An Estimation of Homogeneity in Crop Plants, With Special Reference To Genetic Vulnerability in the Dry Bean, Phaseolus Vulgaris L.

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Summary

A general method of quantitatively assessing genetic similarity among a set of cultivars of a given crop is proposed, and its application to dry beans in the United States is demonstrated. The method is based upon the multi-variate technique of Principal Components Analysis. Using this method it was possible to calculate a "distance" metric between any two cultivars in the set and to show that such distances were highly inversely correlated with genetic relationship estimated from a knowledge of breeding ancestry.

On the basis of distances among cultivars within given production regions (states in the U.S. in this case) and knowledge of the acres of each cultivar grown in the region, an average weighted distance metric appropriate to each region was calculated. Each derived distance metric serves as an index of "genetic homogeneity" for the crop in that region. Arguments are presented for relating the degree of vulnerability to a disease epidemic to the distance index. Indexes are calculated for nine of the major bean producing states in the United States from which it is concluded that, from the standpoint of genetic vulnerability, Colorado is most vulnerable and California least vulnerable to a region-wide epidemic affecting the bean crop.

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Heritability of Available Methionine and Other Characteristics of the Proteins of Dry Beans

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Cereals provide the bulk of the world's supply of protein for human diets. Grain legumes are important because of their relatively high protein content and their supplemental effect on the protein quality of cereal proteins. Diets of corn and beans, for example, provide protein of maximum value when the diet consists of equal proportions of corn and bean proteins. If bean proteins are not digestible and are poorly utilized, diets are of reduced value.

Rat feeding trials by one of us (D. R. W.) at the Institute of Nutrition of Central America and Panama using eight cultivars found in Guatemala revealed protein efficiency ratios (PER) that varied from as low as 0.36 to as high as 1.44. An indication that PER values may be related to digestibility was the finding of a significant correlation (r= 0.84) of these PER values with the quantity of available methionine per gram of protein (Nowick[2]). Nowick also found that the trait, available methionine per gram of protein, was negatively associated (r=0.72) with a protein fraction reported to be resistant to hydrolysis by protease enzyme.

Narrow sense heritabilities of the traits available methionine, total methionine, percent protein and related values calculated to estimate the additive genetic variability for these traits in a bean breeding program.

The materials studied were 20 advanced generation strains with two cultivars of pinto beans as checks. All 20 selections were derived from crosses made in 1962. The F_2 populations were collected into 88 bulks, selected for pinto seed coat pattern, and carried as bulks to the F_{10} generation. Then 301 of the F_{10} plants were selected and progeny rows were established in a nursery infested with the N. Y. 15 strain of common bean mosaic with the most desirable rows selected for testing in 1974 and 1975. Samples of all entries were analyzed for Udy protein, Kjeldahl nitrogen, and available methionine. Seed of these strains was sent to Dr. M. J. Silbernagel for curly top screening at Prosser, Washington. Eleven strains (nine plus two checks) which were reported resistant to curly top were the sub-set analyzed for total methionine.

The 22 entries were all pintos with typical seed patterning and pod characteristics. All but Ouray were of the semi-vine growth habit typified by U.I. 111 and were similar in maturity. The yield averages for the two years ranged from 3860 kilograms per hectacre to a low of 2580. Yield showed a small negative correlation with Udy protein. Udy protein values ranged from 24.7 percent to 18.8 percent. Kjeldahl values were slightly lower, ranging from 23.3 to 20.0. Where averaged over the two years, varieties ranked in roughly the same order in both tests.

Available methionine per gram of protein ranged in value from 15.6 mg. to 8.7 mg. These values were in the range reported by other investigators and were surprisingly high considering that the breeding program that produced these lines had not been selected for any protein or nutritional quality traits.

Total methionine was not related to available methionine which supported the idea that non-digestible protein fractions might vary in quantity from variety to variety. For example, entry 3406 had the highest total methionine content but was among the lowest tested for available methionine while entry 3382 had the smallest amount of total methionine but was also one of the lowest tested for available methionine.

Narrow sense heritabilities were calculated (Table 1) by partitioning the variance components. Udy protein showed low to moderate heritability. This finding suggested that the basic amino acids reacting to the Udy dye-binding method were genetically specified and would provide a more meaningful analysis for breeding studies than the Kjeldahl analysis. Available methionine also showed moderate heritability values while heritability values for total methionine were low or zero.

These results suggest that breeding for increased available methionine per gram of protein is a feasible goal for the Colorado pinto bean breeding program with promise for the development of cultivars with more desirable protein quality.

Table 1. Narrow sense heritabilities for protein characteristics of pinto bean cultivars grown at Fort Collins, Colorado 1974-75.

Protein Characteristic	Number of Cultivars Analyzed	Heritability
Udy	22	0.35
Kjeldahl	22	0.17
AM/Gram of Meal	22	0.48
AM/Gram of Udy	22	0.41
AM/Gram of Kjeldahl	22	0.39
TM/Gram of Meal	11	0.00
TM/Gram of Udy	11	0.25
TM/Gram of Kjeldahl	11	0.09

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[2] Nowick, E. A. 1976. Screening for nutritional value in bean proteins. M. S. Thesis, Colorado State University, Fort Collins, Colorado.

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