How Different Dry Bean Market Classes Achieve Yield: Yield System Analysis

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Large-seeded market classes yield significantly less than small- and medium-seeded market classes in most environments (Singh, 1988), (Figure 1). Dry bean yields have been on a plateau for the past two decades requiring new strategies to improve yields. Breeding for the physiological components of yield has not met expectations because for indirect selection to be successful, a trait must be highly heritable and highly correlated with the indirectly selected trait. Yield components of interest in dry beans are: days to flower, days to maturity, biological efficiency, harvest index, yield efficiency, and seed filling efficiency (Wallace and Masaya, 1988). In physiological terms, biological efficiency is a measure of light harvesting and assimilate production, harvest index measures assimilate partitioning, yield efficiency and seed filling efficiency represents assimilate translocation and sink strength. Preliminary estimates of genetic variances and heritabilities can be made from inbred lines from a population (Hallauer and Miranda, 1981). The assumption is made that inbred lines are an unselected sample of genotypes from the reference population. The objectives of this research were to examine the ways in which different market classes of dry bean achieve final yield, determine relative magnitude of heritabilities of yield components compared to yield, and develop breeding strategies to increase yields of all market classes.

Data were derived from 1986—1988 Cooperative Dry Bean Nurseries, and from 1988 advanced nurseries grown at Kimberly and Parma, ID (Myers, 1986–88). From the parameters days to flower, days to maturity, seed yield, and biomass, the following were calculated: seed fill duration, yield efficiency (seed yield/days to maturity), seed filling efficiency (seed yield/seed fill duration), biological efficiency (biomass/ days to maturity), and harvest index (yield/ biomass X 100). Data were averaged over years and locations, and biplots were derived. Nonorthogonal ANOVAs were performed on 10 locations from the 1987 CDBN for which replicated data were available, and for the navy, pinto, pink, red Mexican, and great northern advanced nurseries grown at two locations in Idaho in 1988. Genetic variances and repeatabilities were calculated for each trait of interest for each nursery. The term repeatability is used in place of heritability because this statistic indicates that the sample was drawn from a genetically unrelated reference population rather than from a population with defined genetic relatedness. Because number of replications was unequal among locations in the CDBN, average number of replications was used to calculate genetic variances and repeatabilities.

Kidneys were less efficient than other market classes with regard to photosynthate accumulation, distribution and sink strength (Figures 2—4). Great northerns and navies were similar to pinks and pintos for photosynthate accumulation, but were less efficient for assimilate distribution, translocation and sink strength (Figures 2-4).

Repeatabilities were highest for CDBN relative to advanced yield nurseries. This is probably because the CDBN reference population is more variable than that of the advanced yield nursery. Yield and yield components showed repeatabilities on the same order of magnitude. Repeatabilities for days to bloom tended to be lower than others. Pinks and navies had lower repeatabilities for yield and related yield components. For navies, the lower repeatabilities may be indicative of greater yield stability because of type II growth habit. This market class had lower GXE variance relative to other variances compared to other market classes. Pinks may lack genetic variation for yield because they are at the high end for yield.

Increasing yields in the small—seeded market classes could be achieved by crossing to the medium—seeded types and selecting for yield efficiency. Raising yields of the kidneys would be more difficult because they are generally less biologically efficient than the Mesoamerican types, and crossing barriers exist with Mesoamerican varieties (Gepts and Bliss, 1985). Limited progress could be made by intercrossing the best lines for seed growth rate and biological growth rate within kidneys. In a similar fashion, the medium—seeded market classes might be improved by intercrossing and selecting for seed and biological growth rates. Ultimately yield increases will require introgression of variation from novel sources.
Fig. 1 The medium-seeded pinks, and pintos form the high yielding group; the small-seeded navys and medium-seeded great northerns are intermediate in yield; and the large-seeded kidneys are lowest in yield. Fig. 2 Entries above and left of the diagonal achieve final yield through partitioning more photosynthate to seed whereas those below and right of the diagonal achieve yield through accumulation of greater biomass. Fig. 3 Entries above and left of the diagonal achieve yield through longer maturity whereas those below and right of the diagonal achieve yield through higher biomass growth rate. Fig. 4 Entries above and left of the diagonal achieve yield through longer maturities whereas those below and right of the diagonal achieve yield through greater seed growth rate.