Our organic breeding program is highly focused on the development of new, organic cultivars of alternative or underutilized cereals such as einkorn and emmer. A new, organically bred, einkorn cultivar, **Mv Menket**, was released last year. This is the first semidwarf einkorn cultivar in the market, with elevated yield potential, and excellent resistance against most of the wheat diseases, except Fusarium. Mv Menket is an organic cultivar, because it is highly sensitive against all herbicides used in the Hungarian farming practice, and there is no possibility to use it in traditional agricultural practices.

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# ITEMS FROM INDIA

**DIRECTORATE OF WHEAT RESEARCH**
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### *A study of floral biology traits in bread wheat.*

S.K. Singh and Dharmendra Singh.

**Summary.** Three floral biology traits, anther length, stigma length, and anther extrusion, were investigated in 92 elite wheat germ plasm lines. A wide range of variability was observed for these floral traits and promising genotypes were identified for their further utilization as parents for hybrid wheat development.

Wheat productivity levels in the present genotypes have reached a saturation level, which limits higher production to meet the targets for food security. Newer, innovative techniques can be promising approaches in order to break yield barriers and, in this regard, hybrid wheat development through exploitation of heterosis may be a potential tool. Wheat production in the Northwest Plains Zone has reached peak yields. Knowledge about the variability and character association between floral characteristics is crucial to identify suitable male or female parental lines for further utilization in hybrid development programs. Our objective was to study the extent of variability present in some wheat genotypes for various floral characters and establish correlations between them.

**Materials and methods.** A total of 92 elite genotypes maintained by the Hybrid Wheat Programme were used in the study. These entries included elite selections from international nurseries and trials from CIMMYT; genetic stocks;

advanced lines for yield, abiotic stress tolerance, and disease resistance; and yield component lines. The experiment was laid out in randomized block design with three replications with plot size of double row of 2.5-m in length. All agronomical practices for raising a good crop were adopted. Wheat is a self pollinated crop and, therefore, floral traits promoting out crossing were investigated. The genotypes were evaluated for three floral traits, anther length, stigma length, and anther extrusion in order to get basic information about their floral behavior. Observations were taken on 10 randomly selected plants from each replication. Anther length was measured in mm and recorded as the average length of three anthers belonging to the lateral florets of the two central spikelets of a spike. Stigma length also was measured in mm and recorded as the average length of two stigmas of the lateral florets from two central spikelets of a spike. Anther extrusion was measured as a percent after counting the extruded anthers of two lateral florets of five central spikelets from 10 spikes/replication. The data were analyzed (Panse and Sukhatme 1967) to work out the range, mean, and correlations among the traits and to identify promising genotypes for further utilization.

**Results and discussion.** Mean values for various traits in different genotypes indicated a very wide range for all three traits under study (Table 1). Anther length ranged from 3.20 to 5.60 mm with a mean value of 4.53 mm. Stigma length ranged from 2.20 to 4.30 mm with a mean value of 3.10 mm. Anther extrusion ranged from 15.17% to 63.07% with an average value of 33.27%. Similar findings also were reported by Hucl (1996), Singh and Joshi (2003), and Singh (2006). The association between these floral traits indicated a high correlation between anther and stigma length.

**Table 1.** Range, mean, and character association for floral traits in wheat.

| Floral trait | Range | Mean | Correlation coefficient: Stigma length | Correlation coefficient: Anther extrusion |
|---|---|---|---|---|
| Anther length (mm) | 3.20–5.60 | 4.53 | 0.36 | 0.08 |
| Stigma length (mm) | 2.20–4.30 | 3.10 | | –0.03 |
| Anther extrusion (%) | 15.17–63.07 | 33.27 | | |

The frequency of genotypes in the different floral traits classes also was recorded (Fig. 1). Most of the genotypes showed an anther length of 4.51–5.00 mm, a stigma length of 2.51–3.00 mm, and anther extrusion of 25.1–45.0%.Twelve genotypes had an anther length of more than 5.0 mm. Genotype HT 97 had longest anthers, at 5.60 mm, followed by Giant 3 and KRL 237 (5.50 mm). Other genotypes with promising anther lengths were 25 SAWSN 3034, 25 SAWSN 3178, DWR 39, GW 273, HD 2009, HUW 34/LR 19, KRL236, LOK 62, and NIAW 1275. HI 1077 showed the highest anther extrusion of 63.07%, followed by 18 HRWSN 2066 (55.91%) and 15 HRWYT 222 (55.63%). NIAW 1275 was the only genotype with a stigma length (4.30 mm) of more than 4.0 mm.

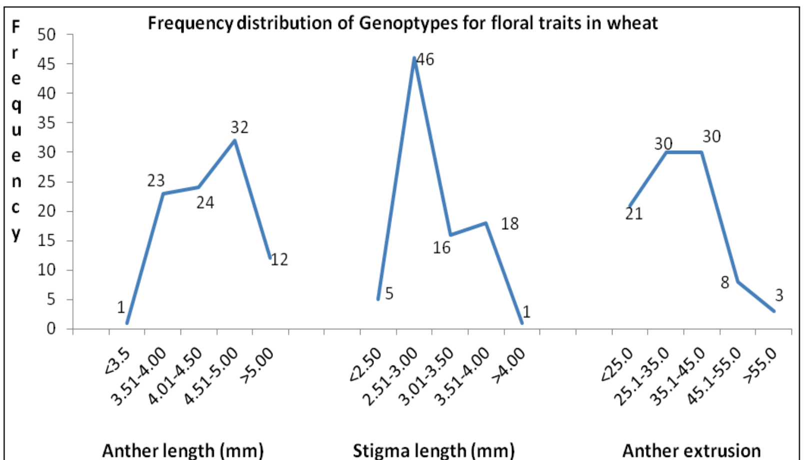

**Fig. 1.** Frequency distribution for floral traits in wheat.

Based on the performance for various floral traits, promising genotypes with high values were identified (Table 2, p. 81). Among these, 15 HRWYT 222, 25 SAWSN 3034, GW 273, HD 2329, KRL 236, and NIAW 1275 were found promising for two or more floral traits. These can be further utilized in conversion into CMS and restorer lines for hybrid wheat development.

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**Table 2.** Promising genotypes for floral traits.

| Genotype | Anther length (mm: >5.00) | Stigma length (mm: >3.75) | Anther extrusion (%: >40.0) |
|---|---|---|---|
| 15 HRWYT 222 | 5.00 | 3.90 | 55.63 |
| 18 HRWSN 2066 | 4.00 | 2.60 | 55.91 |
| 25 SAWSN 3034 | 5.20 | 3.50 | 47.36 |
| 25 SAWSN 3169 | 5.00 | 4.00 | 24.79 |
| 25 SAWSN 3178 | 5.20 | 2.70 | 37.75 |
| DWR 39 | 5.10 | 3.10 | 25.34 |
| FLW 8 | 5.00 | 4.00 | 23.59 |
| GIANT 3 | 5.50 | 3.50 | 27.43 |
| GW 273 | 5.20 | 2.50 | 45.13 |
| GW 411 | 5.00 | 4.00 | 20.15 |
| HD 2009 | 5.30 | 2.50 | 38.08 |
| HD 2329 | 5.00 | 4.00 | 40.03 |
| HI 1077 | 5.00 | 2.90 | 63.07 |
| HP 1296 | 5.00 | 3.90 | 36.11 |
| HT97 | 5.60 | 3.70 | 51.23 |
| HUW 34/LR 19 | 5.20 | 2.50 | 22.13 |
| KRL 237 | 5.50 | 3.00 | 23.33 |
| KRL236 | 5.30 | 3.80 | 29.89 |
| LOK 62 | 5.30 | 2.60 | 21.46 |
| NIAW 1275 | 5.20 | 4.30 | 36.84 |
| PHR 1005 | 4.50 | 3.00 | 53.55 |
| UAS 323 | 5.00 | 3.90 | 22.05 |

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## INDIAN AGRICULTURAL RESEARCH INSTITUTE
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### *Molecular and phenotypic diagnostics applied to verify the presence of rust resistance genes Lr24, Yr15, and Sr2 in a high-yielding bread wheat genotype suited for cultivation in Central India.*

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Wheat area, production, and productivity in the Central Zone (CZ) of India is steadily increasing and this increase in area is attributed to a slow shift from rainfed to limited irrigated areas with the advent of modern irrigation facilities adopted by farmers. This shift leads to an increase in the demand for cultivars suitable for irrigated, timely sown conditions. A bread wheat genotype developed at the IARI, Regional Station, Wellington, and designated as HW 5207, has the potential to meet this requirement, because it has shown consistent yield under conditions prevailing in the CZ. The proposed cultivar carries the durable stem rust resistance gene *Sr2* and leaf rust resistance gene *Lr24* (resistant to all Indian pathotypes of leaf rust) providing high degree of resistance to stem and leaf rusts and *Yr15* for yellow rust resistance. Thus, the identification of HW 5207 as a suitable genotype for cultivation in the CZ will provide an alternative as well as add to the desired genetic variability in terms of yield and rust resistance in the CZ.

**Materials and methods.** The wheat genotype HW 5207 (HW stands for Hybrid Wellington) was developed by the pedigree method from the cross 'HW 3029//*Yr15* (V763-2312)' and tested under multilocation yield trials in the CZ conducted under the aegis of All India Coordinated Wheat and Barley Improvement Project (AICW&BIP) coordinated by the Directorate of Wheat Research (DWR), Karnal (Haryana) for irrigated, timely sown conditions. Trials were conducted over three years, starting with 2007–08, to evaluate yield ability (DWR 2007a, 2008a, 2009a). Yield potential was evaluated comparatively with popular wheat cultivars of the CZ, GW 322, GW 366, Lok 1 ,and HI 1544 (checks). Yield trials were conducted in the states of Gujarat, Madhya Pradesh, Rajasthan, Chhattisgarh, and Uttar Pradesh on selected representative locations. Rust resistance under artificial epidemics was evaluated simultaneously for three years beginning in 2006–07 by entering the genotype in the multilocational Initial Plant Pathological Screening Nursery (IPPSN) and Plant Pathological Screening Nursery (PPSN) conducted by the DWR, Karnal (DWR, 2007b, 2008b, 2009b). After establishing artificial epidemics at multilocations following the method of Joshi et al (1982), the rust scores were determined as Average Coefficient of Infection (ACI) calculated by a formula (Joshi et al. 1982). Reaction to rusts also were recorded under natural conditions at all the test locations following the Peterson scale (Peterson et al. 1948). Only the highest score observed under natural conditions among multilocations was considered. Seedling resistance tests also were made during 2008–09 and 2009–10 at the DWR, Regional Station, Flowerdale, Himachal Pradesh (Prashar et al. 2009). Seedling reactions produced with Indian rust pathotypes were recorded by following the standard methods described by Nayar et al. (1997).

***Validation of rust resistance genes Sr2, Lr24 and Yr15 applying molecular markers.*** Stem rust resistance gene *Sr2* was confirmed by the symptoms of pseudo blackchaff on the glumes of this genotype (Fig. 1). The presence of *Sr2* was further confirmed by applying the microsatellite marker *Xgwm533* that amplified at 120 bp (Fig. 2). Leaf rust resistance gene *Lr24* in HW 5207 was speculated on the basis of pedigree details indicating HW 3029 as one of the parents developed through backcross program at the IARI, Regional Station, Wellington, Tamil Nadu, which has a rust resistance from *Thinopyrum elongatum* (Sivasamy and Brahma 1999). The presence of *Lr24* also was evidenced by seedling resistance data showing HW 5207 as resistant to all Indian pathotypes of leaf rust (Prashar et al. 2009). *Lr24* was further validated by applying the SCAR marker *SCS1302-607bp*. Similarly, the presence of another resistance gene, *Yr15*, also was confirmed by applying the SSR marker *Xgwm273-175bp*. In both cases, detection was done in $F_4$ lines developed out of the cross 'HW 3029 (*Lr24*)//V763-2312 (*Yr15*)'.

**Fig. 1.** Pseudo black-chaff symptoms recorded on the glumes of HW 5207, which indicates the presence of *Sr2* gene.

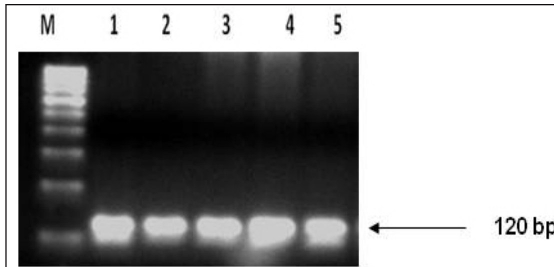


**Fig. 2.** Molecular confirmation of the presence of *Sr2* gene in HW 5207. The marker *Xgwm533* is linked to *Sr2*. Lane M = 100-bp ladder, lane 1 = Kingbird (positive control), lanes 2–5 = HW 5207.

**Results and discussion.** ***Yielding ability of HW 5207***. Genotype HW 5207 has a significantly higher mean grain yield (48.97 q/ha) over all the checks and the recently released HI 1544; it is equal with GW 322. HW 5207 has a yield potential of 51.3 q/ha. This genotype also has ranked 20 times in the first nonsignificant group out of 43 trials conducted at different locations over three years of testing, indicating a wide adaptability and stability in its performance.

***Rust resistance of HW 5207.*** HW 5207 exhibited a high degree of resistance to stem, leaf, and stripe rusts when tested at multiple locations under both artificial (PPSN sites) and natural epidemics (Yield trial sites in the states of Gujarat, Madhya Pradesh, Rajasthan, Chhatisgarh, and Uttar Pradesh). HW 5207 also showed a resistant reaction to all the pathotypes of stem and leaf rust pathogens when tested at the seedling stage at DWR, Regional Station, Flowerdale. For stripe rust, data of only one year, 2009–10, were available.

***Validation of genes Sr2, Lr24, and Yr 15 using molecular markers.*** The stem rust resistance gene *Sr2* present in this study has provided durable, broad-spectrum, adult-plant resistance to the fungal pathogen of stem rust. This resistance gene tends to be nonspecific and is currently effective against all isolates of *P. graminis* throughout wheat-growing regions of the world (Sunderwith and Roelfs 1980; McIntosh et al. 1995). The tightly linked, microsatellite marker *Xgwm533* with specific bands at 120 bp confirmed the presence of *Sr2* (Fig. 2). The HW 5207 genotype also has leaf rust resistance gene *Lr24* introgressed by backcrossing and stripe rust resistance gene *Yr15* (introgressed from Avocet/*Yr15*). Negative and positive controls also were included in our study to confirm molecular markers for *Lr24* and *Yr15*. Both genes were in the background of the wheat HW 3029 (Sivasamy and Brahma 1999). The presence of *Lr24* was confirmed by specific amplification of a single fragment of 607 bp in HD2687+*Lr24* and HW 5207, whereas no amplified product was detected in other genotypes; HD 2687 was used as a negative control (Fig. 3A, p. 83). Similarly, PCR with SSR primers of rust resistance gene *Yr15* resulted in the amplification of a 156-bp fragment in HW 5207 and the positive control 'Avocet/*Yr15*' only (Fig. 3B, p. 83); no amplified product was observed in the negative control genotype

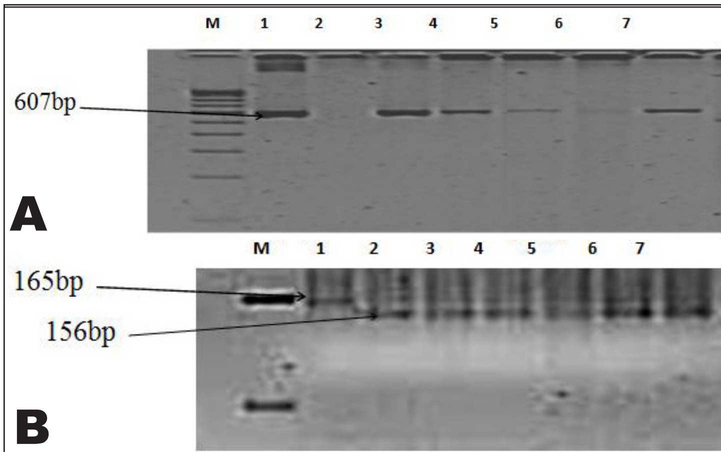


**Fig. 3.** Validation of presence of genes *Lr24* and *Yr15* in HW 5207 through molecular markers. A. Marker *Xscs1302* linked to *Lr24* (Lane M = 100-bp ladder, lane 1 = HD 2687+*Lr24* positive control, lane 2 = HD 2687 negative control, and lanes 3–7 = HW 5207). B. Marker *Xgwm273* linked to *Yr15* (Lane M = 100-bp ladder, lane 2 = HD 2687 negative control, lane 2 = Avocet*6/*Yr15* postitive control, and lanes 3–7 HW 5207).

HD 2687. The leaf rust resistance genes *Lr24* was introgressed from *Th. elongatum*, but the amplified fragment was detected only in the genotypes possessing the *Lr24* gene.

The first line of defence against wheat rusts in India obviously is the cultivation of disease resistant cultivars. Therefore, controlling wheat rust in India depends upon evolving genotypes with major genes conferring high resistance to the existing races of the rust pathogens. When rust epidemiology was investigated in India, the existence of a *Puccinia* path was evident (Nagarajan and Joshi 1980). This path is divisible into subzones depending on the time and mode of arrival of the primary inoculum. Because of a congenial temperature and October sowing, leaf rust appears early in central India, and this area acts as secondary focus of infection for the wheat crop of the North West Plain Zone (NWPZ) including other areas of the Indo-Gangetic plains. By arresting epipdemtic development of leaf rust in central India, the wheat crop can be kept free of rusts to a larger extent in the entire country. Therefore, deploying resistance genes in central India will help curtail the spread of southern Indian inoculum further to northern India (Nagarajan and Joshi 1985). Different resistance genes can be deployed along the *Puccinia* path, which necessitates deployment of strong major genes capable of restricting inoculum build up of the pathotypes at transition areas so as to avoid their further spread to other wheat zones in the country.

Bread wheat cultivar HW 5207 was developed at the IARI, Regional Station, Wellington, by crossing 'HW 3029 (*Lr24*)/V763-2312'. One of the parents, HW 3029, was developed at this station by incorporating the alien gene *Lr24* derived from *Th. elongatum* into a well-adapted wheat cultivar PBW 343 (Sivasamy and Brahma 1999). HW 5207 carries a high degree of stem and leaf rust resistance due to the presence of resistance genes *Sr2* and *Lr24*. *Sr2*, an important source of durable resistance to the wheat stem rust pathogen, is linked to the presence of pseudo-black chaff. Despite the appearance of pseudo-black chaff on the glume, the tightly linked microsatellite marker *Xgwm533* has greatly enhanced the confirmation of this gene (Fig. 2). This gene will prevent the epidemics of rust, thereby curtailing the inoculum load that might spread northward and infect the wheat crop in the NWPZ and other areas of Indo-Gangetic plains. Hence, this genotype will act as an effective genetic barrier for Nilgiri-borne leaf rust inoculum. Gene *Lr24* was molecularly confirmed using SCAR markers. Molecular tests with a SCAR marker revealed the presence or absence of *Lr24* (Fig. 3A). The *Lr24* gene is known to be linked to the gene *Sr24* conferring resistance to stem rust, which is apparently effective against all races of stem rust (Knott 1989) except race 40-1 (62G29-1) in India (Bhardwaj et al. 2010). The selection of genotypes with the molecular marker for *Lr24* gives an additional advantage of selection for *Sr24*. *Lr24* isreported to be resistant to all the races of brown rust in India (Bhardwaj et al. 2010).

Although yellow rust is not a serious problem in the CZ, it has been sporadically observed in areas of Rajasthan and Uttar Pradesh adjoining to Madhya Pradesh. Thus, the presence of *Yr15* was confirmed molecularly (Fig. 3B) in HW 5207 is a desirable and added advantage. HW 5207 is the first genotype developed in the country to have *Yr15*, which is resistant to all pathotypes of the stripe rust pathogen prevailing in India. This additional characteristic of yellow rust resistance in this genotype may extend its utility for direct cultivation in yellow rust prone areas in the NWPZ or as an effective genetic stock for breeding yellow rust resistant cultivars in India.

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## *Leaf rust resistance gene Lr34 recognized in some Indian bread wheat accessions.*

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A total of 2,200 germ plasm accessions of *Triticum aestivum* (bread wheat) were planted at the IARI, Regional Station, Wellington, Tamil Nadu (11°22' N 76°46' E, elevation 1,817 m, rainfall 1,500 mm) during summer (May to September) of 2011. Genotypes were sown in single, 1-m rows with 23 cm spacing maintaining one infector/spreader line after every 20th genotype along with border rows of the universally susceptible bread wheat cultivar Agra Local. Recommended cultural practices were followed until harvest.

Leaf rust survives at Wellington year round through the agencies of self sown/stray plants, breeding materials planted regularly by Indian wheat breeders for resistance evaluation, and a green bridge maintained at the station for the regular supply of rust inoculum to the breeding program. The leaf rust pathotypes 77A(109R31), 77-5(121R63-1), 77-7(121R127), 77-8(253R31), and 17(61R24) were identified from random leaf rust samples collected from fields planted with accessions and analyzed following Nagarajan et al. (1985). Rust severity was recorded following the modified Cobb scale (Peterson et al. 1948) after accessions had completed the growth stage 87 (Zadoks et al. 1974). Simultaneous observations also were made on the presence of leaf-tip necrosis (LTN) on flag leaf. Scores of 40 and below were considered resistant and those above 40 as susceptible. Three types of LTN symptoms, designated as low, medium, and high, were categorized to determine their individual effect on the terminal severity of leaf rust in the accessions. These categories of LTN were distinguished following an earlier description that symptoms of leaf tip necrosis include 2 to 3 cm of necrosis at the end of the leaves, which extend an additional 2 to 4 cm on the edge of the leaves (Singh 1992). The effect of three different categories of LTN on the terminal severity of leaf rust was visualised by counting accessions showing various severities under each category. Genotypes categorised in different classes of LTN are presented (Table 1, pp. 85-88).

**Table 1.** Accessions grouped according to leaf-tip necrosis type (LTN) and their reaction to leaf rust (*Puccinia trticina*). Rating of % severity after Peterson et al. 1948).

| LTN type | Rust reaction | Number | Accession name |
|---|---|---|---|
| Low | Trace | 150 | IC542566, IC542567, IC536168, IC536188, EC573567, EC573571, EC573575, EC573576, EC573577, EC573579, EC573582, EC573583, EC573584, EC573587, EC573589, EC573599, EC573606, EC573629, EC573640, EC573641, EC573644, EC573645, EC573647, EC573649, IC536236, IC536238, IC536256, IC536259, EC573762, EC573766, EC573767, EC573768, EC573777, EC573779, EC573780, EC573783, EC573784, EC573785, EC573787, EC573788, EC573792, EC573820, EC573831, EC573833, EC573834, EC573837, EC573838, EC573841, EC573842, EC573843, EC573844, EC573845, EC573847, EC573853, EC573863, EC573864, EC573868, EC573888, EC573895, EC573896, EC573903, EC573905, EC573907, EC573920, EC573924, EC573925, EC573926, EC573927, EC573960, EC573970, EC573971, EC573974, EC573983, EC573994, EC574016, EC574017, EC574019, EC574020, EC574027, EC574028, EC574037, EC574047, EC574068, EC574069, EC574074, EC574077, EC574078, EC574079, EC574082, EC574086, EC574087, EC574088, EC574091, EC574092, EC574093, EC574094, EC574096, EC574097, EC574104, EC574106, EC574107, EC574108, EC574109, EC574120, EC574121, EC574122, IC536348, IC536364, IC536365, IC536366, IC536394, IC536403, IC536406, IC536510, IC536511, IC536512, IC536521, IC536524, IC535353, IC542418, IC542429, IC542430, IC542432, IC542438, EC574277, EC574313, EC574339, EC574340, EC574341, EC574347, EC574348, EC574384, EC574395, EC574396, EC574436, EC574626, EC574634, EC574749, EC574756, EC574760, EC574762, EC574763, EC577429, EC577431, EC577437, EC577440, EC577443, EC577464, EC577465, EC577486 |
| | 5 | 75 | IC542570, IC542573, IC536131, IC536156, EC573586, EC573607, EC573626, EC573632, EC573642, EC573652, IC536246, EC573800, EC573803, EC573852, EC573859, EC573875, EC573910, EC573930, EC573942, EC573957, EC574075, EC574081, EC574102, EC574113, IC536398, IC536401, IC536405, IC536409, IC542395, IC542438, EC574193, EC574231, EC574234, EC574279, EC574283, EC574289, EC574294, EC574300, EC574302, EC574305, EC574306, EC574337, EC574344, EC574345, EC574365, EC574366, EC574391, EC574394, EC574400, EC574402, EC574405, EC574406, EC574419, EC574433, EC574434, EC574480, EC574481, EC574482, EC574483, EC574502, EC574579, EC574625, EC574662, EC574667, EC574668, EC574748, EC574853, EC574854, EC574934, EC574989, EC575077, EC575079, EC575081, EC575082, EC575090 |
| | 10 | 321 | IC542568, IC542569, IC542572, IC542574, IC536125, IC536128, IC536129, IC536130, IC536136, IC536140, IC536142, IC536147, IC536158, IC536192, IC536199, IC536201, IC536202, EC573553, EC573555, EC573556, EC573557, EC573563, EC573564, EC573573, EC573574, EC573588, EC573594, IC536205, IC536208, IC536209, IC536212, IC536215, IC536226, IC536227, EC573604, EC573608, EC573609, EC573610, EC573612, EC573616, EC573617, EC573618, EC573619, EC573620, EC573622, EC573623, EC573625, EC573627, EC573646, EC573650, EC573651, EC573655, IC536237, IC536241, IC536250, EC573781, EC573790, EC573791, EC573796, EC573797, EC573798, EC573802, EC573804, EC573805, EC573806, EC573812, EC573814, EC573815, EC573824, EC573825, EC573826, EC573851, EC573854, EC573855, C573860, EC573866, EC573867, EC577530, EC577531, EC573871, EC573877, EC573878, EC573879, EC573880, EC573884, EC573886, EC573887, EC573894, EC573897, EC573899, EC573900, EC573901, EC573902, EC573908, EC573917, EC573918, EC573921, EC573938, EC573939, EC573952, EC573955, EC573956, EC573958, EC573972, EC573979, EC573980, EC573992, EC573993, EC574012, EC574018, EC574023, EC574024, EC574025, EC574026, EC574031, EC574032, EC574033, EC574041, EC574042, EC574053, EC574061, EC574062, EC574063, EC574064, EC574083, EC574099, EC574103, EC574119, EC574125, EC574126, EC574127, EC574128, EC574177, IC536349, IC536350, IC536352, IC536392, IC536523, IC535518, IC536321, IC536322, IC536324, IC536334, IC536336, IC536337, IC536338, IC536346, IC542386, IC542392, IC542397, IC542398, IC542411, IC542412, IC542416, IC542420, IC542421, IC542422, IC542423, IC542426, IC542427, IC542431, IC542433, IC542434, IC542436, EC574194, EC574195, EC574203, EC574204, EC574209, EC574230, EC574241, EC574246, EC574258, EC574278, EC574280, EC574285, EC574288, EC574292, EC574301, EC574307, EC574308, EC574309, EC574311, EC574322, EC574338, EC574343, EC574350, EC574351, EC574352, EC574356, EC574358, EC574362, EC574363, EC574369, EC574370, EC574372, EC574373, EC574374, EC574384, EC574392, EC574401, EC574404, EC574405, EC574406, EC574407, EC574408, EC574418, EC576116, EC574431, EC574432, EC574435, EC574477, EC574576, EC574577, EC574582, EC574592, EC574596, EC574612, EC574613, EC574614, EC574628, EC574629, EC574630, EC574633, EC574634, EC574637, EC574647, EC574648, EC574649, EC574650, EC574651, EC574652, EC574653 ,EC574656, EC574657, EC574658, EC574661, EC574669, EC574671, EC574711, EC574720, EC574721, EC574723, EC574737, EC574738, EC574743, EC574744, EC574745, EC574746, EC574778, EC574786, EC574793, EC574793, EC574795, EC574805, EC574809, EC574838, EC574839, EC574849, ,EC574851, EC574852, EC574856, EC574857, EC574863, EC574877, EC574879, EC574883, EC574884, EC574885, EC574886, EC574887, EC574895, EC574914, EC574915, EC574916, EC574917, EC574918,EC574919, EC574921, EC574987, EC574988, EC574992, EC574993, EC574997, EC574998, EC575001, EC575013, EC575015, EC575016, EC575028, EC575029, EC575032, EC575033, EC575036, EC575039, EC575049, EC575050, EC575058, EC575063, EC575066, EC575067, EC575068, EC575069, EC575070, EC575071, EC575072, EC575074, EC575075, EC575084, EC575085, EC575086, EC575087, EC575088, EC575089, EC575091, EC575092, EC575093, EC575094, EC575095, EC577490, EC575364 |

**Table 1.** Accessions grouped according to leaf-tip necrosis type (LTN) and their reaction to leaf rust (*Puccinia trticina*). Rating of % severity after Peterson et al. 1948).

| LTN type | Rust reaction | Number | Accession name |
|---|---|---|---|
| Low | 20 | 169 | IC542575, IC536118, IC536126, IC536132, IC536133, IC536149, IC536154, EC573545, EC573546, EC573552, EC573565, EC573570, EC573581, EC573590, EC573591, EC573593, EC573597, IC536213, IC536224, IC536225, EC573618, EC573621, EC573624, EC573635, IC536245, IC536254, IC536255, EC573793, EC573807, EC573810, EC573822, EC573823, EC573848, EC573869, EC573870, EC573873, EC573874, EC573883, EC573885, EC573889, EC573890, EC573891, EC573909, EC573923, EC573934, EC573940, EC573947, EC573949, EC573953, EC573961, EC573963, EC573964, EC573965, EC573966, EC573967, EC573969, EC573982, EC573991, EC574001, EC574002, EC574004, EC574005, EC574006, EC574011, EC574013, EC574015, EC574021, EC574045, EC574049, EC574060, EC574070, IC536359, IC536516, IC536517, IC536518, IC535487, IC535488, IC535499, IC536311, IC536339, IC536340, IC536341, IC536342, IC536347, IC542380, IC542396, IC542399, IC542408, IC542415, IC542424, IC542425, IC542428, EC574202, EC574226, EC574227, EC574240, EC574247, EC574248, EC574286, EC574287, EC574303, EC574371, EC574403, EC574479, EC574571, EC574573, EC574574, EC574578, EC574581, EC574584, EC574588, EC574591, EC574597, EC574598, EC574599, EC574613, EC574617, EC574632, EC574635, EC574636, EC574646, EC574696,EC574717, EC574719, EC574757, EC574774, EC574777, EC574791, EC574796, EC574798, EC574800, EC574806, EC574815, EC574816, EC574836, EC574837, EC574842, EC574843, EC574850, EC574855, EC574858, EC574859, EC574861, EC574878, EC574980, EC574981, EC574983, EC574985, EC574986, ,EC574991, EC574994, EC574995, EC575002, EC575007, EC575010, EC575037, EC575053, EC575164, EC575287, EC577430, EC577432, EC577433, EC577434, EC577488, EC577489, EC577492, EC575409, EC575503, EC575504 |
| | 40 | 101 | IC536121, IC536127, IC536145, IC536148, IC536150, IC536153, IC536157, EC573542, EC573544, EC573596, EC573598, IC536206, IC536207, IC536214, EC573614, EC573630, EC573638, EC573643, EC573799, EC573809, EC573817, EC573827, EC573828, EC573850, EC573892, EC573893, EC573935, EC573946, EC573950, EC573951, EC573959, EC573962, EC573995, EC573996, EC574003, EC574007, EC574009, EC574035, EC574036, EC574039, EC574055, EC574056, EC574059, IC536360, IC536361, IC536362, IC536363, IC536384, IC535356, IC535358, IC535556, IC536323, IC536345, IC542381, IC542382, IC542383, IC542384, IC542388, IC542400, IC542401, IC542407, IC542413, IC542414, EC574585, EC574589, EC574595, EC574602, EC574779, EC574841, EC574898, EC574913, EC574969, EC574975, EC574976, EC574977, EC574978, EC574979, EC575000, EC575003, EC575004, EC575005, EC575006, EC575009, EC575011, EC575018, EC575019, EC577441, EC577466, EC575391, EC575400, EC575413,EC575423, EC575426, EC575449, EC575456, EC575457, EC575466, EC575490, EC575491, EC575496, EC575505 |
| | 60 | 23 | IC536116, IC536152, EC573543, EC573914, EC574038, EC574043, EC574044, IC535273, IC535289, IC535484, IC536317, IC542385, EC574563, EC577436, EC577442, EC577444, EC577445, EC577446, EC577487, EC575487, EC575510, EC575511, EC575512 |

The effect of the three different LTN categories on terminal severity of leaf rust also was visualised by correlating the extent of LTN expression with disease severity, and it was found to have no impact on final reduction of leaf rust. The three different types of LTN do not behave differently in their effect on the terminal severity of leaf rust supporting the earlier findings of Singh (1992), wherein a range of leaf-tip necrosis was observed but without any individual effect on terminal severity in breeding populations. Many cultivars with different resistant genes have been developed and deployed to reduce the effect of leaf rust on wheat yield (Roelfs 1988; Mc Intosh 1995). However, most of these cultivars carrying major seedling resistant genes have followed the boom-and-bust cycle. For a durable solution, breeders are putting more emphasis on adult-plant resistant genes. One such gene is *Lr34*, which has been widely used as a buffer in case of the immediate breakdown of other major genes. *Lr34* is recognized by the presence of leaf-tip necrosis, and Dyck (1991) associated this trait with *Lr34*. This gene is present in a large number of cultivars either singly, or in combination, and is providing effective and durable resistance against leaf rust (Roelfs 1988; Dyck 1991).

Our observations lead us to conclude that accessions bearing LTN suffered less from leaf rust infection compared to those without this trait. Because leaf-tip necrosis has proved to be genetically linked with *Lr34* (Singh 1992; Dyck 1991), the Indian wheat germ plasm studied here can be assumed to possess this useful gene of resistance for leaf rust. These accessions may find their utility as genetic stocks for breeding varieties with durable resistance to leaf rust.

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**Table 1.** Accessions grouped according to leaf-tip necrosis type (LTN) and their reaction to leaf rust (*Puccinia trticina*). Rating of % severity after Peterson et al. 1948).

| LTN type | Rust reaction | Number | Accession name |
|---|---|---|---|
| Medium | Trace | 62 | EC573540, EC573541, EC573560, EC573568, EC573580, EC573611, EC573636, EC573648, EC573653, IC536231, IC536233, IC536234, IC536235, IC536239, EC573769, EC573856, EC573904, EC573922, EC574072, EC574100, EC574123, IC536356, IC536399, IC536408, IC536412, IC536453, IC536496, IC536506, IC542391, IC542439, EC574199, EC574200, EC574201, EC574210, EC574211, EC574212, EC574213, EC574214, EC574215, EC574216, EC574218, EC574219, EC574221, EC574229, EC574233, EC574244, EC574245, EC574257, EC574265, EC574266, EC574274, EC574282, EC574290, EC574326, EC574327, EC574413, EC574623, EC574756, EC577427, EC577428, EC577435, EC577438 |
| | 5 | 86 | IC536123, IC536159, IC536185, IC536200, IC536219, IC536221, EC573603, EC573613, EC573633, EC573654, IC536230, IC536240, IC536247, IC536257, IC536260, EC573906, EC573929, EC573937, IC542451, IC536351, IC536371, IC536377, IC536380, IC536386, IC536444, IC536467, IC536474, IC536477, IC536483, IC536311, IC542386, IC542440, IC542441, IC542442, EC574196, EC574197, EC574205, EC574222, EC574223, EC574224, EC574235, EC574238, EC574259, EC574260, EC574264, EC574267, EC574281, EC574312, EC574316, EC574317, EC574319, EC574321, EC574325, EC574328, EC574336, EC574354, EC574355, EC574361, EC574383, EC574417, EC574441, EC574442, EC574451, EC574452, EC574580, EC574624, EC574643, EC574644, EC574663, EC574664, EC574665, EC574666, EC574698, EC574794, EC574845, EC574846, EC574847, EC574889, EC575044, EC575045, EC575046, EC575047, EC575064, EC575078, EC575080, EC575083 |
| | 10 | 213 | IC536124, IC536141, IC536144, IC536155, IC536180, IC536186, IC536195, IC536198, IC536203, EC573550, EC573561, EC573562, EC573566, IC536206, IC536210, IC536211, IC536217, IC536223, EC573601, EC573628, EC573634, IC536229, IC536232, IC536242, IC536252, EC573786, EC573789, EC573794, EC573801, EC573813, EC573816, EC573821, EC573830, EC573913, EC573916, EC573931, EC573932, EC573954, EC573973, EC573978, EC573986, EC573990, EC574029, EC574030, EC574064, EC574067, EC574101, EC574177, IC536358, IC536369, IC536373, IC536376, IC536400, IC536407, IC536413, IC536440, IC536465, IC536473, IC536497, IC536505, IC536516, IC535289, IC535518, IC542379, IC542380, IC542383, IC542384, IC542388, IC542389, IC542402, IC542415, IC542422, IC542423, IC542435, IC542437, EC574208, EC574225, EC574236, EC574237, EC574239, EC574242, EC574249, EC574251, EC574252, EC574253, EC574254, EC574255, EC574261, EC574262, EC574293, EC574298, EC574310, EC574314, EC574318, EC574320, EC574323, EC574324, EC574329, EC574330, EC574331, EC574332, EC574333, EC574334, EC574335, EC574342, EC574359, EC574393, EC574430, EC576115, EC574439, EC574440, EC574466, EC574467, EC574490, EC574541, EC574583, EC574611, EC574615, EC574616, EC574618, EC574619, EC574622, EC574640, EC574645, EC574654, EC574655, EC574659, EC574660, EC574670, EC574673, EC574674 EC574675, EC574676, EC574677, EC574678, EC574679, EC574680, EC574681, EC574682, EC574683, EC574684, EC574685, EC574686, EC574695, EC574697, EC574708, EC574709, EC574710, EC574722, EC574731, EC574732, EC574733, EC574734, EC574739, EC574740, EC574741, EC574742, EC574747, EC574751, EC574758, EC574772, EC574788, EC574797, EC574801, EC574802, EC574803, EC574804, EC574811, EC574812, EC574813, EC574840, EC574844, EC574848, EC574852, EC574862, EC574863, EC574864, EC574867, EC574871, EC574875, EC574880, EC574881, EC574882, EC574888, EC574890, EC574891, EC574900, EC574901, EC574902, EC574903, EC574904, EC574905, EC574910, EC574911, EC574912, EC574920, EC574990, EC574996, EC575034, EC575035, EC575042, EC575043, EC575059, EC575060, EC575061, EC575062, EC575065, EC575076, EC575288, EC575289, EC577456, EC575365, EC575411 |
| Medium | 20 | 86 | IC536122, IC536138, IC536162, IC536170, IC536182, IC536191, IC536193, EC573547, IC536228, EC573639, IC536243, IC536249, EC573808, EC573829, EC573876, EC573936, EC573941, EC573984, EC574000, EC574014, EC574022, IC536357, IC536368, IC536370, IC536378, IC536385, IC536404, IC536454, IC536475, IC536482, IC536502, IC536515, IC535358, IC536322, IC536323, IC536324, IC542396, IC542408, EC574206, EC574207, EC574220, EC574228, EC574346, EC574386, EC574493, EC574537, EC574557, EC574558, EC574586, EC574587, EC574590, EC574593, EC574601, EC574610, EC574621, EC574687, EC574688, EC574689, EC574718, EC574759, EC574782, EC574783, EC574784, EC574785, EC574810, EC574814, EC574833, EC574834, EC574835, EC574868, EC574869, EC574870, EC574873, EC574874, EC574876, EC574892, EC574897, EC574999, EC575017, EC575051, EC575052, EC575495, EC575497, EC575498, EC575501, EC575502 |
| | 40 | 50 | IC536190, EC573551, EC573631, EC573881, EC573882, EC573943, EC573944, EC573945, EC573948, EC573968, EC574008, EC574034, EC574057, EC574058, EC574084, IC536375, IC536387, IC536471, IC536484, EC574776, EC574865, EC574866, EC574893, EC574894, EC574982, EC575008, EC577460, EC577483, EC575363, EC575401, EC575419, EC575429, EC575438, EC575442, EC575446, EC575447, EC575448, EC575452, EC575462, EC575464, EC575465, EC575488, EC575492, EC575493, EC575494, EC575499, EC575500, EC575521, EC575522, EC575523 |
| | 60 | 13 | IC536164, EC573549, EC573559, EC574494, EC574781, EC577475, EC575404, EC575514, EC575515, EC575516, EC575517, EC575520, EC575527 |


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**Table 1.** Accessions grouped according to leaf-tip necrosis type (LTN) and their reaction to leaf rust (*Puccinia trticina*). Rating of % severity after Peterson et al. 1948).

| LTN type | Rust reaction | Number | Accession name |
|---|---|---|---|
| High | Trace | 20 | IC536139, IC536168, EC573572, IC536220, EC573975, EC573976, EC573977, EC574115, IC536433, EC574273, EC574390, EC574426, EC574427, EC574437, EC574438, EC574444, EC574445, EC574446, EC574454, EC574627 |
| | 5 | 37 | EC573569, IC536222, IC536431, EC574291, EC574412, EC574421, EC574428, EC574450, EC574458, EC574459, EC574460, EC574461, EC574462, EC574463, EC574475, EC574476, EC574478, EC574484, EC574485, EC574503, EC574504, EC574642,EC574690, EC574691, EC574700, EC574701, EC574702, EC574704, EC574705, EC574706, EC574707, EC574789, EC574828, EC574829, EC574830, EC574831, EC574847 |
| | 10 | 102 | 2IC536161, IC536167, IC536174, IC536176, IC536178, IC536181, IC536183, IC536187, IC536196, IC536197, IC536204, IC536216, EC573911, EC573912, EC573987, EC573988, EC573989, EC573999, IC536475, IC536503, IC536508, EC574217, EC574268, EC574271, EC574367, EC574368, EC574387, EC574397, EC574398, EC574399, EC574409, EC574410, EC574411, EC574414, EC574415, EC574422, EC574423, EC574424, EC574429, EC574447, EC574448, EC574453, EC574455, EC574456, EC574457, EC574459, EC574460, EC574464, EC574465, EC574469, EC574470, EC574471, EC574473, EC574474, EC574487, EC574488, EC574489, EC574491, EC574492, EC574495, EC574496, EC574498, EC574570, EC574594, EC574603, EC574639, EC574642, EC574690, EC574691, EC574693, EC574694, EC574712, EC574713, EC574714, EC574715, EC574716, EC574724, EC574725, EC574726, EC574727, EC574728, EC574729, EC574730, EC574735, EC574736, EC574790 , EC574817, EC574818, EC574819, EC574820, EC574821, EC574822, EC574823, EC574824, EC574825, EC574832, EC574906, EC574907, EC574908, EC574909, EC575040, EC575041 |
| | 20 | 15 | IC536218, EC574387, EC574443, EC574468, EC574476, EC574497, EC574499, EC574501, EC574567, EC574568, EC574620, EC574826, EC574827, EC574899, EC575048 |
| | 40 | 2 | EC573997, IC536383 |
| | 60 | 1 | EC574569 |

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### *Resistance to cereal soilborne mosaic virus in durum wheat is recessive.*

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The type-member of the *Furovirus* genus, soil-borne wheat mosaic virus (WSBMV), was first identified in the U.S. about 80 years ago and, thereafter, reported in most of the wheat-growing areas of the world including Italy. In 2005, following the results of sequence and alignment analyses, the soilborne mosaic virus isolates prevalent in North America, Europe, and far-eastern Asia were subdivided into three distinct species within the *Furovirus* genus denominated by, respectively, soil-borne wheat mosaic virus, soil-borne cereal mosaic virus (CSBMV), and Chinese wheat mosaic virus (CWMV).

According to various reports, resistance to WSBMV and CWMV in common (hexaploid) wheat is governed by 1–3 major genes, whereas CSBMV resistance in durum (tetraploid) wheat is controlled by major genes as well by a plethora of genes with small effects. Indeed, as many as nine minor genes contributed by both parents have been detected in RILs from a single durum wheat cross. In hexaploid wheat, resistance to WSBMV and to CWMV generally is believed to be inherited as a dominant trait, and this view has been implicitly extended to CSBMV-resistance in durum wheat. Quite unexpectedly, observations by the senior author on $F_1$ durum wheat plants grown outdoors near Rome for