Identifying In-Season Phenotypic Predictors of Elevated Grain Protein Concentration in Wheat

Philip Hinson[1], Curtis Adams[2], Qingwu Xue[2], Sushil Thapa[2], Xuejun Dong[2], Gongneng Feng[2], Fernando Guillen-Portal[3], and Clark Neely[4]

[1]Texas A&M University, [2]Texas A&M AgriLife Research, [3]Texas A&M AgriLife Extension, [4]Washington State University

INTRODUCTION

Background

- The quality of wheat grain depends on many factors, but grain protein concentration (GPC) is among the most important.
- GPC influences milling and baking quality, as well as many other end-use qualities of wheat.
- Globally, wheat market value is typically estimated based on GPC, with premiums paid for GPC above baseline levels and/or price dockages made for wheat with GPC below threshold levels.
- Understanding the relationship between GPC and phenotypic traits is paramount to wheat variety improvement.
- Path analysis can be employed to better understand the complex nature of cause-and-effect relationships among phenotypic traits and GPC.

Objective

- To assess direct and indirect relationships among GPC and phenotypic traits using path analysis.

MATERIALS AND METHODS

Experimental Sites and Design

- Field experiments were established under dryland conditions in two locations in Texas: Chillicothe and Uvalde (2018/2019 growing season).
- Twenty genetically diverse wheat genotypes with regional adaptation were studied in each location, with six genotypes common across locations.
- The experimental design was a RCBD with three replications.

Fig. 1. 2018/2019 growing season at Chillicothe

Data Collection

- Crop growth and development data were collected, including total biomass at anthesis and time to anthesis and physiological maturity.
- Grain yield and yield components (harvest index, grain number per unit area, head number per unit area, and 1000-kernel weight) were measured at physiological maturity.
- GPC was determined analyzing grain samples for N using combustion analysis, then applying a multiplier of 5.7.

Data Analysis

- Statistical analyses were conducted individually for each location.
- Pearson's correlation coefficients (r) were generated using SAS 9.4 software to assess bivariate relationships.
- Path analysis was performed using R programming environment to partition the correlation coefficients into direct and indirect effects. The sum of direct and indirect effects is equal to the total effects, which is same as the correlation coefficients.

RESULTS

Table 1: Pearson correlation between traits at Chillicothe

Trait	GY	GPC	HI	GN	HN	TKW	ATB	DANT	DMAT
GY	1.00								
GPC	-0.23**	1.00							
HI	0.33***	-0.17	1.00						
GN	0.21*	0.13	0.44***	1.00					
HN	0.07	0.12	-0.06	0.68***	1.00				
TKW	0.75***	-0.34 ***	0.40***	-0.09	-0.11	1.00			
ATB	0.37***	0.11	0.90***	0.27 **	0.17	0.13	1.00		
DANT	-0.16	0.12	-0.19*	-0.12	-0.15	-0.22*	0.21*	1.00	
DMAT	-0.18 *	0.26**	-0.26**	0.03	0.00	-0.34***	0.20*	0.80***	1.00

GY, grain yield; GPC, grain protein concentration; HI, harvest index ; GN, grain number per m^2; HN, head number per m^2; TKW, 1000-kernal weight; ATB, total biomass at anthesis per m^2; DANT, days to anthesis; DMAT, days to physiological maturity. ***, ** and * represent $p \leq .01$, $p \leq .05$ and $p \leq .1$, respectively.

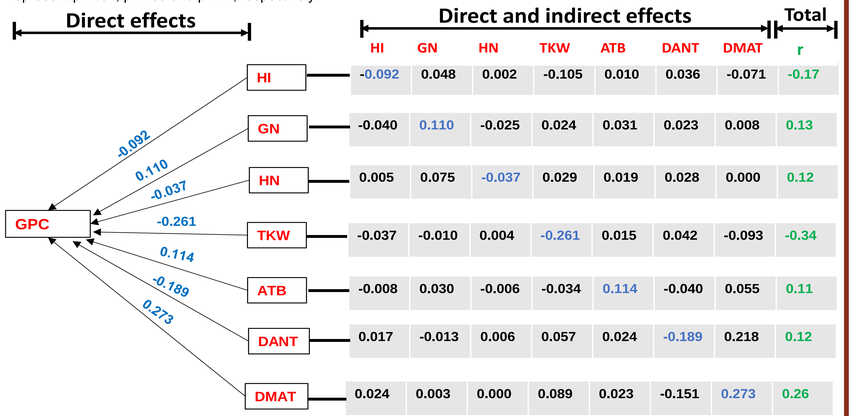

Fig. 2. Path diagram for the relationship between phenotypic traits and GPC at Chillicothe.
Blue, black and green colors represent direct, indirect and total effects, respectively.

Table 2: Pearson correlation between traits at Uvalde

Trait	GY	GPC	HI	GN	HN	TKW	ATB	DANT	DMAT
GY	1.00								
GPC	0.07	1.00							
HI	0.07	-0.09	1.00						
GN	0.37***	0.32***	-0.07	1.00					
HN	0.26**	0.29 ***	-0.18*	0.88***	1.00				
TKW	-0.15	-0.18*	0.44***	-0.22*	-0.26**	1.00			
ATB	0.28**	-0.23**	-0.09	0.18*	0.10	0.10	1.00		
DANT	0.16	0.13	0.19*	-0.15	-0.10	-0.01	0.25**	1.00	
DMAT	0.01	0.44***	0.27**	0.00	0.07	0.04	0.02	0.78***	1.00

See the Table 1 footnote for acronym definitions. ***, ** and * represent $p \leq .01$, $p \leq .05$ and $p \leq .1$, respectively

RESULTS

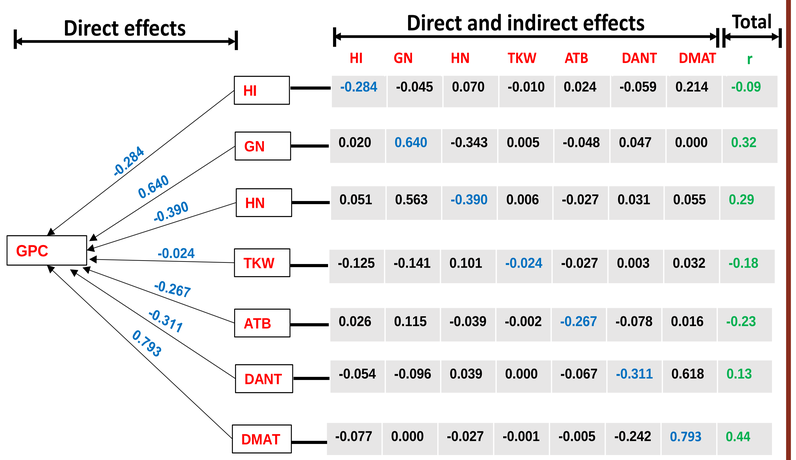

Fig. 3. Path diagram for the relationship between phenotypic traits and GPC at Uvalde.
Blue, black and green colors represent direct, indirect and total effects, respectively.

DISCUSSION AND CONCLUSIONS

- 1000-kernel weight and time to physiological maturity influenced GPC in both locations. Additional parameters (grain number per m^2, head number per m^2 , and total biomass at anthesis per m^2) had an impact at Uvalde.
- Path analysis showed that 1000-kernel weight had a mild negative direct effect on GPC at Uvalde, but a strong negative direct effect at Chillicothe.
- The inverse relationship between GPC and 1000-kernel weight means that heavier kernels, mainly caused by higher carbohydrate content, have lower protein concentration.
- Time to physiological maturity had a strong positive direct effect on GPC in both locations. This could be due to (i) increased time for nitrogen accumulation, and/or (ii) low rates of carbohydrates accumulation under high temperature or heat stress conditions late in the season.
- From the correlation table, there was a positive (insignificant) relationship between GPC and head number per m^2 in both locations. Path analysis showed that the direct effect of head number per m^2 on GPC was negative, but was masked by a strong positive indirect effect through grain number per m^2.
- A similar relationship was found on time to anthesis, where a considerable positive indirect effect of time to anthesis on GPC through time to physiological maturity masked its direct negative influence.

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