Thoughts on breeding for increased forage yield

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Introduction Most forage crops have not experienced yield gains as impressive as those observed in annual grains crops such as maize (*Zea mays* L); in fact, yield improvement in lucerne appears to have stopped in the Midwestern USA (Riday and Brummer, 2002). I contend that much of this disparity can be explained by a failure of breeders to pursue long term recurrent selection programs within populations to capitalize on small, incremental improvements in yield over time. Many selection programs last only two or three cycles, resulting in a germplasm or cultivar release. Either no further selection is attempted or the new population is mixed with a larger germplasm pool in the belief that genetic variation is running low, a belief with little empirical support.

Context Yield is "the 'bottom line' in most plant breeding programs" (Burton, 1982), yet virtually no selection experiments have been conducted in any forage crop expressly for yield. The one striking exception is in Pensacola bahiagrass, in which linear yield improvements have been realized both in a broad based population over the course of 22 cycles and in extremely narrow based populations over the course of 14 cycles (Burton and Mullinix, 1998; Burton, 1982). The selection program was solely phenotypic mass selection; no progeny testing was used. No comparable selection experiments are available in any other forage crop. The success of Burton (1982) is based on a set of "restrictions" that he devised to streamline traditional mass selection, making it faster and more effective at concentrating desirable alleles and improving yield.

Discussion Whether phenotypic selection is the most effective method to improve yield in other forage species is unknown as experiments comparing breeding methods are scarce. Coors (1999) identified 133 maize studies that compared at least two selection methods over at least four cycles of selection. The number of comparable studies in lucerne is zero. Further, an understanding of the optimum population size and structure needed for long term, continual yield improvement is utterly lacking. Narrow populations would facilitate the concentrating of desirable alleles, yet broad based synthetics are the rule in most forage crops today. One of the populations used by Burton (1982) was derived from a single hybrid individual; through six cycles of selection, it showed linear yield gains even larger than those realized in a broad based population (Burton and Mullinex, 1998).

Suggestions Improving yield of forage crops will require a concerted effort to address several fundamental deficiencies in current breeding programs. I suggest the following: (1) Improving yield must be based on evaluation of yield *per se*; few current programs are explicitly selecting for yield *per se*. (2) Careful consideration of selection methodology, revisiting the "restrictions" proposed by Burton (1982) should be undertaken to improve efficiency. (3) Long term recurrent selection programs, continually turning cycles, are needed to evaluate gain and to result in the continual development and release of superior cultivars. (4) Selection should be conducted within populations to avoid disrupting favorable gene complexes. (5) Alternative breeding methods should be evaluated in both narrow and broad based populations to understand the effects of genetic structure on selection response. (6) Multiple improved populations, maintaining genetic diversity within the crop metapopulation, will enhance the development of hybrid or semihybrid cultivars to capture heterosis (Brummer, 1999). (7) Within the context of the foregoing research, molecular markers and genomics tools can be assessed for their utility in breeding quantitative traits. Breeding is often considered slow and inefficient, and biotechnological methods are proposed as a means of making them more effective (e.g., Cook, 1998). Given that a considerable amount of knowledge is needed about appropriate breeding methods, biotechnology does not appear to be the most likely avenue by which to improve yield.

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