Direct Selection Responses in Annual Ryegrass (*Lolium multiflorum* Lam.) Selected for Improved Winter Growth

Amandeep Dhaliwal, Kamal Chugh, and Edzard van Santen*

Dept. of Agronomy and Soils, Auburn University, AL 36849

ABSTRACT

The objective of this study was to evaluate the progress from selection for increased winter dry matter production in annual ryegrass resulting from two cycles of phenotypic recurrent selection. A 1200-plant nursery was established and subdivided into 48 blocks of 25 plants each (5 x 5 arrangement). Plants were harvested and evaluated for dry matter determination 750 GDD after transplanting. The best entries selected from each block were then intermated and bulk-harvested seed used for the next cycle. Populations C_0, C_1, and C_2 as well as check cultivars were established in a RCB design (r = 4) at five locations to assess changes in forage yield in response to selection. Multiple harvests were done on basis of GDD. A significant linear improvement over 2 cycles was obtained at three of the five locations at Belle Mina, Tallassee and Headland, AL. No change in first-cut yield was observed at Fairhope, AL due to high temperature. The negative response at Winfield correspondingly may be related to the extreme cool temperatures indicated by the fact that it took > 5 months to accumulate 1000 GDD compared to 3 months at Tallassee and 2.5 months at Fairhope. The average yield at Winfield was < 50% of the yield at Bella Mina and < 30% of the yield at Tallassee, Headland, or Fairhope. Shiwasuaoba outyielded C_2 at all locations. Population C_2 yielded at least 1158 kg ha^{-1} more than Marshall at Tallassee and Headland, whereas the differences at other locations were 174 kg ha^{-1} or less in favor of Marshall. The trends for Gulf vs. C_2 were similar to Marshall. We can thus conclude that selection in annual ryegrass for improved winter growth was successful.

INTRODUCTION

Annual ryegrass is a cool season bunchgrass, native to Southern Europe. It is a diploid specie with 2n=2x=14 and belongs to family Poaceae. It is utilized as pasture, hay, silage and cover crop due to its high palatability, forage quality, seedling vigor and persistence under close grazing. In southeast USA, autumn grown ryegrass attains 40% of its growth in spring months (December-February) and remaining 60% in late season (March-May). 30% of total production occurs in April alone. Moreover, annual ryegrass has high growth rate during spring months while less during cooler months. Therefore, due to limited availability of standing grasses in cooler months, cattle feed on stored forages which in turn increase management costs.

Increasing winter growth in annual ryegrass can been achieved through agronomic means or through plant breeding. Phenotypic recurrent selection has proven to be very successful in improving numerous forage species. Recurrent selection works on an incremental basis by increasing the frequency of desirable alleles over successive cycles while maintaining constant genetic variance for longer term selection. Recurrent selection is fairly easy to conduct in allogamous species with a strong self incompatibility system as this enforces random mating. If selection occurs before anthesis genetic gains are doubled because of biparental control of mating.

Various high dry matter yielding cultivars have been developed through phenotypic recurrent selection. Recurrent selection with restrictions increased forage yield by 16 to 19% in Pensacola bahiagrass (*Paspalum notatum* Flügge) and 6 to 7% in rye (*Secale cereale* L.).

OBJECTIVE

The objective of this study was to evaluate the progress from selection for increased winter dry matter production in annual ryegrass resulting from two cycles of phenotypic recurrent selection.

MATERIAL AND METHODS

Base population

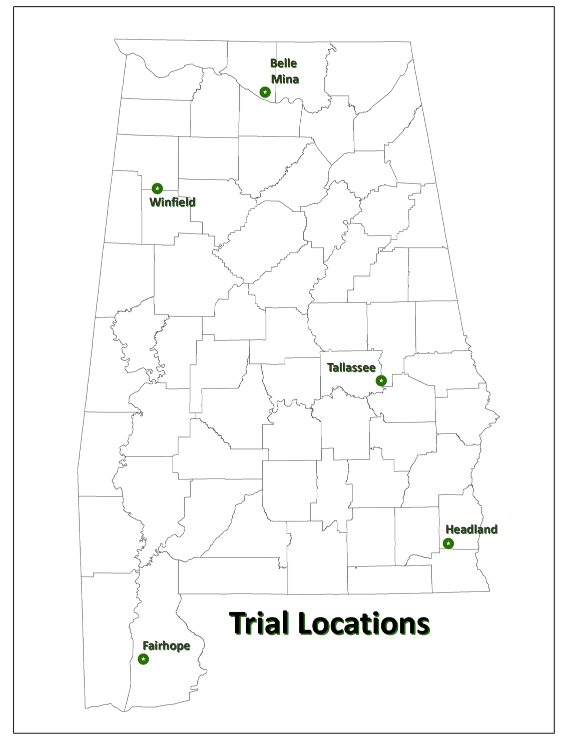
Intermating 50 plants from the six top performers in Alabama Annual Ryegrass Trials formed the base population for the selection experiment. Bulk-harvested seed from the first synthetic generation was intermated again to create a random mating population (C_0) for the selection experiment.

Selection

A 1200-plant nursery was established in late October of each year at the Plant Breeding Unit of the E.V. Smith Research Center, Tallassee, AL with plants spaced 90 cm in all directions. The nursery was subdivided into 48 blocks of 25 plants each (5 x 5 arrangement). Plants were harvested and evaluated for dry matter determination 750 growing-degree-days (GDD) after transplanting. The best entries selected from each block were then intermated in isolation and bulk-harvested seed used for the next cycle.

Seed increase

Seed for populations C_0, C_1, and C_2 was increased in isolation at the same location during the 2007/8 cropping season. In autumn 2008, seeded plots were established at five locations in Alabama (Belle Mina, Winfield, Tallassee, Headland, Fairhope) to assess changes in forage yield in response to selection. The central Alabama site (Tallassee) was the selection location. Populations C_0, C_1, and C_2 as well as check cultivars Gulf, Marshall, and Shiwasuaoba were established in a RCB design (r = 4) at each location. Plots were fertilized with 56 kg N ha^{-1} at seeding and after each harvest. The first harvest occurred 1000 growing-degree-days (GDD) post seeding, allowing 250 GDD for establishment and 750 GDD for dry matter accumulation. Thereafter, the target GDD was 750.



Statistical analysis

Trials were analyzed separately for each location. Despite choosing the most compact arrangement of plots within blocks there was sufficient unexplained variation to warrant the use of nearest neighbor analysis (NNA) based on the following approach. We therefore used NNA in a mixed models environment to evaluate progress from selection. Cycles were compared using polynomial regressions within SAS Proc Mixed. Other comparisons were based on single df contrasts.

RESULTS AND DISCUSSION

- **Selection resulted in significant first-cut gains** of 477 kg ha^{-1} cycle^{-1} ($P \leq 0.001$) at the selection location Tallassee, 396 kg ha^{-1} cycle^{-1} ($P \leq 0.007$) at Headland, and 44 kg ha^{-1} cycle^{-1} at Belle Mina ($P \geq 0.15$). No significant deviations from linearity were observed (Fig.1).
- **No change in first-cut yield was observed at Fairhope, AL.** The explanation for this non-response may be that average temperature at this location never dropped below 4 C and was mostly in the range of 10-15 C.
- **The negative response (-127 kg ha^{-1} cycle^{-1}) at Winfield ($P \leq 0.067$)** correspondingly may be related to the extreme cool temperatures indicated by the fact that it took > 5 months to accumulate 1000 GDD compared to 3 months at Tallassee and 2.5 months at Fairhope. The average yield at Winfield (790 kg ha^{-1}) was < 50% of the yield at Bella Mina and < 30% of the yield at Tallassee, Headland, or Fairhope.

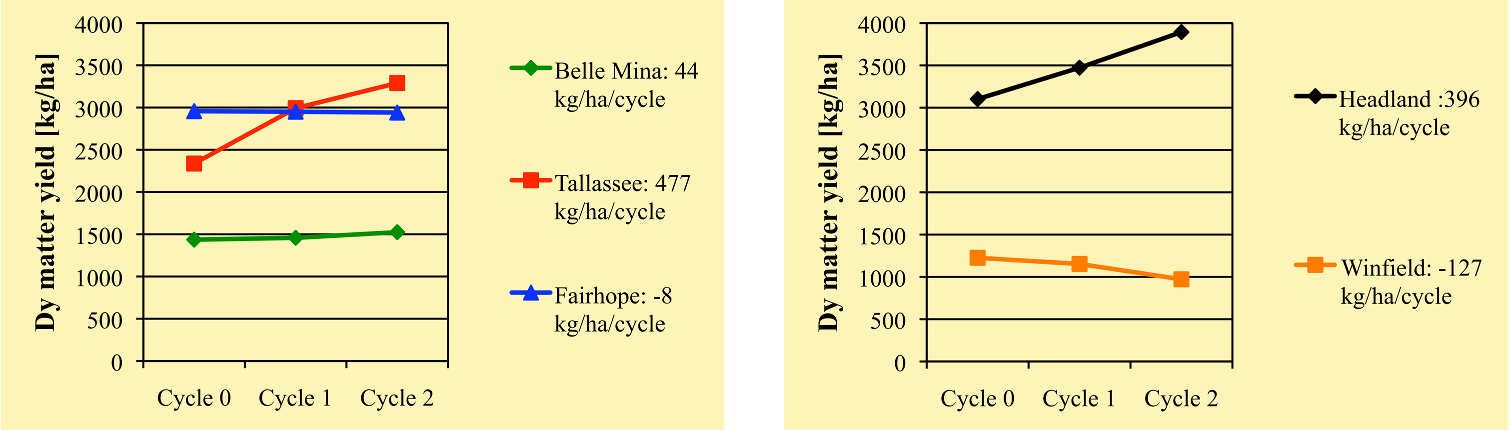


Fig. 1. First-cut yield for cycles of selection for improved winter growth. The numbers to the right of the location are the slope estimates [kg ha^{-1} cycle^{-1}].

The study author and her little helper friend.

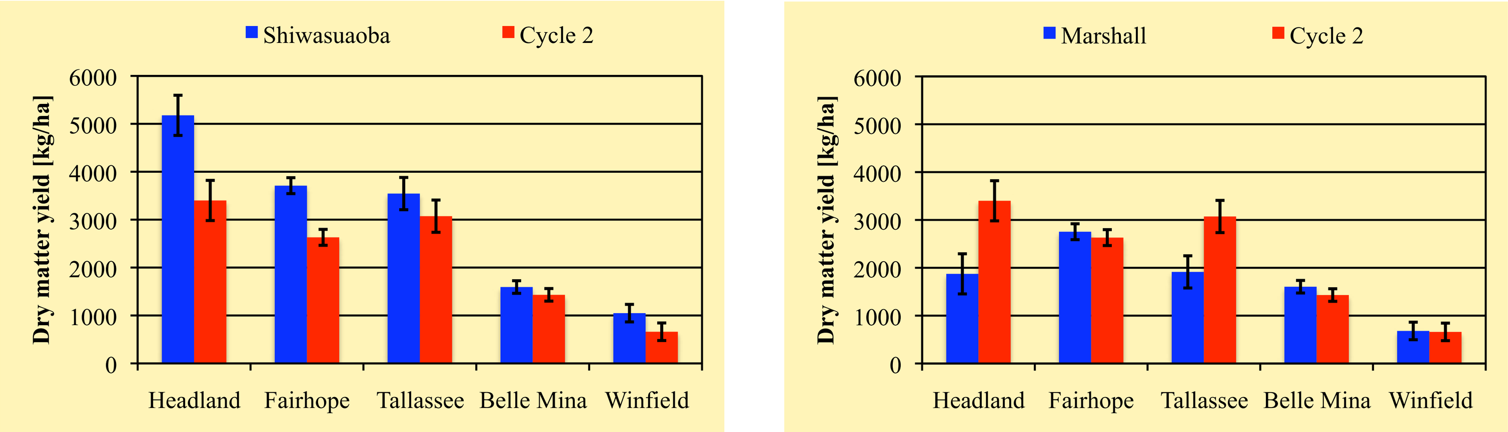


Fig. 2. Comparing first-cut dry matter yield of check cultivars Shiwasuaoba (left panel) and Marshall (right panel) to the first-cut forage dry matter yield of Cycle 2. The vertical bars represent ± 1 SED.

RESULTS and DISCUSSION *continued*

- **Shiwasuaoba outyielded C_2 at all locations, ranging from 163 kg ha^{-1} at Belle Mina to 1777 kg ha^{-1} at Headland (Fig. 2).** Shiwasuaoba is an early maturing cultivar with early fall and spring production, with seed head emergence two to three weeks earlier than Marshall and perennial ryegrass. In our trials, seed heads emerged in some cases even before the first harvest. Early head emergence makes it a useful cool season cultivar for early spring production with high nutrition and palatability. It was evaluated for adaptation and performance in the USA, where its total cumulative seasonal biomass yield was 60% of Marshall.
- **Population C_2 yielded at least 1158 kg ha^{-1} more than Marshall at Tallassee and Headland (Fig. 2), whereas the differences at the other locations were 174 kg ha^{-1} or less in favor of Marshall ($P >$ 0.50). The trends for Gulf vs. C2 were similar to Marshall.** Gulf and Marshall are long term checks used in cultivar performance trials throughout the southern USA that have never been consistently outyielded by any newer cultivar. Gulf, released in 1958 by Texas USDA-AES has higher resistance for crown rust and Texas ability than common ryegrass. It has high forage yield in the southern parts of the USA (from east Texas to Florida). It is an early maturing cultivar well adapted to coastal areas of Texas and Louisiana. It has high value for early fall and winter growth and seed yield. Marshall was released by Mississippi State University in 1980 and has high cold tolerance and seedling vigor. It is a late maturing cultivar, maturing about two weeks later than Gulf, hence providing forage for a longer period in spring than other diploid species. Therefore all these checks provide a basis for comparison of early, mid and late yield distribution.
- **Selection for one cycle based** on green matter yield or visual selection of the highest yielding genotype within a 25-plant block **did not result in any significant yield differences** except for visual rating evaluated at Belle Mina (Fig. 3). This is an important result as it provides an incentive to reduce the cost per unit gain. It takes approximately 100 person hours to harvest weigh, dry, and weigh the individual genotypes. Selection based on green matter yield would reduce this time by about 30%. The closeness of populations based on green matter selection was not a surprise given the close ranking between dry and green matter we have observed during four cycles (data not shown). That the selection based on visual criteria would perform as well was unexpected as the top-ranked genotype based on the dry matter criterion was selected in only half of the blocks in cycle 1. In 85% of the blocks visual ranking picked one of the four top ranked genotypes based on dry matter (data not shown).

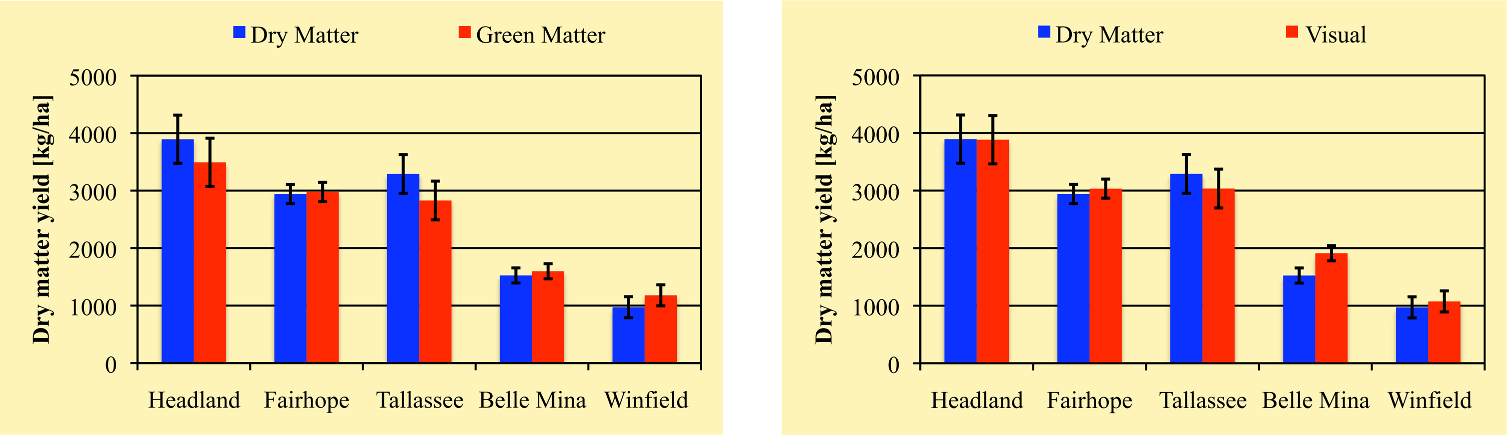


Fig. 3. Comparing cycle 2 selection based on green matter (left panel) and visual scoring (right panel) to the main selection criterion based on dry matter yield. The vertical bars represent ± 1 SED.

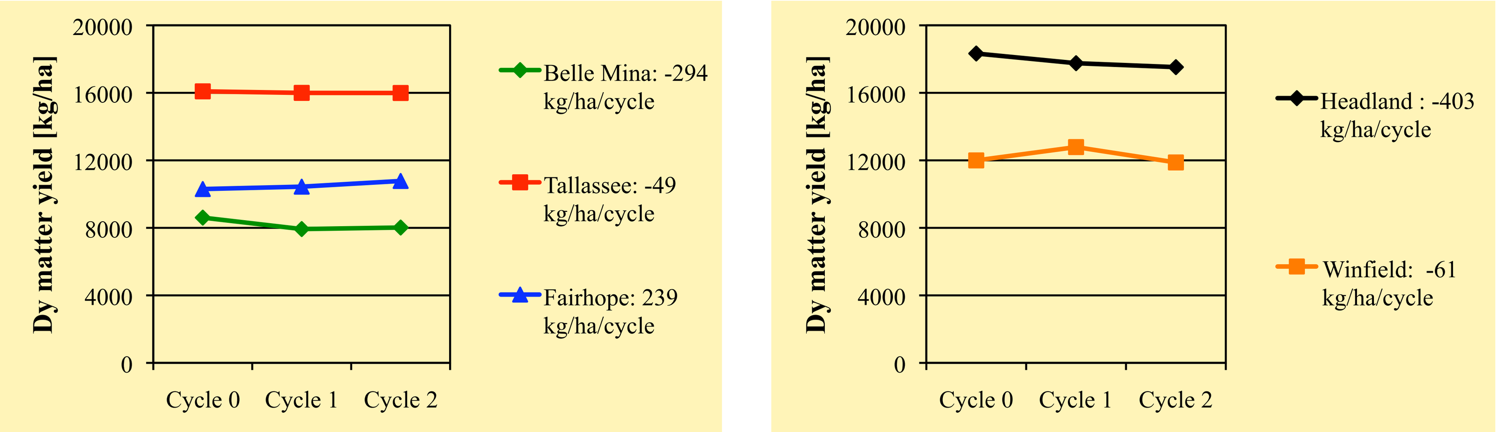


Fig. 4. Total seasonal dry matter yield for two cycles of selection for improved winter growth. The numbers to the right of the location are the slope estimates [kg ha^{-1} cycle^{-1}].

RESULTS and DISCUSSION *continued*

- **Total seasonal biomass yield changed little** over the two selection cycles, ranging from a 7% decline at Belle Mina to a 5% increase at Fairhope (Fig. 3).The only significant change observed was at Belle Mina where the decline was significant at $P < 0.007$.
- Belle Mina was the only location where the **total yield of Marshall significantly (P < 0.001) exceeded the C2 dry matter population** (Fig. 5).
- **Canonical discriminant analysis** based on population x location yield supported that major changes occurred during the first selection cycle (Fig. 6). The highest phenotypic correlations with CAN 1 were for harvest 1 at Tallassee (+), all three harvests at Headland (+ + -), and the 2[nd] harvest at Fairhope (-) (data not shown). Changes along he 2[nd] canonical axis were driven by the 3[rd] harvest at Belle Mina (+), Tallassee (+), and Fairhope (+), as well as the 2[nd] harvest at Belle Mina (+).

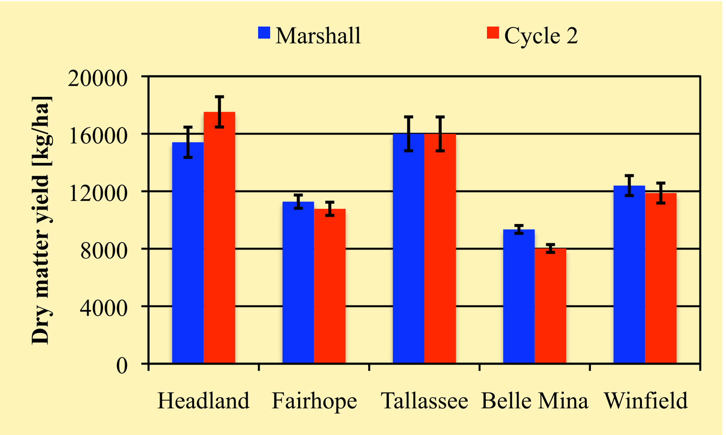


Fig. 5. Total seasonal dry matter yield of C2-dry matter yield vs. cv. Marshall.

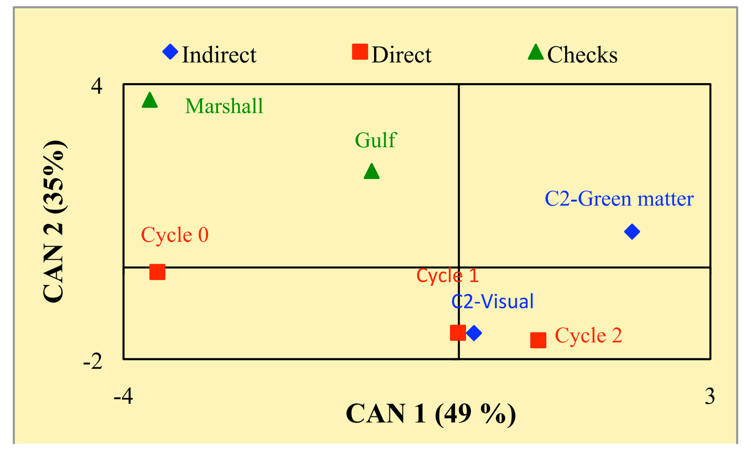


Fig. 6. Centroid means from canonical discriminant analysis using location x cut yields as predictor variables.

SUMMARY

- Two cycles of recurrent selection have shown significant response for increased dry matter yield. There was little effect on total seasonal yield. Thus the objective of changing yield distribution was achieved.
- The test locations allowed for a differentiation among cycles and populations. Locations with extremely high and low temperatures had different results.
- Indirect selection methods based on green matter yield or visual scoring of superior genotypes have shown a strong correlation with dry matter yield. Alternative responses, which are labor and cost effective, may therefore be used to assess dry matter yield during the RRP evaluation phase.

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