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INTRODUCTION

Yield Gains can be estimated by comparing On-Farm yields vs. Potential yield (a.k.a., realized yield) or measured in common trials. The difference between On-Farm yield and Potential yield is known as the Yield Gap. Plant breeders primarily focus on increasing Potential yield while also attempting to optimize the interaction between genotype, environment, and agronomic practices to increase On-Farm yield and reduce the Yield Gap. In recent years, scientists in developing countries and the U.S. have made major advances in dry bean disease resistance, stress tolerance, and increased yield (Kelly, 2004). Agronomic and biotechnological tools have contributed to these achievements. The objective is to estimate Yield Gains in dry beans in the U.S.

MATERIALS AND METHODS

Yield gains in dry bean were estimated as: 1) Comparing On-Farm yields *vs* potential yield: Production data from the National Agricultural Statistical Service (USDA-NASS, 2013) was used to estimate of On-Farm yields, and data obtained from the Cooperative Dry Bean Nursery (CDBN) grown every year since 1950 with an average of 10 locations each year across the most important dry bean production regions in the U.S. was used to estimate Potential yield. For our comparisons, only data between 1981 and 2012 have been used from these trials to provide estimates of Potential yields during the last 30 years. The earliest year in which On-Farm yield values are available from the National Agricultural Statistics Service (NASS) is 1909 (USDA-NASS, 2013). **2) Yield gains as measured in common dry bean trials:** Common trials using cultivars released over time to specifically measure the genetic contribution of yield gain over time without confounding environmental or cultural effects. These trials were conducted by four participants in the Bean Coordinated Agriculture Project (http://www.beancap.org/) project during 2011 and 2012. They included cultivars released since 1956 for 16 navy bean and since 1965 for 20 pinto bean. Analysis of variance was used to determine interactions between location and cultivar, and linear regression was used to estimate genetic progress over time by regressing the response variables on year of cultivar release.

RESULTS AND DISCUSSION

Overall, On-Farm yield across all market classes of dry bean grown in the U.S. show a seed yield increase of 12.9 kg ha-1 yr-1 between 1909 and 2012. Potential yield data from the CDBN also shows a positive trend with and average seed yield increase of 7.3 kg ha-1 yr-1 during the last 31 years. Interpreting these results is difficult because of the large genetic diversity among market classes, yield potential, disease resistance, seed characteristics, and other traits. Therefore, we evaluated individual yield gains among four market classes, namely pinto, navy, black, and kidney beans. These four market classes account for approximately 95% of the total U.S. production.

Yield gain from selection in dry beans tested in common trials ranged between 13.9 to 17.4 kg ha^{-1} yr^{-1} for navy and pinto beans, respectively. These results are similar to the yield increases reported for soybean (Specht et al., 1984; Voldeng et al., 1997), wheat (Lopes et al., 2012), and dry beans (Singh et al., 2007) in previous studies. They are also similar to findings in this report that evaluated On-Farm and Potential yield data from the USDA-NASS and the CDBN, respectively. The fact that similar gains are found by using different sources of data suggest that the results provided here are robust and accurate. The results also suggest that yield increases have been linear since 1956 and suggest that dry bean cultivars have not reached a yield plateau for most market classes. Continued introgression of germplasm from other races of common bean should provide new sources of germplasm to enhance yield into the foreseeable future. For navy bean, seed size, plant height and maturity have not changed since 1956. Plant height for pinto bean cultivars increased from 34 to 57 cm over time due to introgression of Mesoamerican germplasm with upright Type II architecture. Seed size increased slightly in pinto bean but did not change in navy bean cultivars over time. In addition to breeding efforts and to reduce the Yield Gap found in all market classes, there is a need to keep improving management practices that allow for higher production efficiency.

Kidney beans showed a yield gain increase between 19.1 and 39.9 kg ha^{-1} yr^{-1}. This is the highest gain among all market classes, which is surprising given the challenges associated with production and genetic improvement of kidney beans. Yield gains in kidney beans have been a challenge because they have a narrow genetic base and high susceptibility to biotic and abiotic factors (Beaver and Osorno, 2009). In addition, kidney beans have the smallest yield gap among those compared. The small difference between On-Farm and Potential yield in kidney beans may result from the fact that producers of kidney beans tend to manage the crop better than for other market classes because market prices are typically higher.

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