

Genetics of the trade-off between grain yield and quality in winter wheat

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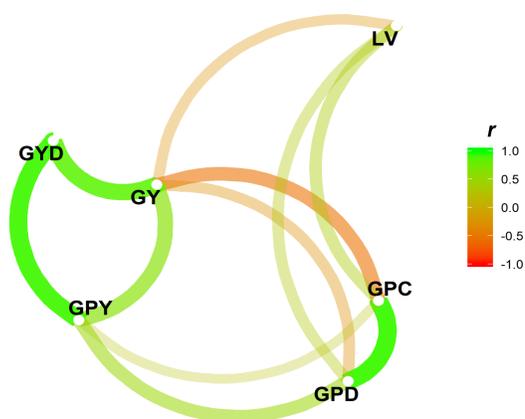
Introduction

- The **inverse relationship** between **grain yield (GY)** and **grain protein content (GPC)** impedes the development of high-yielding wheat varieties with good baking quality.
- The underlying genetic factors controlling this negative correlation have been largely unknown.
- The present study aimed at the **analysis of quantitative trait loci (QTL)** affecting GY, GPC and the derived traits **grain protein deviation (GPD)**, **grain yield deviation (GYD)** and **grain protein yield (GPY)** using a multiparental advanced generation intercross (MAGIC) winter wheat population.

Materials and methods

- QTL analysis was performed using the eight-way-MAGIC population BMWpop, which comprises **394 recombinant inbred lines** [1].
- GY and GPC** was measured in **six and seven environments** at six German locations across four years using an alpha lattice with two replications. GPD and GYD were defined as the residuals of a regression of GPC on GY and vice versa. Loaf volume (LV) was assessed as a reference trait in four environments. QTL mapping was performed using adjusted means across environments.
- The BMWpop was genotyped using a 20k Illumina® Infinium® single nucleotide polymorphism (SNP) array. The **linkage map comprised 5436 SNPs**. Composite **interval mapping** was performed using the R package mpMap [2].

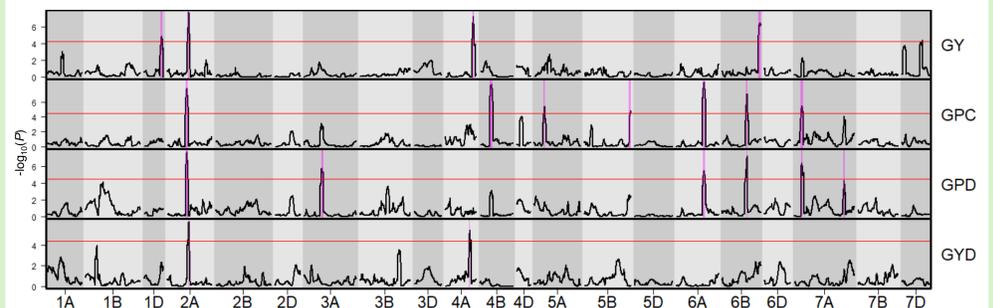
Phenotypic correlations



As expected, **GY was negatively correlated with GPC** ($r = -0.54$) and **LV** ($r = -0.26$). High correlations were observed between **GPC and GPD** ($r = 0.94$). This confirms that selection for high GPD increases mainly GPC while the trade-off for GY is smaller than usual. An analogous observation was made **for GY and GYD** ($r = 0.84$). GPY is mainly influenced by GY ($r = 0.63$) rather than GPC ($r = 0.21$).

QTL analysis

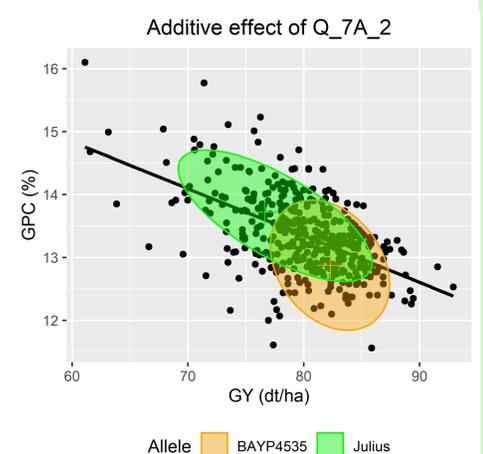
- Interval mapping detected four QTL for GY, of which two QTL were also observed for GYD, indicating that these loci can be used to **increase GY with below-average trade-off effects on GPC**.



- Seven and six QTL were identified for GPC and GPD, respectively. Four of these loci coincided, suggesting that these regions have the potential to **improve GPC** with only **minor adverse effects on GY**. No QTL was detected for GPY.

QTL	Affected traits	Chr.	Position (cM)	R ²	Additive effect
Q_1D_3	GY	1D	112.5	0.08	7.8 dt/ha
Q_2A_5	GY; GYD; GPC; GPD	2A	139	0.10; 0.08; 0.07; 0.06	7.5 dt/ha; 5.3 dt/ha; 0.7%; 0.5%
Q_3A_4	GPD	3A	114	0.08	0.9%
Q_4A_4	GY; GYD	4A	183.6	0.07; 0.07	6.0 dt/ha; 3.1 dt/ha
Q_4B_1	GPC	4B	74	0.09	0.6%
Q_5A_1	GPC	5A	67.8	0.05	0.7%
Q_5B_7	GPC	5B	302.5	0.04	0.5%
Q_6A_9	GPC; GPD	6A	180.8	0.08; 0.05	0.7%; 0.4%
Q_6B_6	GPC; GPD	6B	160	0.04; 0.05	0.4%; 0.3%
Q_6B_7	GY	6B	245.3	0.04	4.0 dt/ha
Q_7A_11	GPD	7A	323.5	0.04	0.3%
Q_7A_2	GPC; GPD	7A	49	0.12; 0.10	0.8%; 0.6%

- For GY, we observed additive effects ranging from **4.0 to 7.8 dt/ha**. QTL for GYD caused deviations between **3.1 and 5.3 dt/ha** from the predicted GY.
- Additive effects for GPC and GPD ranged between **0.4%-0.8%** and from **0.3%-0.6%**, respectively.



Conclusion

The identified QTL for GPD and GYD are a valuable resource to facilitate **marker-assisted and genomic selection** strategies in order to **counteract the inverse relationship** between GY and GPC.

References

- Stadlmeier M, Hartl L, Mohler V (2018) Usefulness of a multiparent advanced generation intercross population with a greatly reduced mating design for genetic studies in winter wheat. *Front Plant Sci* 9:1825. DOI: 10.3389/fpls.2018.01825
- Huang BE, George AW (2011) R/mpMap: a computational platform for the genetic analysis of multiparent recombinant inbred lines. *Bioinformatics* 27:727-729. DOI: 10.1093/bioinformatics/btq719