# Indirect Selection Response and Heritability of Forage Yield in Annual Ryegrass (*Lolium multiflorum* Lam.) Selected for Winter Growth

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## ABSTRACT

Improving winter growth of annual ryegrass through plant breeding has been successful as two cycles of phenotypic recurrent selection (PRS) in Alabama improved first-cut dry matter yields of solid seeded annual ryegrass at three out of five testing locations (see Poster by Dhaliwal et al. in this session).

The first objective of our study was to determine the indirect effects of selection for improved winter productivity on reproductive maturity, seed yield, and plant growth habit by comparing three cycles of PRS for winter growth i.e. $C_1$, $C_2$ and $C_3$ with $C_0$ (base population). The second objective was to calculate heritability of forage yield in three populations ($C_0$, $C_1$, $C_2$) of annual ryegrass.

Significant changes occurred in correlated traits between $C_0$ and $C_1$ while all responses remained constant for other selection cycles ($C_2$, $C_3$). With three cycles of selection, selected populations shifted their heading date 8-d earlier with more erect growth habit than the $C_0$.

For second objective seed was harvested from 24 random plants per isolation block from seed increase nursery (2007/08) for a total of 96 entries per population. These half-sib families were evalated under three harvest regimes: (1) harvest every 500 GDD, (2) harvest every 1000 GDD, and (3) harvest at heading plus end of season. ANOVA among HS-families confirmed the results from the solid-seeded sward studies that indicated progress from selection as well as the presence of genetic variation. Heritability estimates for the first and last cut indicated that (1) narrow sense heritability was high enough to make progress, and (2) all three populations had similar heritability. We conclude that the a priori assumption of sufficient genetic variation for winter productivity was fully warranted.

## INTRODUCTION

Improving winter productivity in Alabama of annual ryegrass, a cool season bunch grass with 2n=2x=14 chromosomes, has been successful through agronomic means by adjusting seeding date and providing supplemental early-establishment irrigation. Similarly, plant breeding efforts towards the same goal have also been successful as two cycles of phenotypic recurrent selection (PRS) improved first-cut yields of annual ryegrass at three out of five testing locations (see poster by Dhaliwal et al. at this conference).

Selection for a given trait often is accompanied by correlated changes in other traits that were not the target of the selection effort. These correlated traits might be of agronomic interest either because changes in a desired direction were induced or negative changes might require some corrective measures.

Unlike breeders of self-pollinated, highly-domesticated crops, those working with cross-pollinated but essentially non-domesticated crops often simply assume that genetic variation for the trait of interest exists and the proof is obtained through a positive selection response. Recurrent selection, particularly phenotypic, has proved to be a powerful breeding method in forage grass improvement. The underlying principle of recurrent selection is an incremental change in the frequency of desired alleles. For long-term recurrent selection programs it is important to maintain genetic variability.

## OBJECTIVES

- The first objective of our study thus was to determine the indirect effects of recurrent phenotypic selection (PRS) for improved winter productivity on reproductive maturity and plant growth habit (erectness).
- The second objective was to evaluate the effect of selection for winter growth on heritability for yield in cycles $C_0$, $C_1$, and $C_2$ of the PRS program.

## MATERIAL AND METHODS

### *Base population and selection*

Procedures are described in the poster presented by Dhaliwal et al. at this conference.

### *Seed increase*

Seed for populations $C_0$, $C_1$, and $C_2$ was increased in isolation at the same location during the 2007/8 and 2008/9 cropping seasons. Spaced-plant seed increase nurseries were replicated (RCB, r = 4 or 2), where each block was surrounded by a 10-m border of cereal rye (*Secale cereale* L.). Each nursery consisted of 200 plants transplanted on 90-cm center in all directions. As soon as heading began, heading date notes were taken every 3 d until all plants had headed. During early heading we also took plant growth habit ratings on a scale of $0 \le 15^\circ$ for the exterior reproductive tiller angle in 15° increments to 5 = tiller angle > 75° and $\le 90^\circ$. Towards the end of taking heading notes, basic disease notes (0 = no symptoms, 1 = symptoms) were taken on every plant. At seed harvest in early June 2008, 24 plants per $C_0$, $C_1$, and $C_2$ nursery were selected at random for a total of 96 plants per cycle. Seed from those plants was harvested, processed, and conditioned separately. These half-sib families were then evaluated during the 2008/9 crop year.

### *HS-progeny trial*

Three replicated HS-progeny trials (RCB; r = 2) were established at the Plant Breeding Unit, Tallassee, AL in autumn 2008. The first trial was harvested every 500 growing degree days (GDD) after a 250 GDD establishment phase. The 2nd trial was harvested every 1000 GDD, again after a 250 GDD establishment phase. Thus every other harvest coincided for these two trials. The 3rd trial was harvest at full heading and again at the end of the growing season. Each HS-family was hand-seeded to a 1-m row on a 25-cm row spacing under simulated sward conditions. All plots were hand-harvested for dry matter yield determination.

While the first harvest for the three harvest schemes occurred on different dates, the last harvest occurred on the same date and corresponded to the fourth harvest for scheme 1 and the second cut for the other two schemes.

### *Statistical Analysis*

Seed yield nursery data were analyzed on a plot (nursery) mean basis. Mixed models procedures as implemented in SAS PROC MIXED were used with year, population and interaction as fixed effects.

Heritability estimates HS progeny and associated standard errors from were obtained according the methods outlined by Holland et al. (Plant Breeding Reviews 22: 9-100, 2003) using SAS PROC MIXED and SAS PROC IML.

## RESULTS - SEED YIELD NURSERIES

### *Heading date*

The average spaced-plant heading date for selected populations ($C_1$, $C_2$, $C_3$) was 8 d earlier ($P < 0.001$) than the base ($C_0$) population while no difference was observed among selected populations ($P > 0.26$). . The change in heading date occurred during the first selection cycle. Although heading was earlier in 2009, the response was consistent between years, a result which is not surprising given the generally highly heritable nature of reproductive maturity. These changes are not trivial as they were based on the heading date of 800 genotypes in 2008 and 400 in 2009. A possible explanation for the drastic change in heading date might be due to inclusion of late maturing plants in cycle 1 which were not included in the next generations because of non synchronous flowering. The response itself however was surprising because selection was done during the early vegetative phase of growth in mid to late January at least two months prior to stem elongation.

### *Plant type*

All selected populations were significantly ($P < 0.0001$) more erect than the base population. As with heading date, most of the change occurred during the first selection cycle and no significant ($P > 0.44$) differences among selected populations were observed. During the evaluation phase of the cycle, all plants were harvested uniformly at 5 cm above ground level since the main criterion was biomass production of individual plants without considering plant habit (erect or prostrate). The association between high DM and erect plant type might be explained by a narrow plant tiller angle that resulted in more photosynthate accumulation.

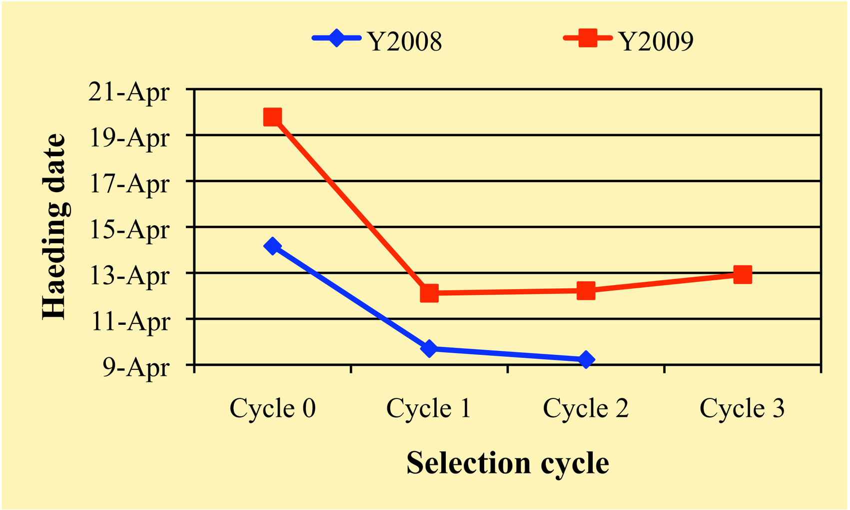


**Fig. 1.** Effect of three cycles of recurrent phenotypic selection for improved winter growth on heading date in a spaced-plant nursery.

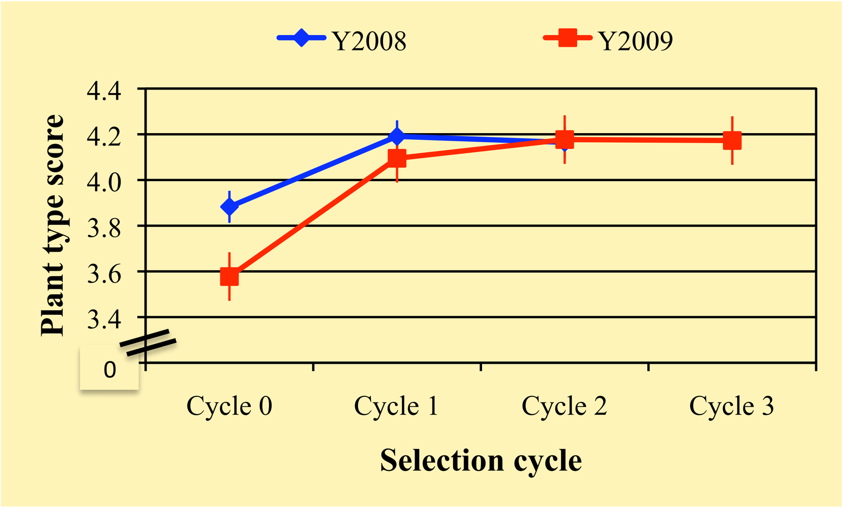


**Fig. 2.** Effect of three cycles of recurrent phenotypic selection for improved winter growth on plant erectness in a spaced-plant nursery.

## RESULTS - HS PROGENY TRIAL

### *Heritability estimates*

Most heritability estimates exceeded 2*SE and were significantly different from zero (Fig. 3) with the exception of the the cycle2 population for the first harvest of harvest scheme 2. Heritability estimates of three populations ($C_0$, $C_1$, $C_2$,) under harvest schemes and cut combinations observed were.

**Harvest Scheme1 (Fig. 3.-top row):**

- Harvest 1 - Narrow sense heritability ranged from 0.64 to 0.53 with $C_0$ having the highest heritability and $C_1$ with the lowest heritability. Of particular interest were the estimates for the first harvest of harvest scheme 1, which was Harvest 750 GDD after sowing.
- Harvest 4 – Narrow sense heritability ranged from 0.44 to 0.40 with not much difference among three populations.

**Harvest Scheme 2 (Fig. 3.-middle row):**

- Harvest 1- Narrow sense heritability spanned from 0.00 to 0.66 with almost linear decline from $C_0$ through $C_2$
- Harvest 2 – High narrow sense heritability values were observed with slight increase from $C_0$ through $C_2$, ranging from 0.62 to 0.68

**Harvest Scheme 3 (Fig. 3.-bottom row):**

- Harvest 1- Observed linear increase in narrow sense heritability values from population $C_0$ through $C_2$ with a span of 0.36 to 0.59
- Harvest 2 – $C_0$ and $C_2$ showed high narrow sense heritability values of 0.60 and 0.64 respectively while 0.39 was the estimate for $C_1$.

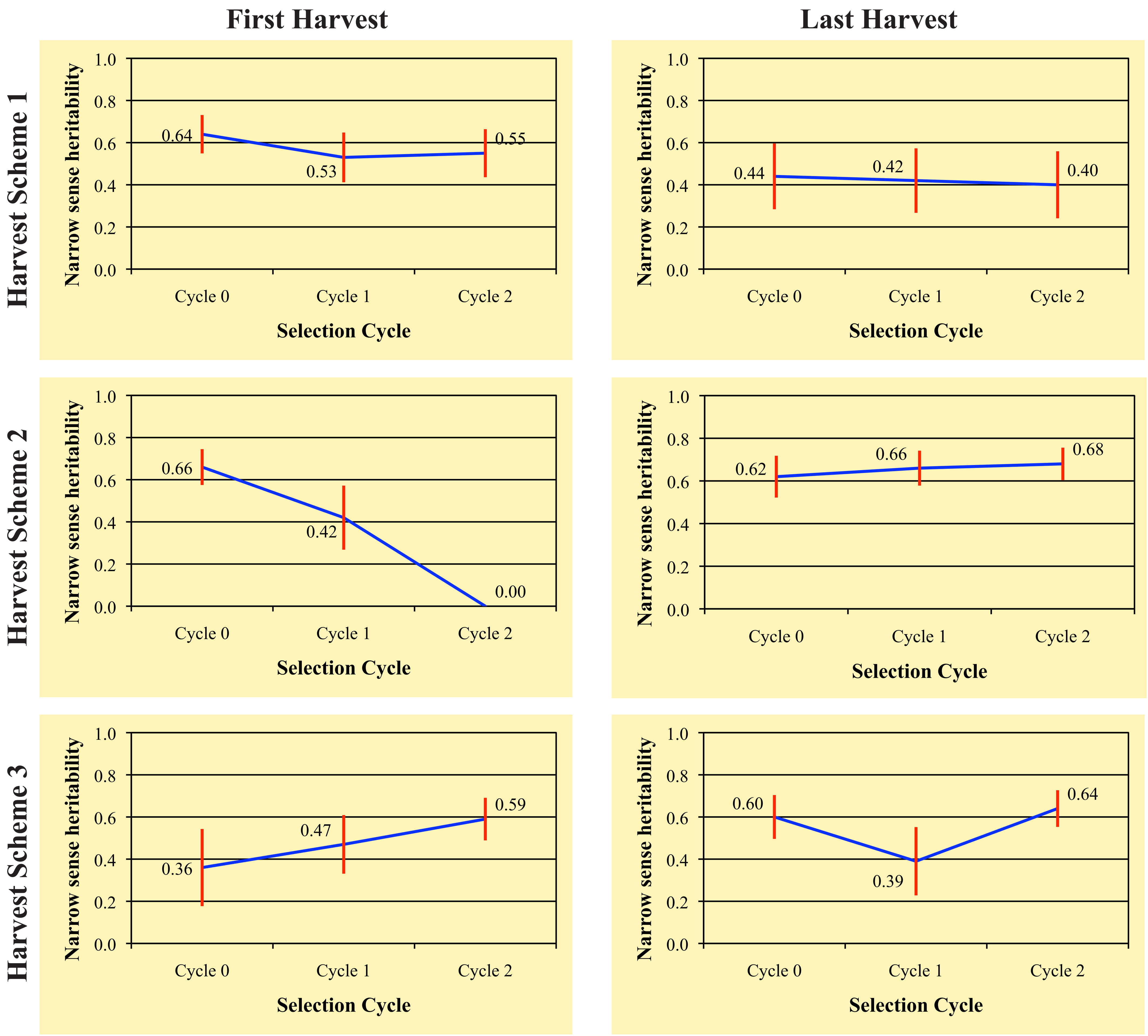


**Fig. 3.** Narrow sense heritability estimates on an half-sib family mean basis ± one standard error for the first and last harvest of three harvesting schemes for the base population and two cycles of phenotypic recurrent selection for improved winter growth.

## CONCLUSIONS

- Both Indirect responses heading date and plant type were significantly affected by direct selection for high dry matter yield
- Under almost all harvest schemes and cut combinations heritability for dry matter yield was found to be high enough to make progress
- A priori assumption of sufficient genetic variation for winter productivity was fully warranted

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