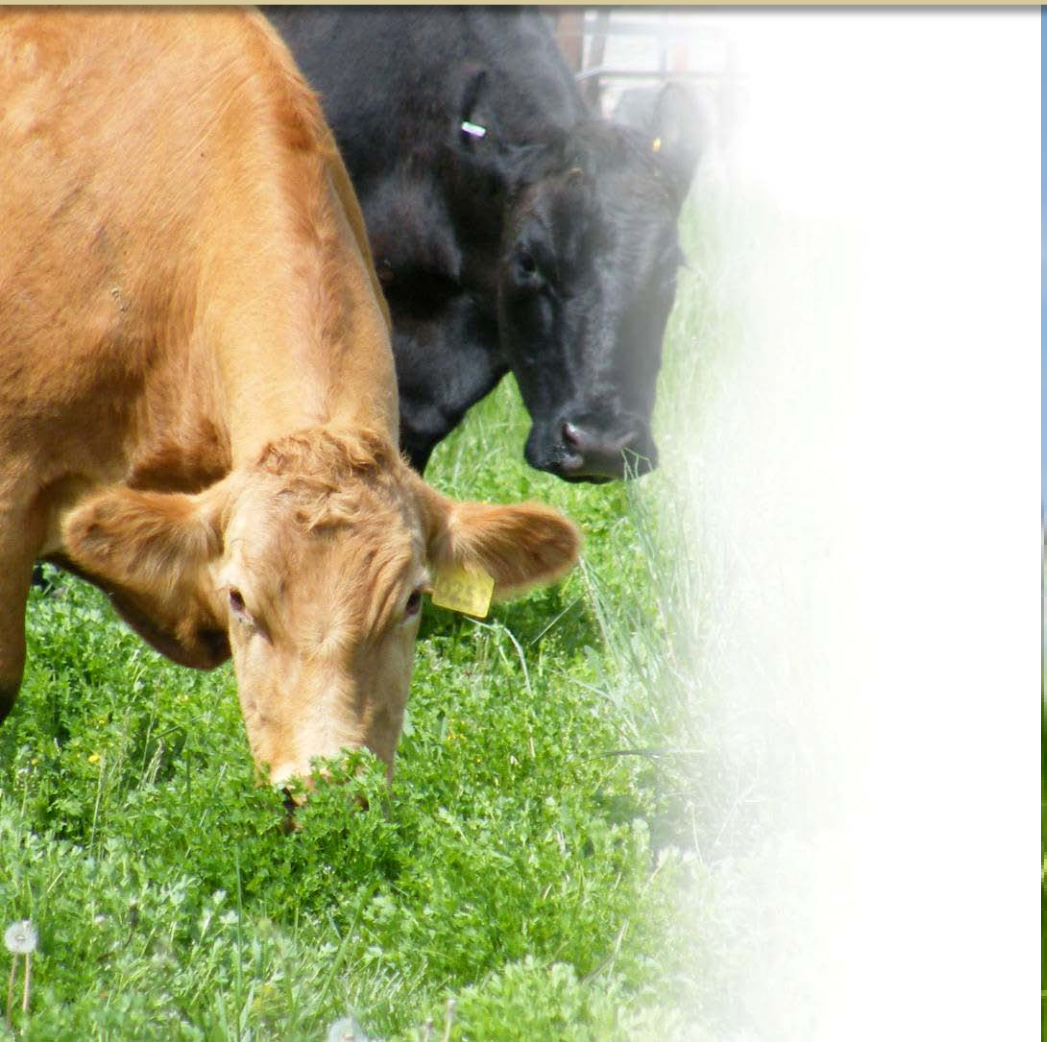
Predicted Efficiency of Indirect Selection to Improve Yield in Tall Fescue/Alfalfa Mixtures

Forage and Range Research Laboratory



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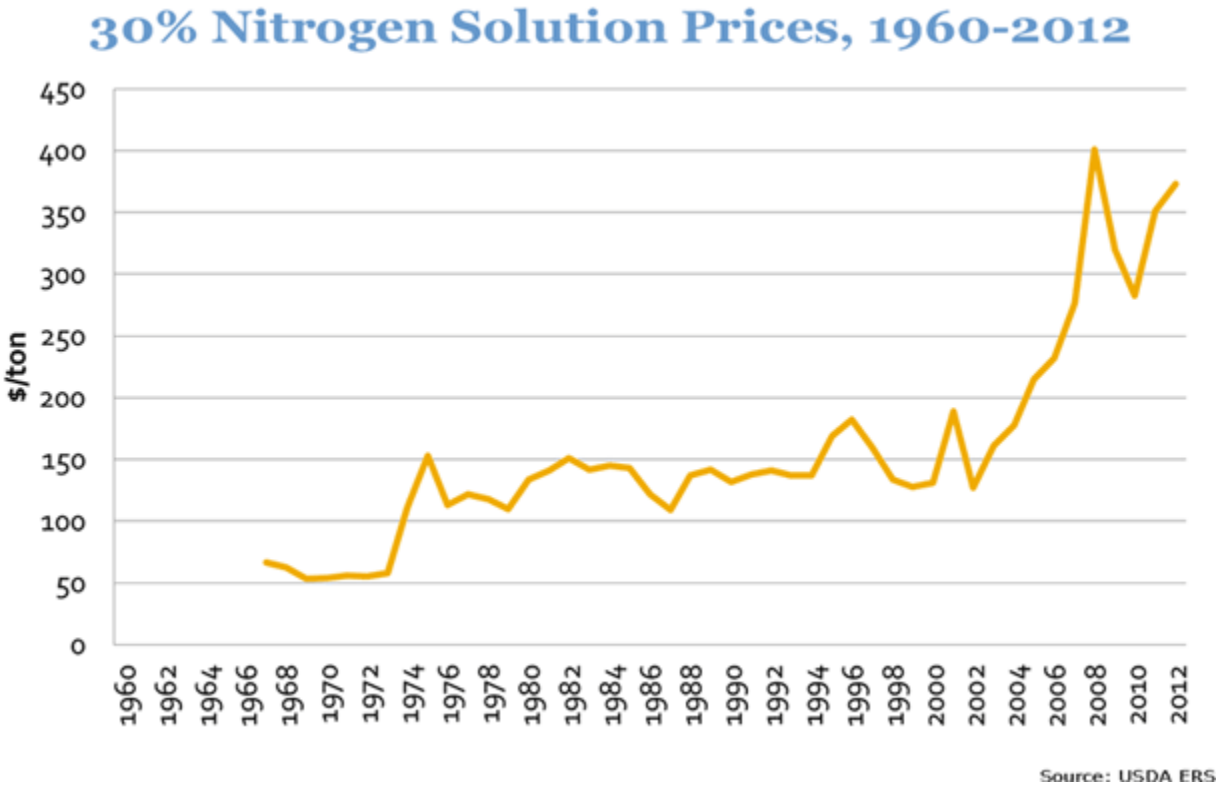
The Need for Grass-Legume mixtures: Nitrogen Fertilizer costs

- Grasses need nitrogen to produce forage.
  - 100 to 150 lbs N per year (usually in 2 or 3 split applications) recommended.
- Drastic increase in fertilizer cost over the last decade.



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The Need: Nitrogen fertilizer environmental concerns

- Environmental issues dealing with N leaching/runoff.


HARVEST
PUBLIC MEDIA
Cultivating stories from the ground up

Nitrates a costly, persistent problem for small towns

Earlier this year, Des Moines, Iowa, made news when the city announced it would sue farmers in a legal battle over fertilizer. The city's water supply from the Des Moines and Raccoon Rivers often surpasses the legal limit for nitrates (10 mg/L), which commonly appear in water contaminated by runoff from farm fields.

- "Earlier this year, Des Moines, Iowa, made news when the city announced it would sue farmers in a legal battle over fertilizer. The city's water supply from the Des Moines and Raccoon Rivers often surpasses the legal limit for nitrates (10 mg/L), which commonly appear in water contaminated by runoff from farm fields." – Harvest Public Media, Oct 27, 2015.

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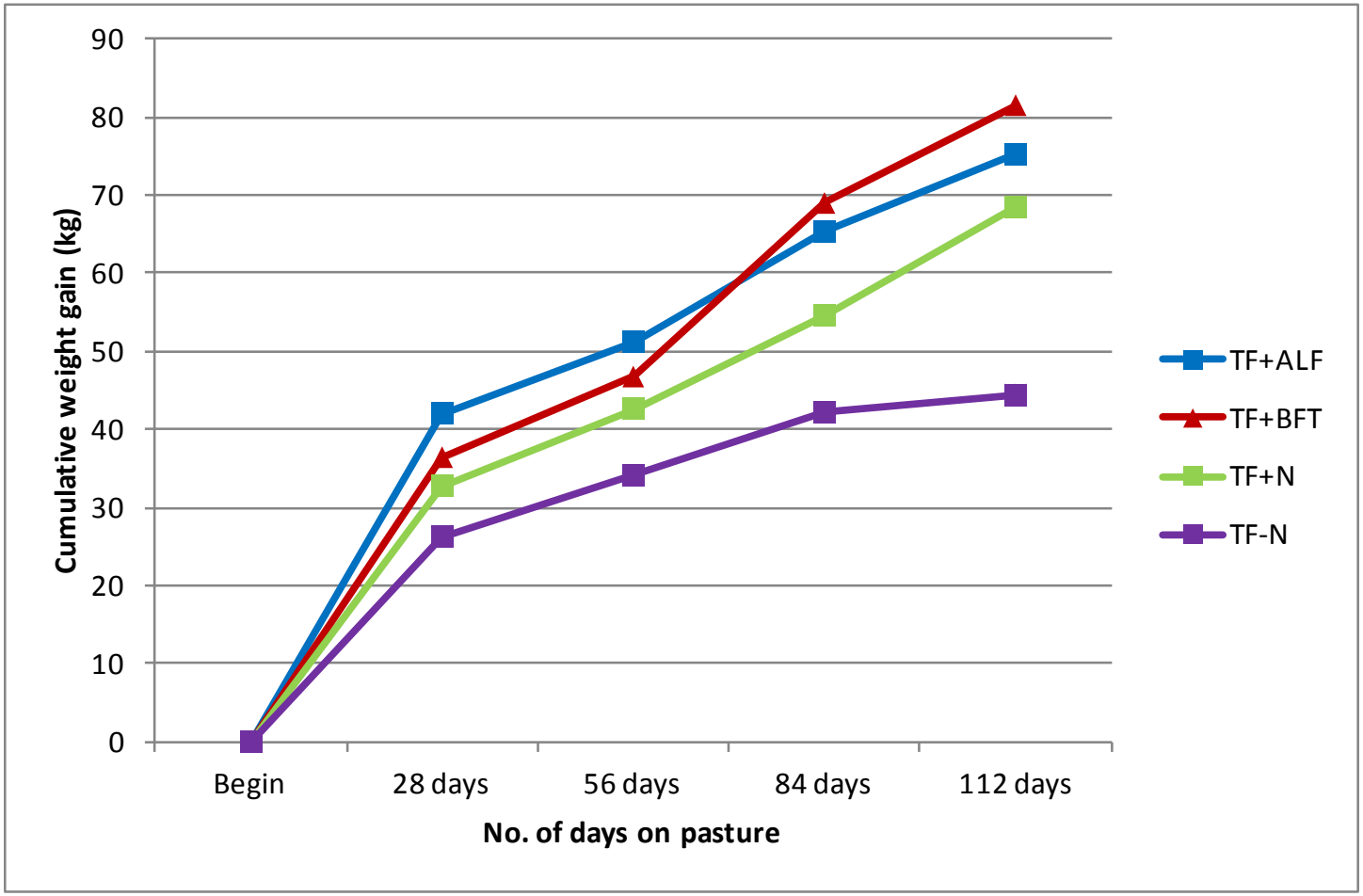
The Need: Enhanced livestock performance – steer weight gain



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Indirect Selection/Correlated Response

- In many instances, selection in a non-target environment is attractive because it is either more controlled and/or easier to manage.
  - Easier agronomic management, lower plot variability, higher h2, etc.

Euphytica **64:** 49-58, 1992.

Relationship between barley grain yield measured in low- and high-yielding environments

Salvatore Ceccarelli, Stefania Grando & John Hamblin
The International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria

Received 7 May 1992; accepted 17 September 1992

Euphytica **44:** 137-142, 1989.

Predicting the relative effectiveness of direct versus indirect selection for oat yield in three types of stress environments

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Received 14 June 1988; accepted in revised form 6 October 1988

Genetic Correlation

- "The genetic correlation expresses the extent to which two measurements reflect what is genetically the same character." (Falconer, 1989)
- Genetic correlation is based upon resemblance between relatives (e.g. variance between HSF = ¼ genetic variance).
- Can be extended from the genetic correlation between 'traits' to the genetic correlation between 'selection environments'.
- $r_G = cov_{xy}/sqrt\ var_x\ var_y$

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Correlated Response –– or Predicted Relative Efficiency of Indirect Selection

- $CR_x/R_x = r_G\ h_y/h_x$ (Falconer, 1989).
- Two important concepts:
  1. Heritabilities alone are not sufficient to identify the best environment for selection.
     - $CR_x/R_x > 1.0$ then indirect selection more efficient.
     - Therefore, r_G must be greater than 0.
  2. ". . . the magnitude and even the sign of the genetic correlation cannot be determined from phenotypic correlation alone." (Falconer, 1989).
     - r_P includes environmental correlation.

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Breeding for Grass/Legume Mixtures

- Hill. 1990. The three C's – competition, coexistence and coevolution and their impact on breeding of forage crop mixtures.
  - Hypothesized that breeding for 'General Ecological Combining Ability' (GECA) between the species would increase compatibility of grasses and legumes grown in mixtures.
  - Largely untested with a few notable exceptions in the literature – which are mainly in terms of legume persistence and performance.
    - Annicchiarico, 2003. White clover persistence and forage mass in mixture. Did report genetic correlations.
    - Riday and Brummer. 2014. Birdsfoot trefoil persistence in mixture. Did not report genetic correlations.
- Our Objectives:
  - Estimate and compare genetic parameters for tall fescue forage mass when grown in a tall fescue monoculture as opposed to a tall fescue-alfalfa mixture.
  - Predict relative efficiency of indirect selection using a grass monoculture environment (CR_x) to improve the tall fescue forage mass in a tall fescue-alfalfa mixture (R_x).

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Materials and Methods

- Plant Materials and Plots:
  - 45 Tall fescue HSF. Developed by 3-cycles of selection for soft leaves and vegetative vigor in non-competitive spaced-plant nurseries.
  - Arranged in two side-by-side spaced-planted nurseries, 5-plant plots with 0.4 m between plants and 1.0 m between rows.
    - Monoculture nursery: Turf-type tall fescue seeded between rows. Formed a dense stand and was kept mowed.
    - Mixture nursery: Spreader-4 alfalfa seeded between rows. Also formed a dense stand was kept mowed.
- Data and Analysis:
  - Forage mass of the tall fescue measured in 2010, 2011, and 2012 using 4-harvests per year.
  - Narrow sense h^2, r_G, and relative efficiency of indirect selection calculated on a family mean basis.
  - Spearman's rank correlation and number of 'correct' or 'in-common' HSF selections assuming *i*=15%.

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Harvesting

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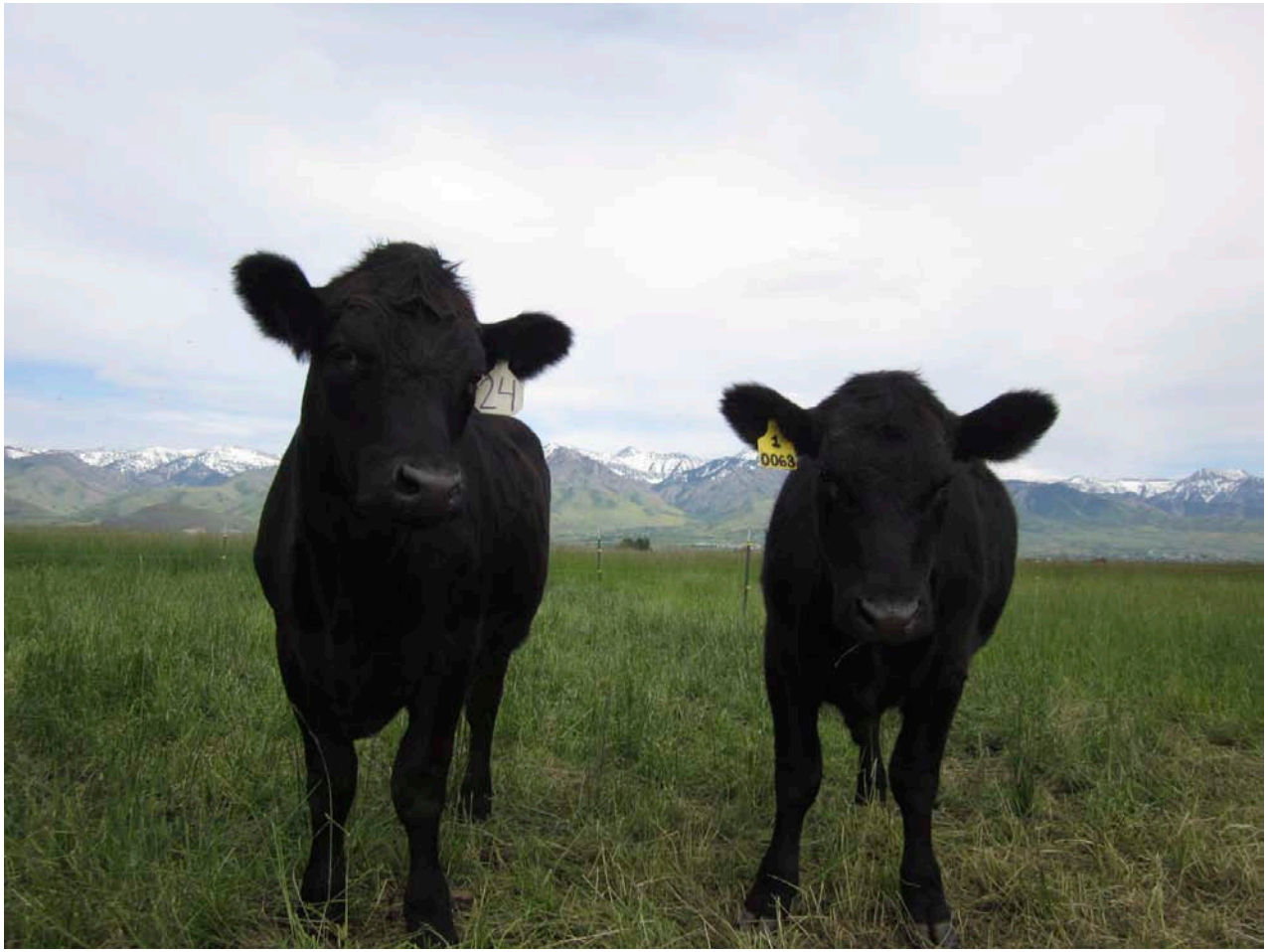
RESULTS & DISCUSSION



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Forage Mass

Table 1. Forage mass of tall fescue plots when growing in grass monoculture and grass-alfalfa mixture environments.

Harvest†	Grass Mono	Alfalfa Mixed	Prob of difference
		- kg plot^{-1} -	
Harv 1, mid-June	0.364	0.428	0.0026
Harv 2, mid-July	0.278	0.288	0.4130
Harv 3, mid-Aug	0.217	0.254	0.0079
Harv 4, mid-Oct	0.146	0.193	0.0002
Annual	1.004	1.163	0.0013

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h^2, r_G, and predicted RE of indirect selection

Table 2. Heritability, genetic and Spearman's rank correlation estimates†, relative efficiency of indirect selection, and number of "correct" family selections (n=7 possible) from indirect selection for forage mass of tall fescue measured in monoculture and alfalfa mixture environments.

Harvest	$h^2_{monoculture}$	$h^2_{mixture}$	$r_{G(mono,mix)}$‡	$RE_{indirect}$§	$r_{Spearman}$	Selections
Harv 1, mid-June	0.63 ± 0.08	0.43 ± 0.13	0.48 ± 0.27	0.58	0.35 *	1
Harv 2, mid-July	0.53 ± 0.11	0.27 ± 0.20	0.92 ± 0.45	1.29	0.35 *	3
Harv 3, mid-Aug	0.47 ± 0.12	0.47 ± 0.14	-0.31 ± 0.36	-0.31	-0.03 NS	0
Harv 4, mid-Oct	0.32 ± 0.21	0.29 ± 0.22	0.70 ± 0.64	0.73	0.26 NS	2
Annual	0.70 ± 0.07	0.55 ± 0.12	0.25 ± 0.24	0.28	0.28 NS	2

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Summary

- Tall fescue forage mass was moderately heritable in both monoculture and mixture environments and varied based upon harvest.
- Heritabilites in monoculture were generally greater and had lower standard errors than in mixture.
- Genetic correlations varied by harvest and ranged from a high of 0.92 to a low of -0.31.
- Predicted relative efficiency of indirect selection was less than “1” in all cases except harvest 2.
- The negative correlated response in harvest 3 limited the potential to indirectly select for overall annual tall fescue forage mass.
- Low Spearman’s rank correlations and lack of agreement in ‘selected’ families between monoculture and mixture environments supports the genetic correlations and predicted relative efficiency results.

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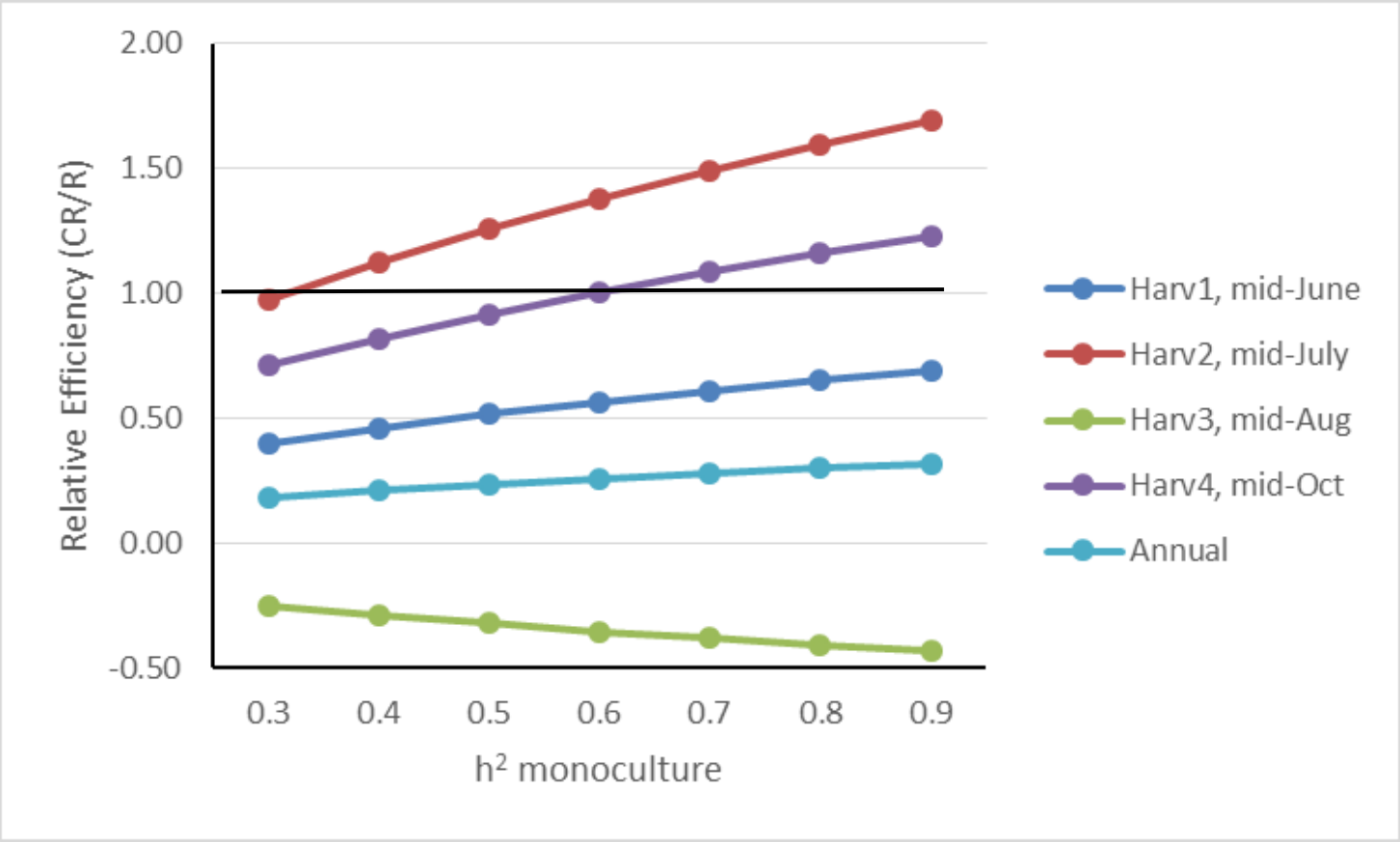
Predicted RE of indirect selection

Figure 1. Effect of increasing heritability for tall fescue forage mass in monoculture on the indirect selection of tall fescue forage mass in a mixture.



Conclusion

- This research supports Hill's (1990) hypothesis that direct selection for Ecological Combining Ability (e.g. selection in a grass-legume mixture environment) is more likely to increase grass-legume mixture performance than combining together grass and legume cultivars that have been selected in monoculture.

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Questions

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Energy (NEg) – season pattern