# Adult Plant Rust Resistance Associated with Leaf Pubescence in Common Bean

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**ABSTRACT**

Mmbaga, M. T., and Steadman, J. R. 1992. Adult plant rust resistance associated with leaf pubescence in common bean. Plant Dis. 76:1230-1236.

Rust disease reactions among pubescent and glabrous genotypes of *Phaseolus vulgaris* from diverse genetic origins were compared at seedling and adult plant stages in the glasshouse and field. The primary leaves of all pubescent genotypes were moderately susceptible or moderately resistant to two single uredinium cultures of *Uromyces appendiculatus* inoculated individually or as a mixture. Size and, in a few cases, density of uredinia were reduced significantly on the upper trifoliolate leaves to give moderately resistant or resistant reactions. Evaluation of reaction to 26 individual bean rust cultures of different virulence patterns showed race-nonspecific reduced uredinia size in the upper trifoliolate leaves of the pubescent genotypes and in one glabrous genotype. Selection against bean rust susceptibility at the seedling stage could result in the loss of useful germ plasm that expresses resistance at the adult plant stage.

Host resistance is an important method of controlling bean rust disease caused by *Uromyces appendiculatus* (Pers.: Pers.) Unger (24,29,31). The durability of bean rust resistance is of great concern to pathologists and breeders because of the extensive pathogenic variability of *U. appendiculatus* (10,21,25,26). All genetic data on rust resistance in beans indicate an oligogenic mode of inheritance (1,2,22), but it has been theorized that race-nonspecific resistance might be available in already identified germ plasm (9).

Components of rust resistance recognized as race-nonspecific include low receptivity (3,5) and slow rusting (18,19). Rust receptivity measured by uredinia intensity was shown to be negatively correlated with density of bean leaf trichomes, especially in the cultivars Jamaica Red (JR) and Pompadour Checa (PC) (14,27). In a study that used field-collected rust cultures, compatible reactions were obtained on the primary leaves of Pompadour Checa in the glasshouse, but the same inoculum source gave only 1-5% infection intensity on the upper leaves in the field (11,27). Both JR and PC have visible pubescence on the upper leaves of adult plants and have nearly glabrous primary leaves. Both genotypes exhibit lower receptivity to rust infection on upper leaves than on primary leaves. The reduced intensity has been attributed to the physical presence of long, straight trichomes on the abaxial surface of the upper leaves. These trichomes are nonglandular, 1–2 mm long, and are often referred to as leaf hairs. They are thought to prevent infection by not allowing the urediniospore germlings to contact the leaf surface (14,17). The term *glabrous* is used for leaves with 0–50 trichomes per square centimeter.

Other components of race-nonspecific resistance, such as reduced uredinia size, reduced spore production, and longer latent period, were not exhibited by JR (14), but reduced uredinia size was exhibited by PC (17). Sixteen lines from the Argentine landrace Alubia showed significant differences between the means of uredinia size and intensity on the glabrous primary leaves and the highly pubescent trifoliolate leaves (30).

Studies on bean leaf pubescence have shown that primary and first trifoliolate leaves of all bean genotypes have few or no long, straight trichomes, but leaves above the second trifoliolate leaf have increasing numbers of trichomes (12,16). Even though the presence of dense abaxial leaf pubescence has been associated with race-nonspecific resistance, the information available is based on only three pubescent genotypes. The objective of this study was to assess the association of abaxial leaf pubescence with rust resistance in diverse dry bean genotypes in glasshouse and field environments.

## MATERIALS AND METHODS

**Bean genotypes and rust cultures.** The following genotypes with dense pubescence and diverse genetic and geographic origins were used in this study: three selections from the Pompadour Checa (PC) landrace, from the southwestern Dominican Republic, selection 83-30 (PC83-30), selection 50 (PC50), and selection Pompadour Q (PQ-5), derived from a Pompadour Checa; Jamaica Red (JR), derived from a landrace in Jamaica;

Journal Series No. 9656, Agricultural Research Division, University of Nebraska. Nebraska Agricultural Research Division research was conducted under Title XII Bean/Cowpea CRSP Project UN/UPR/DR, AID Contract No. DAN-1310-G-SS-6008-00 and UN Project No. 21-049.

Accepted for publication 1 August 1992.

Alubia 25-1 (A25), Alubia 33-1 (A33), and Alubia 42-2 (A42), derived from an Argentinean landrace; Diacol Calima (DC), from Colombia; three African cultivars, Kabanima (KAB-5), Lyamungu 85 (LY-5), and Uyole Agricultural Center selection 221 (UAC), from Tanzania; and TB79/420LY (TB) and GO5621LY (GO), which are CIAT (Centro Internacional de Agricultura Tropical) selections for the Tanzanian bean improvement program. Genotypes with glabrous trifoliolate leaves were Pinto UI 114 (P114), Pinto EP-1 (EP-1), Pinto Fiesta (Fiesta), Great Northern Harris (Harris), a glabrous selection of Pompadour Q (PQ-1) chosen for broad susceptibility, a glabrous selection of Kabanima (KAB-1), California Small White 643 (CSW), and EMP86LY (EMP), selected for their broad specific resistance against many races; Chichara (CHI), known as a common rust-susceptible component of Pompadour Checa in the Dominican Republic; and Arroyo Loro (AL), a rust-resistant cultivar from the Dominican Republic. Another genotype from the Dominican Republic, Jose Beta (JB), was included because of its intermediate density of leaf pubescence (12).

The reactions of pubescent and glabrous genotypes to 26 single uredinium cultures that represent different virulence patterns were compared in replicated glasshouse experiments. The pubescent representatives tested were PC50, PQ-5, JR, KAB-5, TB, GO, UAC, and LY-5, and the glabrous were PQ-1, KAB-1, EP-1, Harris, Fiesta, and EMP. Of the rust cultures tested, 12 were from Honduras, 11 from Tanzania, two from the Dominican Republic, and one was from the United States, and their different and unique virulence patterns were established on the 19 standard rust differentials (21,24).

Further studies were conducted with only two of the 26 rust cultures and a few representative pubescent and glabrous genotypes. US86NP10-1 from Nebraska and 87HP2-19 from Honduras were used individually in one experiment and in a 1:1 (v/v) mixture in a second experiment. A third experiment used a field collection consisting of unidentified races from Honduras. Glabrous primary leaves and potentially pubescent fourth trifoliolate leaves were compared for rust receptivity within each genotype and between the pubescent and glabrous genotypes in glasshouse and field environments.

**Glasshouse experiment.** Bean plants were grown in 12.5-cm pots, using a soil mixture of silty loam, peat moss, vermiculite, and sand (2:2:1:1, v/v). Planting intervals were chosen to generate plants at primary-leaf and fourth-trifoliolate leaf stages for simultaneous inoculation. Six pots (replicates) with two seeds per pot were planted with each cultivar for each growth stage and each rust culture. Plants inoculated with the same culture were arranged in a randomized complete block design in a glasshouse room set at 26 C ± 1 and a 12-hr photoperiod. Inoculation was done when the primary leaves of 6- to 7-day-old seedlings were 35–65% expanded and the fourth trifoliolate leaves were 20–25% expanded on 27- to 28-day-old plants. A urediniospore suspension of 20,000–22,000 spores per milliliter and Tween 20 at 40 μg/L was used as inoculum in all experiments.

Inoculum of 26 rust cultures was applied with a modified hand sprayer described by Stavely (20). Each leaf was inoculated with four rust cultures, each derived from single uredinia and identified by virulence pattern. The primary leaves were inoculated by a quarter-leaf technique, and two opposite leaflets of the fourth trifoliolate leaves were inoculated by a half-leaf technique, a modification of Stavely's quarter-leaf technique (20). In the other experiments in which only one rust culture was applied on each plant, an unmodified hand sprayer, also described by Stavely (20), was used to spray-inoculate the abaxial leaf surfaces as uniformly as possible.

Inoculated plants were placed in a large mist chamber at 19 C ± 1 and 100% relative humidity. After 16 hr of incubation in the dark, they were moved to the glasshouse. Complete randomization of plants of different genotypes and growth stages was done during inoculation, incubation, and postincubation. Disease ratings were made 14 days after inoculation. The size of uredinia was measured with an ocular comparator (Edmund Scientific Co., Barrington, NJ) and the mean size was derived from six measured uredinia. Infection density was recorded as number of uredinia per 9 $cm^2$. Intensity of infection for the 26 cultures was estimated with the modified Cobb scale described by Stavely (23). Resistant, intermediate, or susceptible disease reactions were based on uredinia size and density according to the standard system for measuring bean rust severity (28). A mean uredinium diameter of less than 300 μm was rated resistant (R); 300–450 μm, with none larger than 500 μm, was rated moderately resistant (MR); 450–550 μm, with none larger than 600 μm, was rated moderately susceptible (MS); and 550–800 μm was rated susceptible (S) (10).

**Field experiment.** An additional pu-

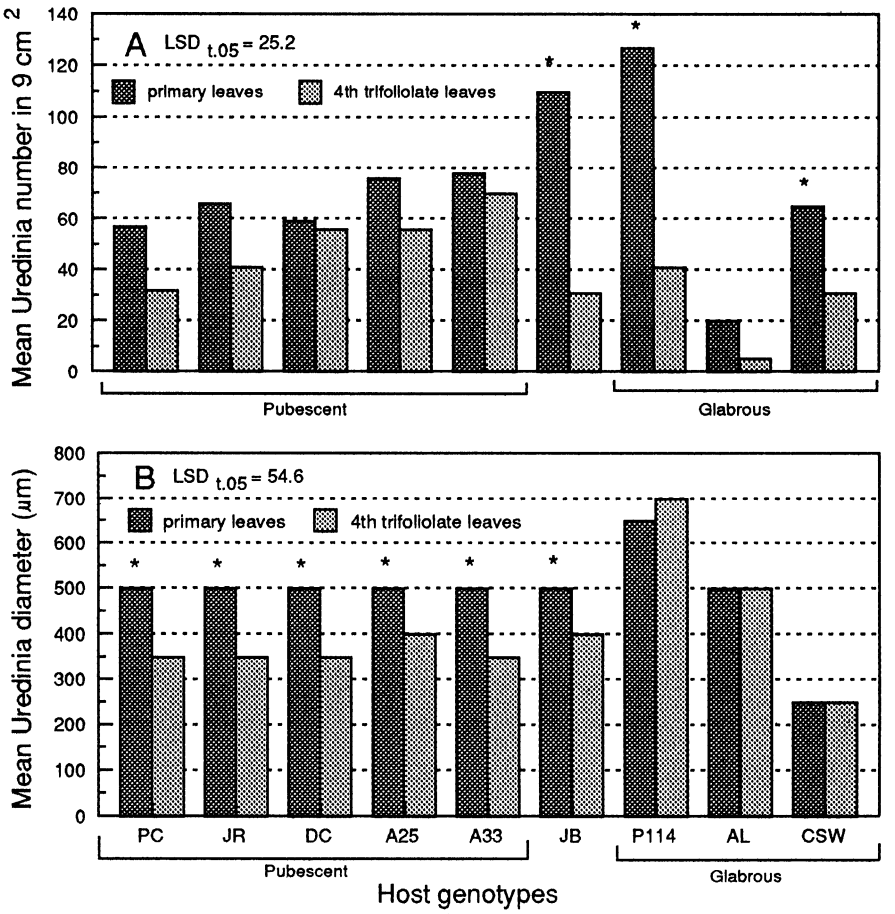


**Fig. 1.** Uredinia density **(A)** and size **(B)** of *Uromyces appendiculatus* on pubescent and glabrous bean genotypes inoculated with an unidentified race mixture at the primary and fourth trifoliolate leaf stages in the glasshouse. * = Significant differences between leaf positions at $P = 0.01$. Genotype abbreviations: PC = Pompadour Checa selection 83-30; JR = Jamaica Red; DC = Diacol Calima; A25 = Alubia line 25; A33 = Alubia line 33; JB = Jose Beta; P114 = Pinto UI 114; AL = Arroyo Loro; and CSW = California Small White 643.

bescent genotype, Pompadour AE (P.AE), was used in the field. Additional glabrous genotypes were TMO959 (TMO), a glabrous section of Lyamungu 85 (LY-1), Pompadour E (PE), and Pompadour U (PU).

A comparison of primary and fourth trifoliolate leaves for rust receptivity was done in a split-plot experimental design in which the genotypes formed the main plots and the two growth stages formed subplots. Two plantings done 3 wk apart generated plants at two growth stages in adjacent rows 1.2 m long at the West Central Research and Extension Center in North Platte, Nebraska, in an area where beans were not grown the previous year. A replication of four plots per genotype and two rows per growth stage was used. Plants, 10 and 31 days old, at primary and fourth trifoliolate leaf stages, respectively, were inoculated with urediniospores of rust cultures US86NP10-1 and US86NP5-1 in a 1:1 mixture blended in talcum powder to give approximately 25,000 spores per milliliter. A florist's central dusting-spray bottle was used to dust every row with dry inoculum. Disease was recorded 20 and 32 days after inoculation. Uredinia size was measured on a scale of 1–6 (24), and infection intensity was recorded as percentage of foliage covered with uredinia, using a modified Cobb scale (23). This experiment was conducted from June to September 1990, following a 1989 smaller experiment that utilized only four genotypes.

**Data analysis and interpretation.** Statistical Analysis Systems (SAS) was used for two-way analysis of variance on disease scores. Since leaf position effects within the genotypes represented a split-plot design, comparisons of primary versus trifoliolate leaf infection within genotypes were done by least significant differences (LSD) calculated with a split-plot formula from Gomez and Gomez (4).

## RESULTS

**Rust reaction under glasshouse environment.** In general, mean uredinia density was lower on the upper trifoliolate leaves than on primary leaves for pubescent genotypes. However, the differences often were not statistically significant and were not significant for the genotypes PC, JR, and DC, which were in all four experiments (Figs. 1–3). Glabrous genotypes often had lower uredinia density on upper trifoliolate leaves than on primary leaves. This was consistently true for the genotypes P114 and CSW, which were used in all glasshouse experiments (Figs. 1–3).

Uredinia diameters on upper trifoliolate and primary leaves of glabrous genotypes did not differ, in contrast to pubescent genotypes, which, with few exceptions, had significantly smaller uredinia diameters on the upper trifoliolate than on the primary leaves (Figs. 1–3). The genotype Jose Beta, with an intermediate abaxial pubescence density, reacted similarly to the pubescent genotypes.

Uredinia diameters on the primary leaves of all the pubescent genotypes were MS with the field rust collections, but on the fourth trifoliolate leaves they were MR. The glabrous genotypes P114, AL, and CSW developed S, MS, and R reactions, respectively, on both primary and trifoliolate leaves (Fig. 1). Few uredinia developed on Arroyo Loro, probably because of its resistance to components of the mixed races (Fig. 1). A 1:1 (v/v) mixture of two single uredinium cultures produced slightly smaller uredinia on the genotypes than did the field collection, but the results were similar in the overall differences between primary and trifoliolate leaves and pubescent versus glabrous genotypes (Fig. 2).

Results from the experiment that used a single uredinium culture on eight pubescent genotypes (Fig. 3) were similar to the results described above for 1:1 mixtures and field collections. The pubescent genotypes expressed reduced uredinia size on the trifoliolate leaves compared to the primary leaves, but pubescent genotypes TB and GO had MR reactions to US86NP10-1, and TB had MR to 87HP2-7, at both the primary and trifoliolate leaf stages, without significant change in uredinia size. Differences between genotypes in uredinia size were significant at $P = 0.001$ for both primary and trifoliolate leaf infections. The average rust reactions derived from uredinia size and density on both primary and trifoliolate leaves, from individual and mixed rust cultures, are presented in Table 1. All pubescent genotypes were categorized as MR, glabrous P114 and CHI as S, and AL and CSW as R. The uredinia density was variable in all genotypes but consistently highest in P114.

**Rust reaction under field environment.** Rust cultures US86NP10-1 and US86NP5-1 and any unidentified races that may have contributed to disease establishment in the field produced an MS reaction on the primary leaves of the pubescent JR, DC, TB, LY-5, and P.AE and the glabrous PU. Pubescent genotypes A33, GO, PC50, and PC83-30 and glabrous TM0 and LY-1 were MR, whereas the primary leaves of pubescent UAC and glabrous PE, EMP, and CSW were R. Pinto 114 was the only genotype

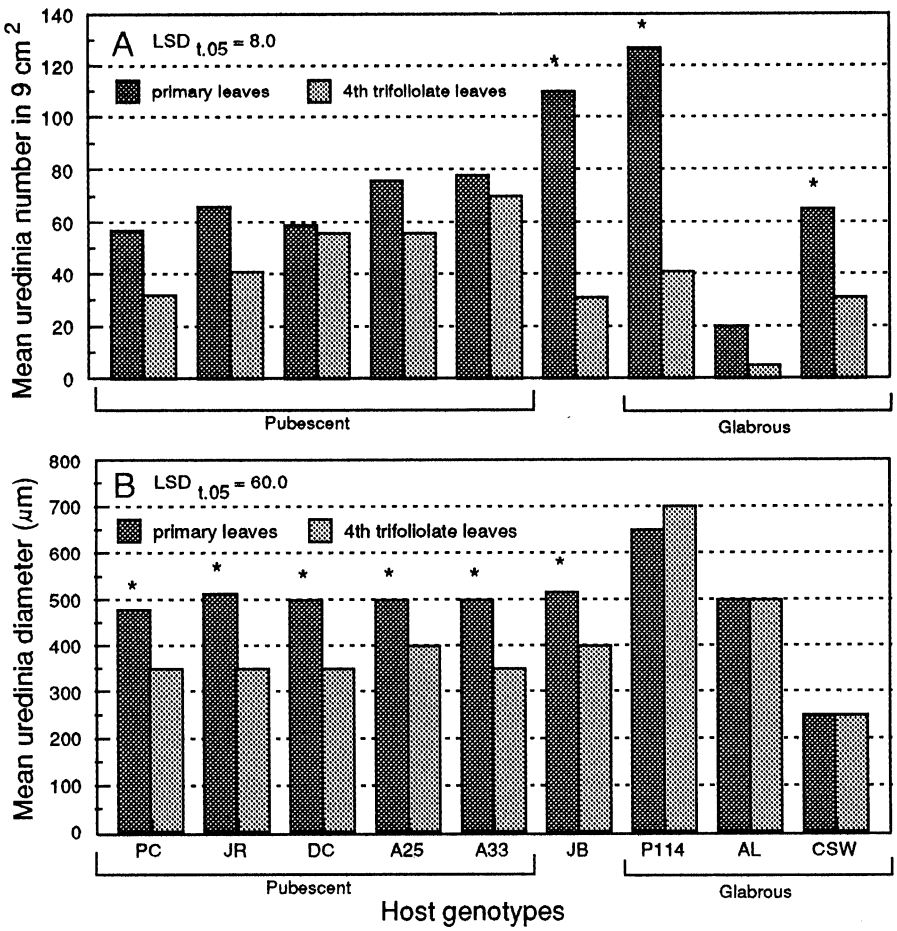


**Fig. 2.** Uredinia density **(A)** and size **(B)** of *Uromyces appendiculatus* on pubescent and glabrous bean genotypes inoculated with a 1:1 mixture of two races on primary and fourth trifoliolate leaves in the glasshouse. * = Significant differences between leaf positions at $P = 0.01$. Genotype abbreviations: PC = Pompadour Checa selection 83-30; JR = Jamaica Red; DC = Diacol Calima; A42 = Alubia line 42; KAB = Kabanima; P114 = Pinto UI 114; CHI = Chichara; and CSW = California Small White 643.

with large uredinia (>700 μm). Uredinia size was significantly smaller on the upper trifoliolate leaves than on the primary leaves in all pubescent genotypes except UAC, in which small uredinia (R) were produced on both primary and trifoliolate leaves. The primary and trifoliolate leaves of all glabrous genotypes developed uredinia of similar size (Fig. 4). The intensity of infection was slightly reduced in the upper leaves in all the pubescent genotypes, but the difference was significant only in TB and P.AE. Some glabrous genotypes also had reduced infection intensity in the upper leaves, but the difference was significant only in PE. Pinto 114 was the only genotype with significantly greater intensity on the trifoliolate leaves (infection intensity of 50%) than on the primary leaves. The other genotypes in general had less than 10% infection intensity.

**Genotype reaction to 26 rust cultures.** Differential reactions to 26 rust cultures were observed in all pubescent and glabrous genotypes except PQ-5 (MS or MR reaction to all cultures) and EP1, Harris, Fiesta, and P114 (S to all cultures) (Table 2). All other genotypes were MR, R, hypersensitive resistant (HR), or immune (I) to at least two cultures. Of the pubescent genotypes, PC50 had the most variation in rust reaction on the primary leaves (i.e., R to 10 cultures, MR to three, and MS to 11). KAB-5 was R to six cultures, MR to seven, and MS to seven. All the pubescent genotypes had smaller uredinia on the upper trifoliolate leaves compared to the primary leaves, which changed the reactions of these genotypes to different cultures from MS and MR to MR and R, respectively (Table 2). The glabrous selection of Kabanima, KAB-1, was similar to the pubescent genotypes. It was R to nine cultures and showed reduced susceptibility in the upper leaves to all the other cultures. The glabrous genotype EMP had the broadest range of resistance: R to 18 cultures, MR to two cultures, MS to two cultures, and not S to any cultures. Also, glabrous PQ-1 showed R with necrotic spots and minute uredinia of

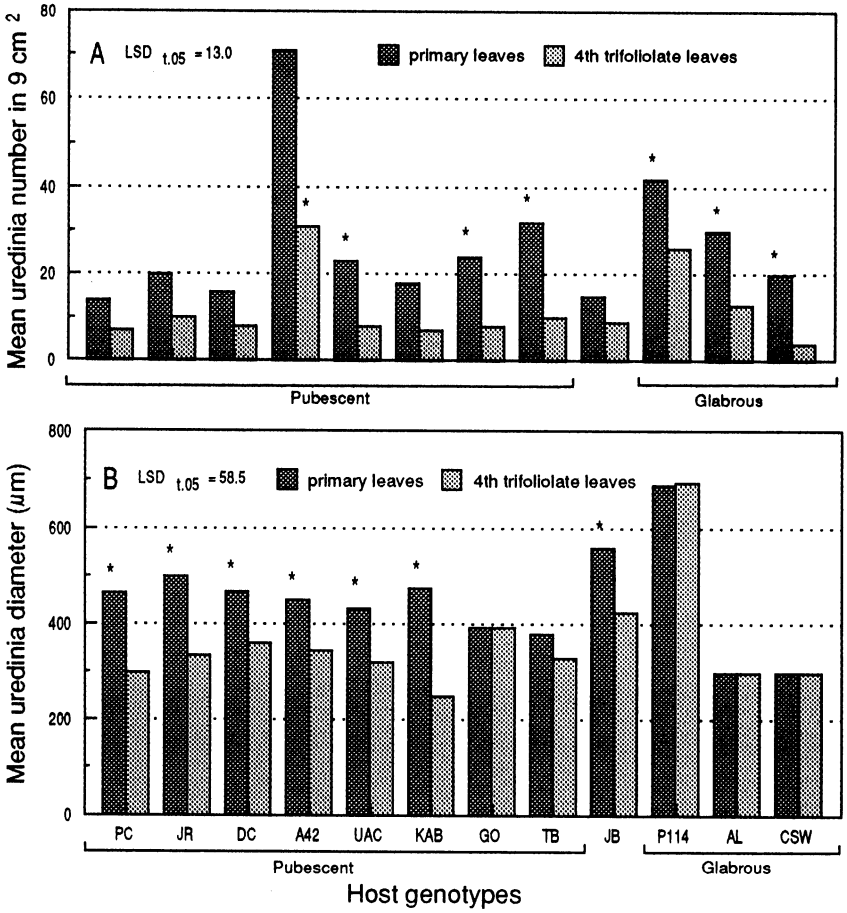


**Fig. 3.** Uredinia density **(A)** and size **(B)** of *Uromyces appendiculatus* culture US86NP10-1 on the primary and fourth trifoliolate bean leaf stages in the glasshouse. * = Significant differences between leaf positions at $P = 0.01$. Genotype abbreviations: PC = Pompadour Checa selection 83-30; JR = Jamaica Red; DC = Diacol Calima; A42 = Alubia line 42; UAC = Uyole Agricultural Center selection 221; KAB = Kabanima; TB = TB79/420LY; GO = GO5621LY; JB = Jose Beta; P114 = Pinto UI 114; AL = Arroyo Loro; and CSW = California Small White 643.

**Table 1.** Mean uredinia size (diameter) and density on pubescent and glabrous bean genotypes derived from primary and trifoliolate leaves inoculated with two cultures of *Uromyces appendiculatus* in the glasshouse

| | | Uredinia diameter (μm) | | | Uredinia density[v] | | | |
|---|---|---|---|---|---|---|---|---|
| | | Rust cultures | | | Rust cultures | | | |
| Genotype | Pubescence[w] | A (US86NP10-1) | B (87HP2-7) | A + B mixture[x] | A (US86NP10-1) | B (87HP2-7) | A + B mixture | Rust reaction[y] |
| Pompadour Checa 83-30 | P | 372.5 cd[z] | 390.0 bc | 471.9 cd | 10 c | 16 cd | 10 e | MR |
| Jamaica Red | P | 417.5 c | 415.0 b | 468.8 cd | 15 bc | 30 bc | 29 bc | MR |
| Diacol Calima | P | 413.9 c | 438.2 b | 471.9 cd | 12 c | 19 cd | 9 e | MR |
| Alubia 42-2 | P | 392.5 cd | 415.0 b | 503.1 c | 51 a | 23 cd | 34 ab | MR |
| Uyole Agric. Center 221 | P | 377.8 cd | 372.2 bc | ... | 16 bc | 23 cd | ... | MR |
| GO5621LY | P | 394.4 cd | 410.0 bc | ... | 16 bc | 24 cd | ... | MR |
| Kabanima 5 | P | 357.5 de | 442.5 b | 463.1 d | 12 c | 16 cd | 10 e | MR |
| TB79420LY | P | 355.0 de | 322.5 cd | ... | 21 b | 15 d | ... | MR |
| Jose Beta | I | 492.5 b | 465.0 b | ... | 12 c | 28 cd | ... | MS |
| Pinto UI 114 | G | 692.5 a | 702.5 a | 737.5 a | 34 a | 44 ab | 41 a | S |
| Arroyo Loro | G | 300.0 f | 300.0 cd | ... | 22 b | 51 a | ... | R |
| California Small White 643 | G | 310.0 ef | 300.0 cd | 300.0 e | 12 c | 19 cd | 25 c | R |
| Chichara | G | ... | ... | 678.1 b | ... | ... | 16 de | S |
| LSD ($P = 0.05$) | ... | 47.8 | 48.0 | 39.5 | 10 | 15 | 8 | ... |

[v] Infection density, recorded as number of uredinia per 9 cm$^2$.
[w] P = pubescent, G = glabrous abaxial side of trifoliolate leaves, I = moderately pubescent, R = resistant, MR = moderately resistant, MS = moderately susceptible, and S = susceptible.
[x] Mixture of cultures A and B (1:1, v/v).
[y] Overall rust reaction based on the mean uredinia size and density from primary and trifoliolate leaf infections (10).
[z] Values within columns followed by the same letter are not significantly different ($P \leq 0.01$) according to Student's $t$ test.

<300 μm in diameter to six cultures, I to two cultures, and S to the other cultures at both primary and trifoliolate leaf stages.

## DISCUSSION

Reduced uredinia size in the upper trifoliolate leaves compared to primary leaves characterized rust infection in most pubescent genotypes in glasshouse and field experiments. Figures 1–4 show some pubescent and glabrous genotypes with significantly lower uredinial density on upper leaves than on primary leaves. The uredinia size-reduction data could help explain reports of reduced rust severity associated with leaf pubescence (12,14,15,27); however, the data do not support the theory that the rust resistance mechanism is based only on the physical interference of infection by the trichomes (15). Certainly physical interference of urediniospore deposition would reduce the amount of effective inoculum for disease establishment on the leaf surface and therefore result in reduced uredinia density on the pubescent trifoliolate leaves compared to the glabrous primary leaves. However, since some glabrous genotypes also exhibit reduced density on trifoliolate leaves, other mechanisms must be involved. Another proposed mechanism of action of leaf pubescence that could result in reduced uredinia density relates to dew formation above the leaf surface and subsequent failure of germ tubes to contact the surface (16). The effect of leaf pubescence on the position of water film during dew formation may not be expressed if the method of moisture formation in the plastic mist chamber (i.e., use of cool-mist humidifiers during incubation) does not adequately simulate natural dew formation. Infection in the field resulted from natural dew formation, but overall infection intensity was too low on primary leaves to demonstrate significant differences from the trifoliolate leaves. A separate study on leaf-surface moisture formation is planned.

Variations in uredinia size within genotypes observed in the different experiments may be attributed to seasonal temperature fluctuations in the glasshouse as a result of variations in solar heating and fluorescent lighting at different times of the year. Experiments conducted during the fall and spring months had slightly larger uredinia than those conducted during winter, and the size increase may be a response to slightly higher temperatures, as reported by Imhoff et al (6). Since high density of uredinia can reduce the size of individual uredinia, care was taken to use moderate levels of inoculum. In any case, different experiments were analyzed separately, and comparisons between pubescent and glabrous genotypes and between primary and trifoliolate leaf stages in each experiment showed similar results. Since leaf size at the time of inoculation affects uredinia size (17), leaf age was carefully controlled and should not be a contributing factor in the slight experiment-to-experiment variation of uredinia size. The primary leaves were not classified as S in any of the pubescent genotypes to any of the rust cultures, and pubescent genotypes had reduced uredinia size on trifoliolate leaves to give MR or R reactions. Two exceptions, TB79/420LY and GO5621LY, exhibited uredinia size reduction, but the change was insufficient to affect the MR classification of the primary and upper trifoliolate leaves. The smaller uredinia size on the upper leaves, even without a change in density, would reduce the percentage of leaf area covered by uredinia and result in the reduced infection intensity on pubescent leaves as previously reported (12,14,15, 27,30).

Despite careful control of inoculation procedures, leaf pubescence was not consistently associated with a reduction in uredinia density, which would have reflected a reduction in the amount of effective inoculum. This indicates that the physical presence of the trichomes may not be the primary factor in the rust resistance on trifoliolate leaves. Reduced uredinia size in the upper leaves, however, was consistently associated with leaf pubescence in both glasshouse and field environments and resulted in a reduced susceptibility to rust in the upper leaves. This phenomenon resembles adult plant resistance in cereal rust (7,8,13) and is thought to be race-nonspecific (3,5).

When pubescent and glabrous genotypes were challenged by 26 rust cultures of different virulence patterns, the phenomenon of adult plant resistance was race-nonspecific and was also associated with leaf pubescence. Differential reactions observed in both pubescent and glabrous genotypes indicate the occurrence of race-specific resistance in both groups and also show a valuable combination of high resistance to some pathotypes and adult plant resistance to other pathotypes (i.e., in PC50 and KAB). Pubescent TB and GO, although generally not fully susceptible to most cultures, did not show significant changes in uredinia size on the upper trifoliolate leaves and gave further evidence that the phenomenon of adult plant resistance may not always be

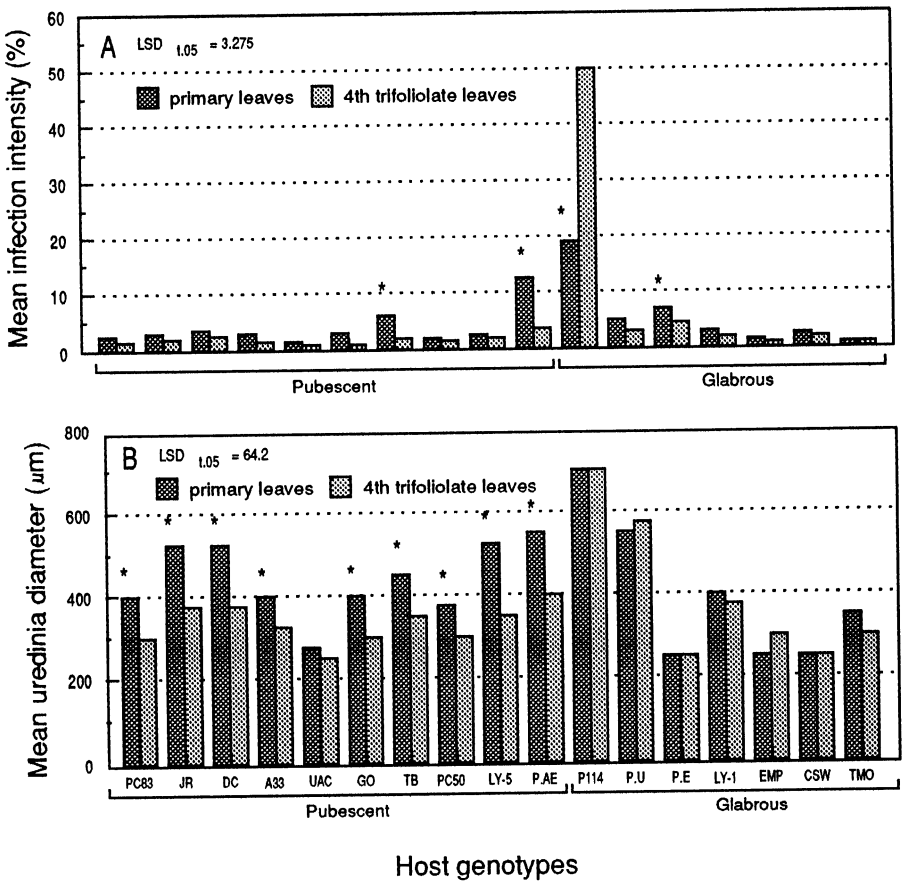


**Fig. 4.** Uredinia density **(A)** and size **(B)** of *Uromyces appendiculatus* on primary and upper trifoliolate leaf stages of pubescent and glabrous bean genotypes in North Platte, Nebraska, in 1990. * = Significant differences between leaf positions at $P = 0.05$. Genotype abbreviations: PC = Pompadour Checa selection 83-30; JR = Jamaica Red; DC = Diacol Calima; A33 = Alubia line 33; UAC = Uyole Agricultural Center selection 221; TB = TB79/42OLY; GO = GO5621LY; PC50 = Pompadour Checa selection 50, LY-5 = Lyamungu 85 pubescent selection; PAE = Pompadour AE; P114 = Pinto UI 114; PU = Pompadour U; PE = Pompadour E; LY-1 = Lyamungu 85 glabrous selection; EMP = EMP86LY; CSW = California Small White 643; and TMO = TMO595.

**Table 2.** Reactions of *Phaseolus vulgaris* host genotypes to 26 cultures of *Uromyces appendiculatus* at seedling and adult plant stages in the glasshouse

| Rust culture | Growth stage[x] | Host genotype rust reaction[y,z] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pubescent | | | | | | | | | Glabrous | | | |
| | | LY-5 | KAB-5 | PQ-5 | PC50 | UAC | GO | TB | PG | JR | KAB-1 | EMP | PQ-1 | P114 |
| H87Za3 #2 | A | MS | MR | MS | R | MR | MS | MS | MS | MS | R | R | R | S |
| | B | MR | R | MR | R | R | MR | MR | MR | MR | R | R | R | S |
| H87Za3 #10 | A | MS | MR | MS | R | MR | MS | MR | MS | MS | R | MS | HR | S |
| | B | MR | R | MR | R | R | MR | MR | MR | MR | R | MS | HR | S |
| H87Da4 #12 | A | MS | R | MS | R | MR | MR | I | MS | MS | R | R | I | S |
| | B | MR | R | MR | R | R | MR | I | MR | MR | R | R | I | S |
| TA88T1-4b | A | MS | MS | MS | R | MR | MS | MS | MS | MS | MS | R | R | S |
| | B | MR | MR | MR | R | R | MR | MR | MR | MR | MR | R | R | S |
| TA88T1-20a | A | MS | MS | MS | MS | MR | MR | MS | MS | MS | MS | R | S | S |
| | B | MR | MR | MR | MR | R | MR | MR | MR | MR | R | R | S | S |
| H87EAP7 #16 | A | MS | R | MS | R | MR | MR | MR | I | MS | MR | MR | S | S |
| | B | MR | R | MR | R | R | MR | MR | I | MR | R | MR | S | S |
| H87EAP7 #14 | A | MS | R | MS | R | I | I | MR | I | MS | R | I | I | S |
| | B | MR | R | MR | R | I | I | MR | I | MR | R | I | I | S |
| H87Za3 #16 | A | MS | MS | MS | MS | MR | MR | MS | MS | MS | MR | MR | R | S |
| | B | MR | MR | MR | R | R | MR | MR | MR | MR | R | MR | R | S |
| H87Q3 #15 | A | MS | I | MS | MS | MS | MS | MS | MS | I | R | R | R | S |
| | B | MR | I | MR | MR | MR | MR | MR | MR | I | R | R | R | S |
| T-3 | A | MS | R | MS | MS | MS | MS | MS | MS | MS | R | R | S | S |
| | B | MR | R | MR | MR | MR | MR | MR | MR | MR | R | R | S | S |
| T-1 | A | MS | R | MS | MS | MS | MS | MS | MS | MS | R | R | S | S |
| | B | MR | R | MR | MR | MR | MR | MR | MR | MR | R | R | S | S |
| H87HP2 #14 | A | MS | MR | MS | R | MS | MS | MS | MS | MS | MR | R | S | S |
| | B | MR | R | MR | R | MR | MR | MR | MR | MR | R | R | S | S |
| H87Q3 #14 | A | MR | MR | MS | R | I | I | MS | MS | I | MR | R | S | S |
| | B | MR | R | MR | R | I | I | MR | MR | I | R | R | S | S |
| T-4 | A | MR | MS | MS | MR | MR | MS | MR | MS | MS | MR | R | S | S |
| | B | MR | MR | MR | R | R | MR | MR | MR | MR | R | R | S | S |
| T-9 | A | MR | R | MS | MR | MS | MS | MS | MS | MS | R | R | S | S |
| | B | R | R | MR | R | MR | MR | MR | MR | MR | R | R | S | S |
| H87Da3 #14 | A | MR | I | MS | MS | I | I | MS | MS | I | I | I | S | S |
| | B | R | I | MR | MR | I | I | MR | MR | I | I | I | S | S |
| D85 C1-1 | A | MS | MS | MS | MS | MS | MS | MR | MS | MS | MS | R | S | S |
| | B | MR | MR | MR | MR | MR | MR | MR | MR | MR | MR | R | S | S |
| H87Da4 #20 | A | MS | MS | MS | MR | MR | I | MR | MS | I | MS | R | ... | S |
| | B | MR | MR | MR | R | R | I | MR | MR | I | MR | R | ... | S |
| T-6 | A | MS | MS | MS | MS | MR | MS | MR | MS | MS | MS | R | S | S |
| | B | MR | MR | MR | MR | R | MR | MR | MR | MR | MR | R | S | S |
| T-7 | A | I | MS | MS | MS | MR | MS | MS | MS | MS | MS | R | ... | S |
| | B | I | MR | MR | MR | R | MR | MR | MR | MR | MR | R | ... | S |
| T-8 | A | MS | MS | MS | MS | MR | MS | MS | MS | MS | MS | R | ... | S |
| | B | MR | MR | MR | MR | R | MR | MR | MR | MR | MR | R | ... | S |
| D82Vc74fh | A | MS | MS | MS | R | MS | MS | MS | MS | MS | MS | R | HR | S |
| | B | MR | MR | MR | R | MR | MR | MR | MR | MR | MR | R | HR | S |
| T-5 | A | I | MS | MS | MS | MS | MS | MR | MS | MS | MS | R | ... | S |
| | B | I | MR | MR | MR | MR | MR | MR | MR | MR | MR | R | ... | S |
| T-2 | A | I | MS | MS | MS | MS | MS | MR | MS | MS | MS | MS | ... | S |
| | B | I | MR | MR | MR | MR | MR | MR | MR | MR | MR | MS | ... | S |
| US86NP10-1 | A | MS | MS | MS | MR | MS | MR | MR | MS | MS | MS | R | S | S |
| | B | MR | MR | MR | R | MR | MR | MR | MR | MR | MR | R | S | S |
| 87HP219 | A | MS | MS | MS | MR | MS | MS | MR | MS | MS | MS | R | S | S |
| | B | MR | MR | MR | R | MR | MR | MR | MR | MR | MR | R | S | S |

[x] A = Primary leaf of seedlings; B = fourth trifoliolate of adult plants.

[y] LY-5 = Lyamungu 85, KAB-5 = Kabanima pubescent selection, KAB-1 = Kabanima glabrous selection, PQ-5 = Pompadour Q pubescent selection, PQ-1 = Pompadour Q glabrous selection, PC50 = Pompadour Checa selection 50, UAC = Uyole Agricultural Center selection 221, GO = GO5621LY, TB = TB79/420LY, PG = Pompadour G, JR = Jamaica Red, EMP = EMP86LY, and P114 = Pinto UI 114. Genotypes Harris, Pinto Fiesta, and Pinto EP-1 had the same reaction as P114.

[z] Reactions: I = immune with no symptom, HR = highly resistant necrotic spots with no uredinia, R = resistant (uredinia diameter <300 μm), MR = moderately resistant (uredinia diameter 300–450 μm, with none larger than 500 μm), MS = moderately susceptible (uredinia diameter 450–500 μm, with none larger than 600 μm), S = susceptible (uredinia diameter 550–800 μm).

associated with leaf pubescence. The reaction change in KAB-1 to a number of cultures indicates that this adult plant resistance, previously associated with leaf pubescence (11,12,14,15,27,30), may not be unique to pubescent genotypes and is related to other factors in addition to leaf pubescence. More studies are required to understand the nature of adult plant rust resistance, and the role of leaf pubescence needs to be established not only for rust but for other environmental variables as well. Rust resistance that is effective against all races of the pathogen is the ultimate control for bean rust. Irrespective of the role of leaf trichomes, screening for rust resistance at the primary leaf stage may eliminate useful germ plasm that could provide durable adult plant or field resistance. Selecting for genotypes with trifoliolate pubescence also could have a high probability of giving adult plant resistance.

**ACKNOWLEDGMENTS**

We thank K. M. Eskridge and Linda Pavlish for assistance with statistical analysis, Rand Paul for preparation of illustrations, and Daniela O'Keefe for assistance in the glasshouse work. We also thank Dale Lindgren for his assistance in the field experiments.

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