# CLUSTER ANALYSIS OF BEAN RUST (*UROMYCES APPENDICULATUS*) ISOLATES COLLECTED IN NEBRASKA AND COLORADO, 1979-1986.

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Single pustule rust isolates collected from pinto and great northern (*Phaseolus vulgaris*) cultivars were inoculated onto 19 bean rust differentials which represent sources of resistance. The most common primary leaf reaction from these 58 isolates and previously reported U.S. races 38-57 (Stavely, J.R. 1984. Plant Dis 68:95-99) were used in a cluster analysis. Using an R of 0.80 to limit variation within clusters resulted in the identification of three clusters containing more than three isolates (Fig. 1). Cluster 1 - seven isolates from three field collections obtained in 1984. Cluster 2 - two races and 18 isolates from five field collections obtained in 3 years. Cluster 3 - six races from North Dakota (Races 55, 52, and 54), Texas (Races 54 and 57), and Tennessee (Race 56) and 12 Nebraska isolates from three field collections from 3 different years.

Three races from Florida (races 45, 46 and 47) also cluster. Race 42 was also from Florida but clustered with isolates from Nebraska and Race 41, a race found commonly on the U.S. east coast. Races 38 and 39 were the only isolates from snap beans included in the analysis. They differ from the remaining isolates by their reaction types on seven differentials.

Cluster analysis was a useful tool in examining virulence relationships among *U. appendiculatus* isolates. Isolates that had similar reaction patterns were clustered. As expected isolates that were the same race had the smallest distances between them. However, in one case the distance between two distinct races was the same as the distance calculated for isolates that were from the same race. This resulted from use of the most common reaction in each isolate-differential combination to calculate distances. Environmental variation may cause small differences in the reaction type that is most common. Thus, to separate similar isolates into distinct races, second or third most common reactions on each differential should be compared.

Clusters contained isolates from different locations or years indicating the presence of virulence patterns that, with some variation, may be reappearing. Further, within one cluster were isolates obtained throughout the central U.S. This may be interpreted as evidence of widespread dispersion of *U. appendiculatus* inoculum, similar to the "Puccinia pathway".

Among 58 isolates examined in this study, 56 races of *U. appendiculatus* were identified. These new races differ from those previously reported by Stavely. Among these races was virulence to all 19 differentials. Since many of the differentials were not from the Midwest and have not been used in breeding programs, their susceptibility was an indication of unnecessary virulence within the local pathogen population.

Fig. 1. Differential reactions and dendrogram showing similarities among 20 (Stavely) races and 58 Nebraska isolates of *Uromyces appendiculatus*. Rust reactions were graded according to Stavely et al. 1983. BIC 26:iv-vi. Rust differentials were: 1-US 3; 2-CSW 643; 3-Pinto 650; 4-KW 765; 5-KW 780; 6-KW 814; 7-Golden Gate Wax; 8-Early Galatin; 9-Redlands Pioneer; 10-Ecuador 299; 11-Mex 235; 12-Mex 309; 13-Brown Beauty; 14-Pinto Olathe; 15-AXS 37; 16-NEP-2; 17-Aurora; 18-51051; 19-Campuesto Negro Chimaltenango (CNC).

| Race or Isolate | Differential Number | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| U 81 M 36bd.2 | 4,3,2 | 4,3 | 5,6 | 2,3 | 2,3 | 5,6 | 2 | 2 | 4,3 | 2 | 2 | 3 | 2 | 3,4 | 4,3 | 4,5 | 4,5 | 4,3 | 2 |
| U 82 Np 10-4 | 5 | 2 | 6 | 4 | 2,3 | 5 | 2,3 | 2,3 | 4 | 2 | 2 | 2 | 2,3 | 2,3 | 3 | 2 | 2 | 2,3 | 2 |
| U 84 M 2 | 5,6 | 4,3 | 5 | 2 | 2,3,4 | 5 | 2 | 3,2 | 5,4 | 2 | 2 | 3,4 | 3,2 | 4 | 2,3 | 2 | 2 | 2 | 4,3 |
| U 83 Np 6 | 2,3 | 3,2 | 6 | 3 | 2,3 | 6 | 1 | 2 | 4 | 2 | 2,3 | 2 | 2,3 | 4 | 3 | 2 | 2,3 | 3 | 3 |
| U 83 Cl 5 | 2,3 | 3 | 6 | 3 | 2,3 | 6 | 1 | 2 | 4 | 2 | 2 | 2,3 | 3,2 | 4 | 3 | 3 | 2,3 | 3 | 3 |
| U 84 Sb 1.2 | 4,5 | 2,3,4 | 5,4 | 3,4 | 2 | 2 | 5 | 2 | 2,3 | 2 | 2,3 | 2 | 4,5 | 5,3,4 | 2,3 | 2,3 | 2 | 2 | 2,3 |
| U 84 L 1.1 | 2,3 | 2,3 | 4 | 3,2 | 2,3 | 3,4 | 3 | 2,3 | 2,3 | 3 | 2,3 | 2,3 | 2,3 | 2,3 | 2,3 | 2,3 | 2,3 | 2 | 2,3 |
| U 84 L 1.2 | 4,3 | 2 | 4,3 | 2 | 2 | 3,4 | 2 | 2 | 2,3 | 2 | 2,3 | 2,3 | 2 | 3,2 | 3,2 | 3,2 | 2,3 | 2,3 | 2,3 |
| U 84 M 1.2 | 3,4 | 2,3 | 4,3 | 2,4,3 | 2,3 | 3 | 2,3 | 2,3 | 2,3 | 2 | 2 | 2,3 | 2,3 | 3,4,2 | 2,3 | 2,3 | 2,3 | 2,3 | 2,3 |
| U 84 M 1.1 | 5 | 2,3 | 5,6 | 2,3 | 2,3 | 3,4 | 3,4 | 2,3 | 3,2 | 2 | 2 | 2 | 2,3 | 3,4 | 2,3 | 2,3 | 2 | 2 | 3 |
| U 84 M 1.3 | 4,5 | 2,3 | 4,5 | 4,3,2 | 2,3 | 3,4 | 4,3 | 2,3 | 3 | 2 | 2 | 3,2 | 2,3 | 4,3,2 | 2 | 2,3 | 2 | 2 | 3,2 |
| U 84 Cl a1.2 | 3,4 | 2 | 4,3 | 2 | 4,3 | 2,3 | 2 | 2,3 | 2 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 2 | 2,3 |
| U 84 Cl b1.2 | 5 | 2 | 5 | 2 | 2 | 2 | 2 | 4,3 | 2 | 3 | 2 | 4 | 2,3 | 2 | 2 | 2 | 2 | 2 | 3 |
| U 81 M b-2a | 6 | 4 | 5,6 | 3 | 5,6 | 5 | 2 | 6 | 3,4 | 2 | 2 | 3 | 5 | 2,3,4 | 3,4 | 2 | 2 | 2 | 3 |
| U 81 M 36b2.1 | 6,5 | 2,3 | 6,5 | 2,3,4 | 6,5 | 5,6 | 2 | 5,6 | 5,4 | 1 | 2 | 3,2 | 5,6 | 3,2,4 | 4,3 | 2 | 2 | 2 | 3,4 |
| U 81 M 36b2.2 | 6,5 | 3,2,4 | 6,5 | 3,2 | 6,5 | 5 | 2 | 4,5 | 5 | 2 | 2 | 3 | 5 | 2 | 4,3 | 2 | 2 | 2 | 3 |
| U 85 Np 10-1 | 6 | 3 | 6 | 3 | 6 | 6 | 2 | 5 | 5 | 2 | 2 | 3 | 5 | 2 | 2,3 | 2 | 2 | 2 | 3 |
| U 84 Cl a20 | 5 | 3 | 6,5 | 2,3 | 6,5 | 5,6 | 2 | 5 | 4 | 2 | 2 | 3 | 5 | 4,3 | 3,4 | 2 | 2 | 2 | 3,4 |
| U 81 Np 1-2a | 5,6 | 3 | 5,6 | 4,3,2 | 6,5 | 5 | 2 | 4,5 | 4,5 | 2 | 2 | 3 | 4,5 | 3,4 | 2 | 2 | 2 | 2 | 2,3 |
| U 85 Np 4-1 | 6 | 2,3 | 5 | 4 | 5 | 5 | 2 | 5 | 4 | 2 | 2 | 4 | 5 | 2,3 | 2 | 2 | 2 | 2 | 2 |
| U 85 Np 11-1 | 5 | 2,3 | 5 | 4 | 5 | 5 | 2 | 5 | 4 | 2 | 2 | 3 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| RACE 42 | 5,4,6 | 3 | 5,6 | 5,4 | 5,4,6 | 4,3,5 | 2 | 4 | 3 | 2 | 2 | 3,2 | 4 | 3,4 | 2 | 2 | 2 | 2 | 3,2 |
| U 85 Np 14-1 | 5 | 4 | 5 | 4 | 5 | 4 | 2 | 4 | 4 | 2 | 2 | 4 | 4 | 5 | 2 | 2 | 2 | 2 | 2 |
| U 86 Ne 9-1 | 5 | 4 | 5 | 4 | 5 | 5 | 2 | 3 | 4 | 2 | 2 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 2 |
| U 85 Np 17-1 | 5 | 4 | 5 | 4 | 5 | 5 | 2 | 5 | 4 | 2 | 2 | 4 | 5 | 4,5 | 2 | 2 | 2 | 2 | 2 |
| U 84 Cl a2 | 4 | 3,4 | 5,6 | 3 | 5,6 | 5 | 2 | 5 | 4 | 2 | 2 | 2,3 | 4 | 4 | 2,3 | 2 | 2 | 2 | 3 |
| U 85 Np 5-1 | 5 | 2 | 4 | 2 | 5 | 4 | 2 | 4 | 4 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| RACE 41 | 5,4,6 | 3,2 | 6,5 | 2,3 | 5,4,6 | 5,4 | 2 | 4,5 | 4,3 | 2 | 2 | 3,2 | 4,5 | 2 | 2 | 2 | 2 | 2 | 2 |
| U 85 Np 3-1 | 5 | 3 | 6 | 4 | 5 | 5 | 2 | 5 | 4,5 | 2 | 1 | 3 | 5 | 4 | 3,4 | 2 | 2 | 2 | 5 |
| U 81 Sb 48g | 2,3 | 2,3 | 4 | 2,3 | 5 | 4,5 | 2 | 4,5 | 3 | 2 | 2 | 3 | 4 | 3,5 | 3 | 2 | 2,3 | 2,3 | 3 |
| U 84 Cl a1.1 | 4 | 2 | 4,5 | 2 | 5,4 | 4,5 | 2 | 4,3,2 | 3,2 | 1 | 1 | 2,3 | 3,2 | 3 | 3 | 2 | 2 | 2 | 3,2 |
| U 84 Cl b1.1 | 2,3,4 | 2 | 6,5 | 2,3 | 5 | 5 | 2 | 4,3 | 3 | 2 | 2 | 2,3 | 5,4 | 2,3 | 2,3 | 2 | 2 | 2 | 2,3 |
| U 85 Ln 14-1 | 5 | 2 | 4,5 | 4 | 5 | 4,5 | 2 | 5 | 5 | 2 | 2 | 4 | 5 | 2 | 2 | 2 | 2 | 2 | 5 |
| RACE 43 | 5,4,6 | 3 | 6,5 | 2 | 5,4,6 | 3 | 2 | 4,5 | 3,4 | 3 | 2,3 | 3,2 | 4 | 2 | 2 | 2 | 4,5 | 5,6,4 | 3,2 |
| RACE 45 | 4,5 | 3,4 | 5,6 | 3,4 | 5,6 | 3 | 1 | 4,5 | 4 | 3 | 3,2 | 3,2 | 4,3 | 2 | 2 | 4,5 | 4,5 | 3 | 2,3 |
| RACE 47 | 4,5 | 3 | 5,6,4 | 3 | 5,6 | 3 | 2 | 4,3 | 4,5,3 | 3 | 3,2 | 3,2 | 4,3,5 | 2 | 2,3 | 4,5 | 4,5 | 3 | 1 |
| RACE 46 | 5,4,6 | 3,4 | 5,6,4 | 3,4 | 5,6 | 3,4 | 4,5 | 4,3,5 | 4,3 | 3 | 3,2 | 3,2 | 4,3,5 | 3,2 | 4,5 | 5,4,6 | 4,5 | 3 | 2 |
| U 81 Sb 48e.1 | 5,4 | 2,3 | 4,5 | 3 | 5,6 | 3 | 2 | 4,5 | 3,4 | 5 | 2,3 | 3 | 4 | 3,2 | 3,2 | 2 | 2 | 3,2 | 2,3 |
| U 81 Sb 48e.2 | 5 | 2,3 | 4 | 2,3 | 5 | 3 | 2 | 4 | 3 | 5 | 2,3 | 2,3 | 4 | 3,2 | 3,2 | 2,3 | 2 | 3,2 | 2,3 |
| U 84 M 2sp6 | 6,5 | 4,3 | 5,6 | 2,3 | 6 | 4,3 | 2 | 2,3 | 3 | 2 | 2 | 3,4 | 2,3 | 2 | 2,3 | 2 | 2 | 2 | 3,2 |
| U 81 Sb 48f.1 | 5,6,4 | 5,4 | 5,6,4 | 4,5 | 6,5 | 3,4 | 5,6 | 4,3 | 3,4 | 2 | 2 | 3,2 | 4 | 6 | 3 | 2 | 2 | 2 | 3 |
| U 81 Sb 48f.2 | 5,4 | 5,4 | 5 | 5,4 | 5,4 | 5,4 | 4,5 | 4 | 4,3 | 2 | 1,2 | 2 | 4,5 | 5 | 3 | 2 | 2 | 2 | 2 |
| RACE 53 | 5,6,4 | 6,5 | 6,5 | 4,5 | 5,6,4 | 5,4,6 | 4,5 | 4 | 4,3 | 2 | 2 | 3,2 | 4,3 | 6,5 | 2,3 | 2 | 2 | 2 | 3,2 |
| RACE 55 | 6,5,4 | 4,3,2 | 6,5 | 5,4,6 | 5,6,4 | 5,4 | 4,5 | 4 | 3,4 | 2 | 2 | 3,2 | 4,3 | 5,6,4 | 2,3 | 2 | 2 | 2 | 3,2 |
| RACE 57 | 6,5 | 5,4 | 6,5 | 5,4 | 5,6 | 4,5 | 4,5 | 4,5 | 4,5 | 2 | 2 | 3,2 | 4 | 5,6 | 2 | 2 | 2 | 2 | 2,3 |
| U 86 Ne 6-1 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 2 | 2 | 3 | 5 | 5 | 2 | 2 | 2 | 2 | 2 |
| U 86 Ne 5-1 | 5 | 4 | 5 | 4 | 5 | 5 | 4 | 4 | 4 | 2 | 2 | 4 | 4 | 5 | 4 | 2 | 2 | 2 | 4 |
| U 86 Ne 14-1 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 2 | 2 | 4 | 4 | 5 | 4 | 2 | 2 | 2 | 2 |
| RACE 52 | 5,6,4 | 3,4,2 | 6,5 | 4,5,3 | 5,6,4 | 5,4 | 4,5 | 4,3 | 3,4 | 2 | 2 | 3,2 | 4,3 | 6,5,4 | 2,3 | 2 | 2 | 2 | 3,2 |
| RACE 56 | 5,6,4 | 3,2 | 5,6 | 4,5,3 | 5,6,4 | 4,5 | 4,5 | 4,3 | 3,2 | 2 | 2 | 2 | 4,3 | 6,5,4 | 2 | 2 | 2 | 3,2 | 3,2 |
| U 86 Ne 8-1 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 2 | 2 | 4 | 5 | 5 | 4 | 2 | 2 | 4 | 5 |
| U 86 Ne 21-1 | 5 | 4 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 2,3 | 2 | 3 | 5 | 5 | 3 | 2 | 2 | 2,3 | 5 |
| U 84 Sb 1.1 | 5,4 | 2,3 | 5,4 | 4,2 | 3 | 5,4 | 5,4 | 2,4 | 3,4 | 2 | 2 | 2 | 4,3,2 | 5,4 | 2 | 2 | 2 | 2 | 2,3 |
| U 84 Sb 16 | 5 | 2,3 | 5 | 5 | 2,3 | 5 | 5 | 2 | 4,5 | 2 | 2,3 | 3 | 2 | 5 | 2 | 2 | 2 | 2 | 2,3 |
| RACE 54 | 6,5,4 | 3,4,2 | 6,5 | 4,5,3 | 2 | 5,6 | 5,4 | 2 | 3,2 | 2 | 2 | 3,2 | 2 | 5,4,6 | 2,3 | 2 | 2 | 2 | 3,2 |
| U 86 Ne 2-1 | 5 | 3 | 6 | 5 | 6 | 5 | 5 | 2 | 4 | 2 | 2 | 2,3 | 2,3 | 6 | 3 | 2 | 2 | 2 | 3 |
| U 86 Ne 4-1 | 4 | 3 | 5 | 5 | 5 | 5 | 5 | 2 | 5 | 2 | 2 | 3 | 2,3 | 5 | 2 | 2 | 2 | 2 | 2 |
| U 86 Ne 7-1 | 5 | 3 | 6 | 5 | 4 | 5 | 5 | 2,3 | 5 | 2 | 2 | 3 | 4 | 5 | 3 | 2 | 2 | 2 | 2 |
| U 81 Np 91af | 5,6 | 5,6 | 5,6 | 5 | 5 | 5 | 2 | 2,3 | 5 | 2 | 2,3 | 3 | 2,3 | 5,6 | 4,3 | 2 | 2 | 3 | 2,3 |
| U 81 M 36ba | 5,4 | 4,5,3 | 5,6 | 4,5 | 2 | 3 | 2 | 2 | 4,3 | 4,5 | 4,5 | 3 | 2 | 5 | 2,3 | 3,4 | 5 | 3 | 3 |
| RACE 44 | 5,4,6 | 3 | 5,6 | 3,4 | 2 | 4,5,3 | 2 | 2 | 2 | 4,5 | 5,6,4 | 3,2 | 2 | 2 | 3,4 | 3,2 | 4,5 | 4,5 | 3,2 |
| RACE 51 | 2 | 5,4,6 | 5,6 | 4,5,3 | 2 | 3 | 2 | 2 | 2 | 4,5 | 5,6,4 | 4,5 | 2 | 2 | 2 | 3 | 5,4 | 4,5 | 3 |
| RACE 48 | 5,6 | 3,4 | 5,6 | 4,3 | 2 | 4,5,3 | 4,5 | 2 | 4,5 | 3 | 3 | 3,2 | 4,3 | 3,4 | 5,4 | 4,5 | 4,5 | 3 | 1 |
| RACE 49 | 5,6 | 3 | 6,5 | 3 | 2 | 4,5,3 | 4,5 | 2 | 4,5 | 3,4 | 2 | 5,6,4 | 4,5 | 3,2 | 2 | 5,4 | 5,4 | 5,4 | 3 |
| RACE 50 | 5,4,6 | 3,4 | 5,6 | 3,4 | 2 | 4,5,3 | 5,6,4 | 2 | 4,3 | 3 | 2 | 4,5 | 2 | 3,4 | 2 | 4,5 | 5,4 | 4,5 | 3 |
| U 84 Sb 17 | 5,6 | 4,3,5 | 5,6 | 5,6,4 | 2,3 | 5 | 3,4 | 2 | 5,4 | 4,5 | 4,3 | 3,4 | 3,2 | 3 | 3 | 2 | 2 | 2 | 3 |
| RACE 40 | 5,6,4 | 5,4 | 6,5 | 5,4 | 2 | 5,6,4 | 2 | 2 | 2 | 2 | 2 | 3,2 | 5,4 | 2 | 2 | 2 | 2 | 2 | 2 |
| U 85 Np 21-1 | 5 | 3 | 5 | 3 | 5 | 5 | 2 | 5 | 4 | 3 | 3 | 5 | 5 | 4 | 5 | 2 | 2 | 2 | 5 |
| U 86 Ne 13-1 | 5 | 4 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 5 | 5 | 5 | 5 | 4 | 2 | 2 |
| U 86 Ne 15-1 | 5 | 4 | 5 | 5 | 5 | 5 | 4 | 3 | 4 | 3 | 2,3 | 3 | 4 | 5 | 4 | 4 | 5 | 4 | 3 |
| U 79 Np 7a | 5 | 5 | 6 | 5 | 2 | 5 | 2 | 2,3 | 5 | 2 | 2,3 | 2 | 3,2 | 5 | 2,3 | 5 | 2 | 3,2 | 3 |
| U 84 M 10 | 5,6 | 5,6 | 5,6 | 5,4 | 5,6 | 5 | 2,1 | 5,4 | 5,4 | 2 | 2 | 1 | 5,4 | 1,2 | 3,2,4 | 2 | 2 | 1 | 1,2 |
| U 81 M 36bd.1 | 5,6 | 4,5 | 2 | 3 | 2 | 2 | 2 | 2 | 2,3 | 2 | 4,5 | 3,2 | 2 | 5,4 | 3,2 | 3 | 4,5 | 3,4 | 2,3 |
| U 81 M 36bd.2 | 2,3 | 5 | 6 | 2,3,4 | 2,3 | 3 | 5 | 2 | 3,4 | 4,5 | 4,5 | 2,3 | 3 | 5 | 3 | 3 | 5 | 3,2 | 3 |
| RACE 38 | 2,3 | 2 | 2,3 | 2 | 2 | 2 | 2 | 6 | 2 | 1 | 1 | 2 | 6,5 | 2 | 2 | 2 | 2 | 2 | 1 |
| RACE 39 | 2,3 | 2 | 3,2 | 2 | 2 | 2 | 6,5 | 6 | 2 | 1 | 1 | 2 | 6,5 | 2 | 2 | 2 | 2 | 2 | 1 |