $1^+$ 3C type of reaction with Thacher near-isogenic line (having *Lr13* in it=s background) (Table 2). Low infection type shown by *Lr13* avirulent isolates, varying from; through X to 3 on seedling, depend on pathogen culture, environmental conditions and host genetic background (McIntosh *et al.*, 1995). *Lr13* is an important adult plant resistance gene and was postulated in V-4, V-93BT022, 94B2707, 94B2779, WS940102, Bluesilver, Zardana, Chakwal-86, Soghat-90, Parwaz-94, Wattan-94, Shahkar-95, V92128, V93001, V94042 and V95069. This gene had a low virulence frequency in past and in order to maintain low virulence against this gene it must be deployed very carefully in combination with other genes. Combined virulence against *Lr13, Lr17* and *Lr26* is missing in Pakistan (Hussain *et al.*, 1999) and is postulated in four lines 94B2779, 93BT022, Chakwal-86 and Kaghan-93. *Lr17* (LIT ; to ;1 with pathotypes BBB/BB, TCB/TD and X with MFB/SP; table 2), in combination with Lr26 ( LIT 0; to $1^+$ with BBB/BB, CBJ/QB, CBJ/QL, CBJ/QQ and ; with TBB/JP and TBB/TM; Table 2), is postulated in V94042 and Kohinoor 83. Virulence against *Lr17* though reported missing in Pakistan during past, but Innia 66 carrying Lr13 and *Lr17* have shown high susceptibility (Singh personal communication). *Lr26* is known to be associated with 1B1R translocation is one of the most common translocations in the recent spring wheat cultivars derived from CIMMYT germplasm (Rajaram *et al.*, 1996). The translocation is of great interest as it carries stem rust resistance gene *Sr31*, stripe rust resistance gene *Yr9* and powdery mildew resistance gene *Pm8* in addition to Lr26. *Lr10*, another gene with low virulence frequency in past, is postulated in 21 lines (Table 3). This gene usually gives LIT ; to ;1 with pathotype BBB/BB, CBJ/QB and TCB/TD. Genes *Lr10 and Lr21* in V93032 are coming from RL6043 in its pedigree and reaction; $12^+$ with pathotype MCJ/SP (Table 3) provided base for *Lr10*=s postulation. *Lr21*, sometimes ineffective at seedling stage (McIntosh et al. 1995), gave 23C reaction in this study (Table 2). Adult plants with *Lr21* are reported to be resistant in Indian subcontinent (Huerta-Espino, 1992). *Lr23* was identified by its LIT with pathotypes BBB/BB, CBJ/QB, CBJ/QL, CBJ/QQ, TBD/TM and MCJ/QM, TBD/TM (Table 3). This gene, which is very close to *Lr13* (RA McIntosh and WM Hawthorn, unpublished 1981), was postulated in combination with *Lr13* only in 3 out of 10 lines having *Lr13*. The lines having *Lr23*, either in combination with *Lr13* or alone, can provide good resistance in the wormier areas of Pakistan, as it is more effective at temperatures above 20°C (Dyck and Johnson, 1983). *Lr16* postulated in V7002, S190157 and DW-2, with LIT 1 to 3C with pathotype BBB/B, CCJ/SP and MFB/SP (Table 2), is coming from BUCK >S= in the former two and from CNO 79 in the latter. Gatcher gene complex (*Lr27+31* ) which usually gives

Table 2: Seedling infection types displayed by isogenic differential lines with 12 different pathotypes of P. recondita tritici Pathotypes

| No. | Accession | BBB/BB | CBJ/QB | CBJ/QL | CBJ/QQ | CCJ/SP | TBB/JP | TBD/TM | TCB/TD | MFB/SP | MCJ/QM | MCJ/SP | NCJ/BN | NCJ/BN* | LCJ/BN* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lr22B | 3+ | 3+ | 3+ | 3+ | 3 | 3 | 3 | 3+ | 3+ | 3+ | 3+ | 3 | 3 | 3+ |
| 2 | Lr1 | ; | 0; | 0; | 0; | 0; | 3+ | 3 | 3+ | 3+ | 3+ | 3+ | 3 | 3+ | 3+ |
| 3 | Lr2a | ; | ; | 0; | 0; | 0; | 3+ | 3+ | 3+ | ; | 0; | 0; | ;1- | ; | 1 |
| 4 | Lr2b | ; | ;1- | ; | ; | ; | 3+ | 3+ | 3+ | ;1- | 0; | 0; | ;1 | ;1 | 1+ |
| 5 | Lr2c | ; | 1 | ; | ;1 | ; | 3+ | 3+ | 3+ | 11+ | ; | ; | 3C3 | ;1+3C | 3C3 |
| 6 | Lr3 | ; | 3+ | 2+3C | 3C | 12 | 3 | 3 | 3+ | 3+ | 3+ | 23C | ; | ; | ;1- |
| 7 | Lr3ka | ;2= | 12 | ; | ; | ; | ;12 | 12 | ;12 | 12 | ;12 | ; | 12 | ;1- | ;12 |
| 8 | Lr3bg | ; | 23C | 3 | 3+ | 3 | 12 | 3+ | 3+ | 3+ | 3+ | 23 | ; | ; | 0; |
| 9 | Lr9 | 0; | 0; | ; | 0; | ; | 0; | 0; | 0; | 0; | 0; | 0; | 0; | 0; | 0; |
| 10 | Lr10 | ; | ;1- | 3+ | 3+ | 3 | 3 | 3 | ; | 3+ | 3+ | 3+ | 3+ | 3+ | 3+ |
| 11 | Lr11 | 3C | 4 | 3+ | 3+ | 3+ | 3+ | 3 | 1+ | 3C | 3C3+ | 3+ | 3+ | 3+ | 3+ |
| 12 | Lr12 |  | 3+ | X | 3C3 | 3+ | 3+ | 3 | X+ | 3+ | 3+ | 3+ | 3+ | 3C3 | 3+ |
| 13 | Lr13 | 3C3 | 3+ | 3+ | 3+ | 3 | 3 | 3 | 3+ | 3+ | 3+ | 3+ | 3 | ;1 | 1+3C |
| 14 | Lr14a | 3+ | 3+ | 3+ | 3+ | 3 | 3+ | 3 | 3+ | 3+ | 3+ | 3+ | 3+ | 3 | 3+ |
| 15 | Lr14b | 3+ | 3+ | 3+ | 3+ | 3 | 3+ | 3 | 3+ | 3+ | 3+ | 3+ | 3+ | 3+ | 3+ |
| 16 | Lr15 | ; | ; | ; | 0; | 3 | 3+ | 3 | 3+ | 3+ | ; | 3+ | 1 | ;1- | 1- |
| 17 | Lr16 | 1+3C | 1 | 1+ | ;1 | 12 | 1 | 1 | 1 | 1 | 1 | 1+ | 1 | 1 | 1 |
| 18 | Lr17 | ;1 | 3C3+ | X | 3C3 | 3 | ;1- | 3 | ; | X | 3+ | 3+ | 3 | 3 | 3+ |
| 19 | Lr18 | 3C3 | 3+ | 3+ | 2C3 | 3 | 3 | 3 | 3+ | 3+ | 3C3 | 3+ | 3+ | 3 | 3+ |
| 20 | Lr19 | ; | 0; | ; | 3 | 0; | 0; | 0; | ; | ; | 0; | 0; | ; | 0; | 0; |
| 21 | Lr20 | 3+ | 3+ | 3+ | 3+ | 3+ | 3+ | 3 | 3+ | 3+ | 3+ | 4 | 3+ | 3 | 3+ |
| 22 | Lr21 | 12 | 23C | 23C | 12 | 12 | ;12 | 12- | ;12 | 12 | 12 | 23C | 12 | ;1- | 12 |
| 23 | Lr22a | _ | 3+ | 3+ | 3+ | 3 | 3+ | 3 | 3+ | 3+ | 3+ | 3+ | 3 | 3 | 3+ |
| 24 | Lr23 | ;1 | ;1 | ;1 | ;1 | 3 | 3+ | 12 | 3+ | 3+ | ;1 | 3+ | 3 | 3 | 3+ |
| 25 | Lr24 | ;1 | 0; | 1 | ;1 | ; | ; | ; | ; | 33+ | ;1 | ;1 | ; | ;1 | ; |
| 26 | Lr25 | ; | ; | 0; | ; | ; | 0; | 0; | ; | ; | ; | 0; | ; | ; | ; |
| 27 | Lr26 | 1+ | 11+ | ;1- | 0; | 3 | ; | ; | 3+ | 3 | 3 | 3+ | 3+ | 3 | 3+ |
| 28 | Lr27+31 | ;1 | ; | ;1 | ;1 | 3+ | 3+ | 3+ | ; | 3+ | 3+ | 3 | X | ;1- | ;1 |
| 29 | Lr28 | 0; | 0; | 0; | 0; | 0; | 3+ | 3 | 3+ | 4 | 0; | 0; | 3+ | 3 | 3+ |
| 30 | Lr29 | ; | ;1 | ;1- | ; | ;1- | 1 | 12 | ;1 | ;1 | ;1- | ;1 | 11+ | ;1 | ;1- |
| 31 | Lr30 | ;12 | 3- | ;12 | 23C | 12- | 2- | 2= | 23C | 23 | 12 | ;12 | 3C3 | ;1 | 23C |
| 32 | Lr32 | ;12 | 3 | 12 | 3C | 3 | 3 | 2 | ;12 | 12 | 22+ | 22+ | 3 | 3 | 12 |
| 33 | Lr33 | 3C3 | 3-,3 | 3 | 3 | 22+ | 12 | 22+ | 23C | 3C3 | 23C | 23C | 3 | 22+ | 3C3 |
| 34 | Lr34 | 3 | 3-,3 | 2+3 | 3 | 3 | 3+ | ;23 | 2+3C | 3 | 3 | 3 | 3 | 3 | 3 |
| 35 | Lr35RL5711 | 3 | 3 | 3 | 3C3 | 3 | 3 | 3 | 3+ | 3C3+ | 3C3 | 3C3 | 3 | 1+3C | 3C3 |
| 36 | Lr36 | ;1 | 1 | 3C3 | 12 | 3 | 3 | 1 | ;1 | ;1 | 1+3C | 3C3 | 1+3C | ; | ; |
| 37 | Lr37RL6081 | 3+ | 3+ | 3+ | 23C | 3 | 3+ | 3 | 3+ | 3+ | 3+ | 3+ | 3+ | 3 | 3+ |
| 38 | LrB | 3C | 3+ | 3+ | 3 | 3+ | 3+ | 3 | 3C3 | 3+ | 3+ | 3+ | 3+ | 3+ | 3+ |
| 39 | WL711Lr13 | X+ | 3+ | 3+ | 3+ | 3+ | 3+ | 3 | 3+ | 3+ | 3+ | 3+ | 3 | X- | X |
| 40 | GhazaW23,+ | ; | ; | ; | ; | 3 | 3C3 | ; | 2+3C | 2+3C | ; | 3C3 | 3 | - | 3+C |
| 41 | Altare | ; | ; | ; | ; | ;1 | ;1 | ; | ;2= | ;1 | ; | ;12- | 12 | ;1 | 12 |
| 42 | Dnline | 1+3C | 23C | 12 | 12 | ;12 | 12 | 12 | ;12 | 12 | ;11+ | ;12 | - | - | 12 |
| 43 | lumino | ;1 | ;13C | 3C3 | 3C | 3C3 | _ | 12 | ;12 | ;12 | ;13C | X | - | - | 23C |
| 44 | Euroga | 23C | - | - | - | - | 3+ | - | ; | - | - | 3 | - | ; | 12 |
| 45 | Cananea | - | - | - | - | - | - | - | 3 | - | - | 3C3 | - | - | 12 |
| 46 | Siikiyou | - | 3+ | 3+ | 3+ | - | - | - | 4 | 3+ | 3+ | 3+ | - | - | 3+ |
| 47 | Tapir/yogui/Mus | - | - | - | - | - | - | - | 3 | - | - | 3+ | - | - | 3+ |
| 48 | BAV92 | - | X | X | X | - | - | - | X | 3+ | 3+ | 4 | - | - | X+ |

* Infection types re-recorded on 14th day for Lr13

Table 3: Seedling infection types displayed by Pakistani varieties/lines when tested with 12 pathotypes of P. recondita tritici, and postulated genes

| | Pathotypes | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Varieties/lines | BBB/BB | CBJ/QB | CBJ/QL | CBJ/QQ | CCJ/SP | TBB/JP | TBD/TM | TCB/TD | MFB/SP | MCJ/QM | MCJ/SP | NCJ/BN* | LCJ/BN* | Lr Genes postulated |
| DW-1 | ; | ;1- | 22$^{+}$ | 1 | 3C3 | 1 | ; | ; | ;1 | 1 | 3$^{+}$ | ;1 | ;1 | 3,17,23,26 |
| NR-15 | 0; | 0; | 0; | 0; | 0; | 3$^{+}$ | ;1 | 3 | ;12 | 3C3 | 3$^{+}$ | X | 2p3C'3P3$^{+}$ | Mixed |
| PR-65 | ; | 0; | 0; | 0; | ;12 | 0; | 0; | 3 | 3 | ;1- | 3$^{+}$ | 4 | 3$^{+}$ | 23,26 |
| NR-102 | ; | 3-,3 | 3 | 2$^{+}$3 | - | ; | ;12 | 3 | 23 | 3 | 2$^{+}$3 | ;1 | 3 | 3,($^{+}$) |
| 93CO65 | ; | X$^{+}$ | X | X | 3$^{+}$ | 3 | 3 | ;1 | 3 | 3$^{+}$ | 3$^{+}$ | ; | ; | 3,10,27$^{+}$31 |
| V-94195 | 0; | 0; | 0; | ; | 0; | 3 | ;1 | ; | 3 | ; | 3$^{+}$ | X | 3$^{+}$ | 1,10,23,($^{+}$) |
| BWP-949549 | 0; | 0; | ; | ; | 3 | 3 | 1P0;'2P;12 | 0; | 3 | ;1- | 3$^{+}$ | 0; | 0; | 3,10,23 |
| 95R48 | X | ;12 | ;1- | X- | 3$^{+}$ | 3 | 3 | ; | 3 | 3$^{+}$ | 3$^{+}$ | ;1 | X- | 10,27$^{+}$31 |
| 95CO22 | ; | 3$^{+}$ | 3 | 3 | 3$^{+}$ | ; | ;12 | 1L3-,2L3$^{+}$ | X | 3$^{+}$ | 3$^{+}$ | 0; | X | Mixed |
| 95202 | 0; | ;11$^{+}$ | ; | 0; | 4P0;'2P;12 | 0; | 0; | 3C3 | 23 | 3$^{+}$ | 3 | 0; | 0; | 3,26 |
| V-4 | ; | 12$^{+}$ | ; | 0; | 3 | 0; | 0; | 3C3 | 3C3 | 3$^{+}$ | 3$^{+}$ | ;1 | X | 13,26 |
| V-7002 | ; | ;1- | ; | 0; | 1$^{+}$ | 0; | ; | ; | ;1 | ;1- | 2$^{+}$3C | ; | ; | 3,16,26 |
| V-7012 | ; | 0; | 0; | 0; | 3$^{+}$ | ; | 12 | 3 | 3 | 3C3 | 3$^{+}$ | 3$^{+}$ | 3 | 26 |
| V-93BT022 | ; | ;1 | ; | 0; | ;23 | 0; | ; | ;12 | 12 | 3C3 | 1L3C3'2L3$^{+}$ | ;1- | X- | 13,17,26 |
| V-93032 | ; | ; | ;1 | ;1- | ;1- | ; | ; | 0; | ;1- | 3P;1-'2P3$^{+}$ | ;12$^{+}$ | ; | ; | 10,21,($^{+}$) |
| V-93118 | 0; | 0; | 0; | 0; | 0; | 0; | ; | ; | 3 | 3$^{+}$ | ;12$^{+}$ | ;1- | ;1$^{=}$ | 1,3,10,26 |
| V-94042 | 0; | 0; | 0; | 0; | 0; | 0; | ; | ; | 1 | 3$^{+}$ | 3 | ; | ;1 | 1,3,17,26 |
| V-94091 | 0; | ;1 | ; | 0; | 12 | 0; | 0; | 3C3 | 3 | 3C3 | ;11$^{+}$ | ; | ; | 3,26 |
| V-94105 | ; | ; | ; | ; | 3$^{+}$ | 3$^{+}$ | ; | ; | 2$^{+}$3 | ;1- | 3$^{+}$ | 3$^{+}$ | 3$^{+}$ | 10,23 |
| V-94654 | X | ;1- | 3 | 3 | 1$^{+}$ | ;1 | ; | ; | ; | ;1- | ; | ;1 | 12 | Durum |
| V-95219 | ; | ;11$^{+}$ | ; | 0; | 3 | 0; | ; | ; | 3C3 | 4 | 3$^{+}$ | 23C | 3$^{+}$ | 10,26 |
| 93B2707 | ; | 11$^{+}$ | ;1- | ; | 3$^{+}$ | 0; | ; | 3C3 | 23C | 2P;'4P3 | 3 | X | X- | 13,26 |
| 93B2779 | ; | 11$^{+}$ | ; | 0; | 23C | ; | ; | ;12 | ;2- | 3 | 3C3 | ; | X- | 13,17,26 |
| AUP9701 | ; | ;12 | ; | 0; | 3 | 0; | 0; | 23C | 23- | 3$^{+}$ | 1L;12'2L3$^{+}$ | 2$^{+}$3 | 3 | 26,($^{+}$) |
| DW-2 | ; | 1$^{+}$2 | 2$^{+}$3C | ;1 | 3C | ; | 1$^{+}$ | ; | ;12 | 1 | 3C3 | 11$^{+}$ | 11$^{+}$ | 16,17 |
| WS94012 | ; | ; | 2P;1-'2P3$^{+}$ | 2P;'2P3 | 3$^{+}$ | 3 | - | ; | 3C3 | 2P;1-'2P3$^{+}$ | 3$^{+}$ | X | X- | 10,13,23 |
| WS94130 | 0; | 0; | 0; | 0; | - | ; | 3 | ; | ; | 3$^{+}$ | 3$^{+}$ | 0; | 0; | 1,3,17 |
| S-190157 | ;1- | 1 | 1$^{+}$ | ;1- | 1$^{+}$ | - | 1 | ;1 | ;1 | 1 | 1$^{+}$'Lr16 | 0; | 0; | 3,16 |
| BLUESILVER | X | 3$^{+}$ | 3$^{+}$ | 3$^{+}$ | 3$^{+}$ | 3 | 3$^{+}$ | 3$^{+}$ | 3 | 3$^{+}$ | 3$^{+}$ | ;1 | X- | 13 |
| WL-711 | X | 3$^{+}$ | 3$^{+}$ | 3 | 3$^{+}$ | 3$^{+}$ | 3$^{+}$ | 4 | 3$^{+}$ | 3$^{+}$ | 3$^{+}$ | X | X | 13 |
| ZARDANA | ; | 0; | 0; | ; | 0; | 3$^{+}$ | 3$^{+}$ | ; | 3$^{+}$ | 3 | 3$^{+}$ | X | X | 1,10,13 |
| SARSABZ | 0; | ; | 1 | ;1- | 1 | ; | ; | ; | ; | 1 | 1$^{+}$ | ; | ;1 | Resis.toallraces(16,($^{+}$) |
| PAK-81 | ; | ;1 | ; | ; | 3 | ; | ; | 3 | 3 | 2P;1-,1P3 | 3 | 4 | 3 | 23,26 |
| KOHINOOR-83 | 0; | ;1- | ; | 0; | 1$^{+}$3C | 0; | 0; | ; | ;1- | 3 | ;23 | ; | ; | 3,17,26 |
| FAISALABAD-83 | ; | 0; | 0; | 0; | 0; | 3 | 3 | ; | 3 | 3$^{+}$ | 3 | X- | 3$^{+}$ | 1,10 |
| FAISALABAD-85 | ; | ;1 | ; | 0; | 2$^{+}$3 | 0; | ; | ;12 | 3 | 3C | 3$^{+}$ | X- | 3$^{+}$ | 10,26 |
| CHAKWAL-86 | ; | ;1 | ; | 0; | 3$^{+}$ | ; | 3 | ;12 | ;12 | 23C | 3C3 | ;1 | X | 13,17,26 |
| RAWAL-87 | ; | ;1 | ; | 0; | 3 | 0; | ; | ;12 | ;23C | 3 | 3C3 | X- | 3 | 10,26 |
| SOGHAT-90 | 0; | ; | 0; | 0; | 0; | 3 | 3$^{+}$ | ; | 3$^{+}$ | 3$^{+}$ | 3$^{+}$ | ;1 | ;1 | 1,10,13 |
| INQALAB91 | ; | ; | X | X | 3$^{+}$ | 3$^{+}$ | 3$^{+}$ | ; | 3$^{+}$ | 3$^{+}$ | 4 | X | X | 10,27$^{+}$31 |
| PIRSABAK-91 | ; | ; | ; | 0; | 3 | ; | 0; | 3C3 | 3C3 | ;1 | 3 | 3$^{+}$ | 3$^{+}$ | 26,23 |
| KAGHAN-93 | ; | ; | ; | 0; | 3 | ; | ; | ;12 | ;12 | ;1 | 3 | 0; | X | 17,23,26,13 or27$^{+}$31 |
| BAKHTAWAR-93 | ; | ;1 | ; | 0; | 3 | 0; | ; | 3C3 | 23C | 3 | 3 | 3 | 3$^{+}$ | 26,($^{+}$) |
| PARWAZ-94 | X | 3$^{+}$ | 3$^{+}$ | 3 | 3$^{+}$ | 3 | ;12 | 3$^{+}$ | X | 3$^{+}$ | 3$^{+}$ | X- | X- | 13,($^{+}$) |
| WATAN-94 | ; | ; | ; | ; | 3 | 3 | ;12 | ; | 3C3 | ;1- | 3$^{+}$ | ;1 | X | 10,13,23 |
| SHAHEEN-94 | ; | ;1 | ; | 0; | 3 | 0; | ; | 3 | 23 | 3 | 3 | 3$^{+}$ | 3$^{+}$ | 26 |
| SHAHKAR-95 | ; | ;1 | ; | 0; | 3 | 0; | ; | 3 | ;23C | 3$^{+}$ | 3 | X | X | 13,26 |
| KIRAN-95 | ; | ; | 3$^{+}$ | X$^{+}$ | 3$^{+}$ | 3 | 3 | ; | 3 | 3$^{+}$ | 3$^{+}$ | ;12 | 4 | 10 |
| Punjab96 | ; | ;1 | 3$^{+}$ | 3 | 3$^{+}$ | ; | 3$^{+}$ | ; | 3 | 3$^{+}$ | 3$^{+}$ | X | 4 | 10 |
| V92128 | ; | ; | ; | 0; | 3 | ; | ; | ;1 | 3C3 | ; | 3$^{+}$ | ;1 | X | 10,13,26 |
| V93001 | ; | ; | ;1- | ; | 3$^{+}$ | 3$^{+}$ | ;12 | 3$^{+}$ | X | ; | 3$^{+}$ | ;1 | X- | 13,26,($^{+}$) |
| V95042 | ; | ;1 | ;1- | ;1 | 3$^{+}$ | 3$^{+}$ | 3$^{+}$ | ; | 3 | 3$^{+}$ | 4 | X | X | 10,27$^{+}$31 |
| V95069 | 0; | 0; | 0; | 0; | 0; | 0; | 0; | 3$^{+}$ | 23C | ; | 3$^{+}$ | X | X | 1,13,23,26 |
| V92145 | 0; | ; | 0; | 0; | 3 | 0; | 0; | 3$^{+}$ | ;23C | 3$^{+}$ | 3 | X$^{+}$ | 3 | 1,26 |
| V92145 | ; | ; | 3$^{+}$ | ;23 | 3 | ; | ; | 3$^{+}$ | 3 | 3$^{+}$ | 3 | 3 | 3$^{+}$ | 26 |
| V93108 | ; | ;1 | ; | 0; | 3 | ; | 0; | ; | ;23C | 3$^{+}$ | 3 | ;1- | X | 10,13,26 |
| V94091 | ; | ;1 | ; | 0; | ;12 | ; | ; | 1L3C3'2L3$^{+}$ | 3$^{+}$ | 3$^{+}$ | 3C3 | ; | 0; | 3,26 |

(+) Indicate presence of additional unidentified gene(s), *Infection types re-recorded on 14th day for Lr13

Table 4: Final disease rating (FDR) and the area under disease progress curve (AUDPC) of Pakistani cultivars/advance lines when inoculated with pathotype MCJ/SP of Puccinia recondita at El-Batan.

| Cultivar | %AUDPC** | FDR* | *Ltn* | Cultivar | %AUDPC** | FDR* | *Ltn* |
|---|---|---|---|---|---|---|---|
| DW-1 | 2.22 | 5S | P/A | ZARDANA | 45.63 | 70S | A |
| NR-51 | 2.04 | 5MS-S | A | PAK-81 | 25.28 | 40MS | A |
| PR-65 | 73.91 | 100S | A | KOHINOOR-83 | 50.09 | 15-100MS-S | A |
| NR-102 | 9.13 | 20M | P | FAISALABAD-83 | 63.21 | 100S | A |
| 93CO65 | 4.28 | 5MS | P | FAISALABAD-85 | 19.86 | 30MS-S | P |
| V-94195 | 3.73 | 10S | A | RAWAL-87 | 29.49 | 40MS-S | P |
| BWL-949549 | 3.02 | 10MS | A | SOGHAT-90 | 37.62 | 60MS-S | P |
| 95R48 | 8.08 | 15MS | A | INQALAB-91 | 35.51 | 70MS-S | A |
| 95CO22 | 1.81 | 5MS | P | PIRSABAK-91 | 35.75 | 70MS-S | A |
| 95202 | 29.56 | 30MS | P/A | KAGHAN-93 | 18.19 | 50MS | A |
| V-4 | 16.72 | 30MS | A | BAKHTAWAR-93 | 5.3 | TS | P |
| V-7012 | 7.89 | 20MS | A | PARWAZ-94 | 39.16 | 70MS-S | A |
| V-93BT022 | 24.28 | 30MS | P | WATAN-94 | 44.91 | 70MS-S | A |
| V-93032 | 0.61 | 0 | A | SHAHEEN-94 | 13.13 | 30MS-S | P |
| V-93118 | 3.73 | 5MS | A | SHAHKAR-95 | 13.87 | 30MS-S | P |
| V-94042 | 25.57 | 40MS | A | KIRAN-95 | 5.93 | 15MS | P |
| V-94091 | 8.08 | 15MS | P | PUNJAB-96 | 4.73 | 10MS | P |
| V-94105 | 18.38 | 40MS | A | V92128 | 22.57 | 40MS-S | A |
| V-94654 | 0 | 0 | A | V93001 | 26.34 | 40MS-S | A |
| V-95219 | 70.9 | 80S | A | V95042 | 38.68 | 60MS-S | A |
| 94B2707 | 33.84 | 40MS | A | V94105 | 22.57 | 40MS-S | A |
| 94B2779 | 1.41 | 5M | A | V94042 | 69.53 | 100S | A |
| AUP9701 | 1.63 | 5MS | P | V95069 | 74.11 | 100S | A |
| WS94012 | 86.95 | 100S | A | V92145 | 9.81 | 15MS-S | A |
| WS94130 | 3.07 | 0 | P | V92145(Sister line) | 9.81 | 15MS-S | A |
| BLUE SILVER | 82.27 | 100S | A | V93108 | 26.78 | 30MS-S | A |
| WL-711 | 100 | 100S | A | V94091 | 16.6 | 30MS-S | A |

*Final diseae rating includes two components: Disease severity based on modified Cobb scale (Peterson *et al.*, 1948) and host response, e.g., 10 = 10% severity; MS-moderately susceptible IT, MS-S = moderately susceptible to susceptible IT, TS=trace susceptible IT, S = susceptible IT, M = moderate IT, **Area under disease progress curve as a percentage of (AUDPC) of WL-711, Ln (Leaf tip necrosis), 'P' indicate ltn present and 'P' indicate Ltn absent

X = to $X^+$ LIT showed up in BAV92 (Table 2) and was postulated in 93CO65, 95R48 (coming from Cocoraque 75). Kaghan-93, which gave X with LCJ/BN, probably has Gatcher complex inherited from Teeter in its pedigree (coming from Cocoraque in Teeter's pedigree). Gatcher gene may be of little use when deployed alone because Jupatico73 carrying this gene had been highly susceptibility in past. Varieties/lines possessing Gatcher gene complex in combination with *Lr17* and *Lr16* can serve as source of resistance in areas lacking virulence for these genes. Lines V94195, AUP7091, Sarsabz and V93001 are postulated to have some additional unidentified genes.

Inqilab-91, leading variety of Pakistan, possess *Lr27+31* in addition to Lr10. Resistance of Inquilab and other varieties possessing *Lr27+31, Lr16* and *Lr17* can be combined with slow rusting type of durable resistance to increase the life of these genes.

**Field studies:** Table 4 gives the final disease reaction (FDR) and AUDPC (area under disease progressive curve) of the cultivars/advance lines evaluated with Mexican pathotype MCJ/SP. *Lr34* which showed low infection types with all the pathotypes used, was also low (LIT **3**) with pathotype MCJ/SP (Table 2). Lines S190157, DW-2, V-7002 and Sarsabz are omitted due to effectiveness of *Lr16.* V-94654, resistant to all the Mexican pathotypes used at seedling stage, was also omitted. Sixteen cultivars/advance lines showed leaf tip necrosis with varying AUDPC values, while two did not expressed *Ltn* clearly (table 4). Lines 95CO22, 93CO65, V-93BTO22, AUP9701, Kiran-95 and Punjab-96, with MS type of final disease reaction specific to *Lr34* (Roelfs *et al.*, 1992), expressed to have *Ltn* gene and low AUDPC (Table 4). It is quite probable that the lines having *Ltn* may have gene *Lr34* in combination with *Ltn*, as Dyck (1991) indicated that these two genes are linked. This leaf rust resistance gene, if present in AUP9701, expressing *Ltn*, must be inherited from Jupatico-73 in its pedigree. Singh (1992) failed to recover recombinants for *Lr34* and *Ltn*. It is thus possible that lines expressing *Ltn* with higher final disease reaction may not have *Lr34.* Similarly lines having lower AUDPC with MS type of reaction may have *Lr34*. V-93CO32 and WS94130 appeared to have additional unidentified adult plant resistance genes, as thy gave 0 FDR (Table 4). Although line V-94195 has expressed 10S type of FDR but a 3.7% AUDPC value and seedling data indicate the presence of additional unidentified adult plant leaf rust resistance genes in it (Table 3 and 4). Bakhtawar-93, having Jupatico-73 in its pedigree, had low AUDPC (5.7%) but a TS type of FDR. This line probably lack *Lr34* but do have additional adult plant resistant genes, as indicated by its seedling analysis (Table 3). Lines lacking *Ltn* but showing lower AUDPC could be crossed with cultivars carrying *Lr34*. If adult plant genes are additive, such crosses should result in transgressive segregants with increased resistance (Singh 1993).

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