Increasing Grain Protein Content (GPC) In Wheat – The Genomic way

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Promilleafgiftsfonden for landbrug

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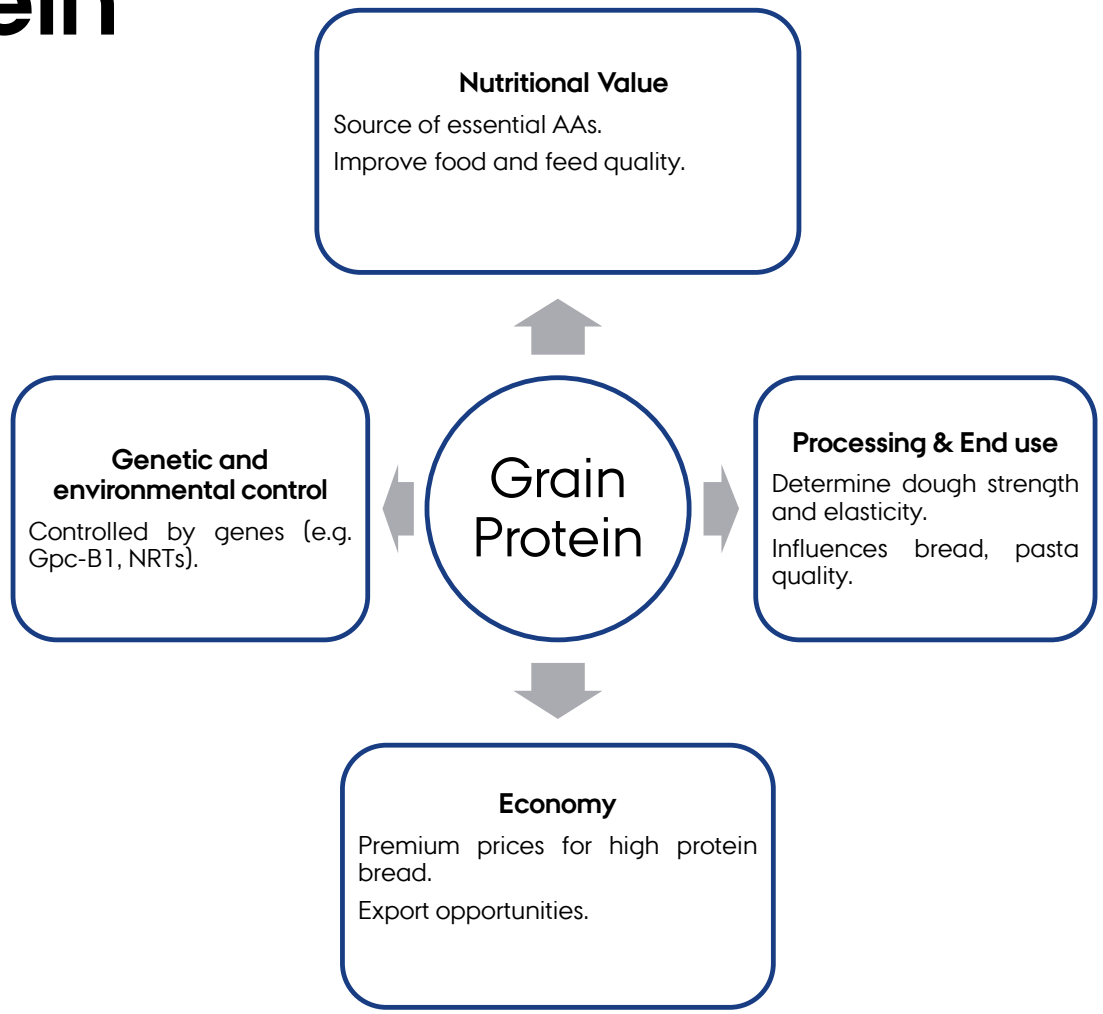
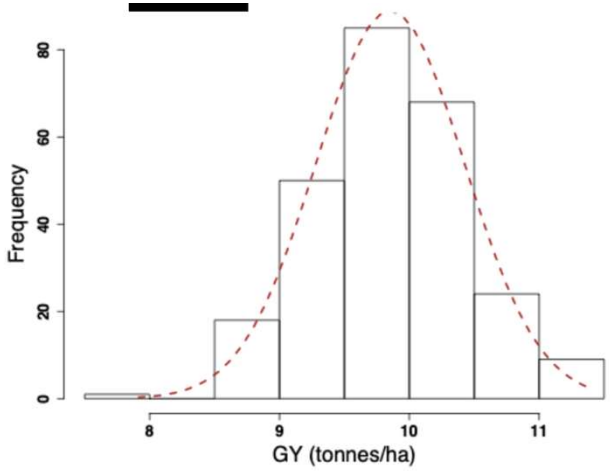
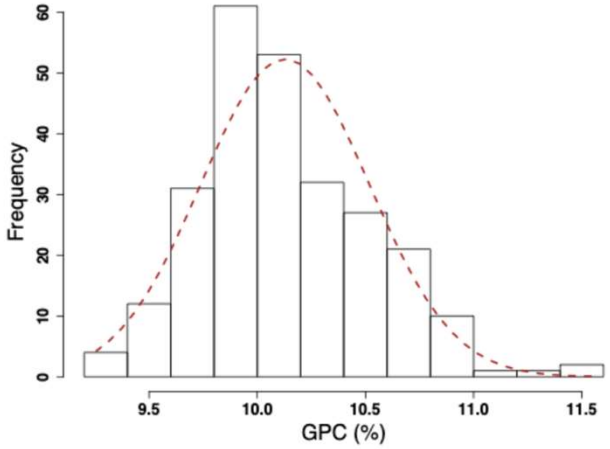
AARHUS UNIVERSITY

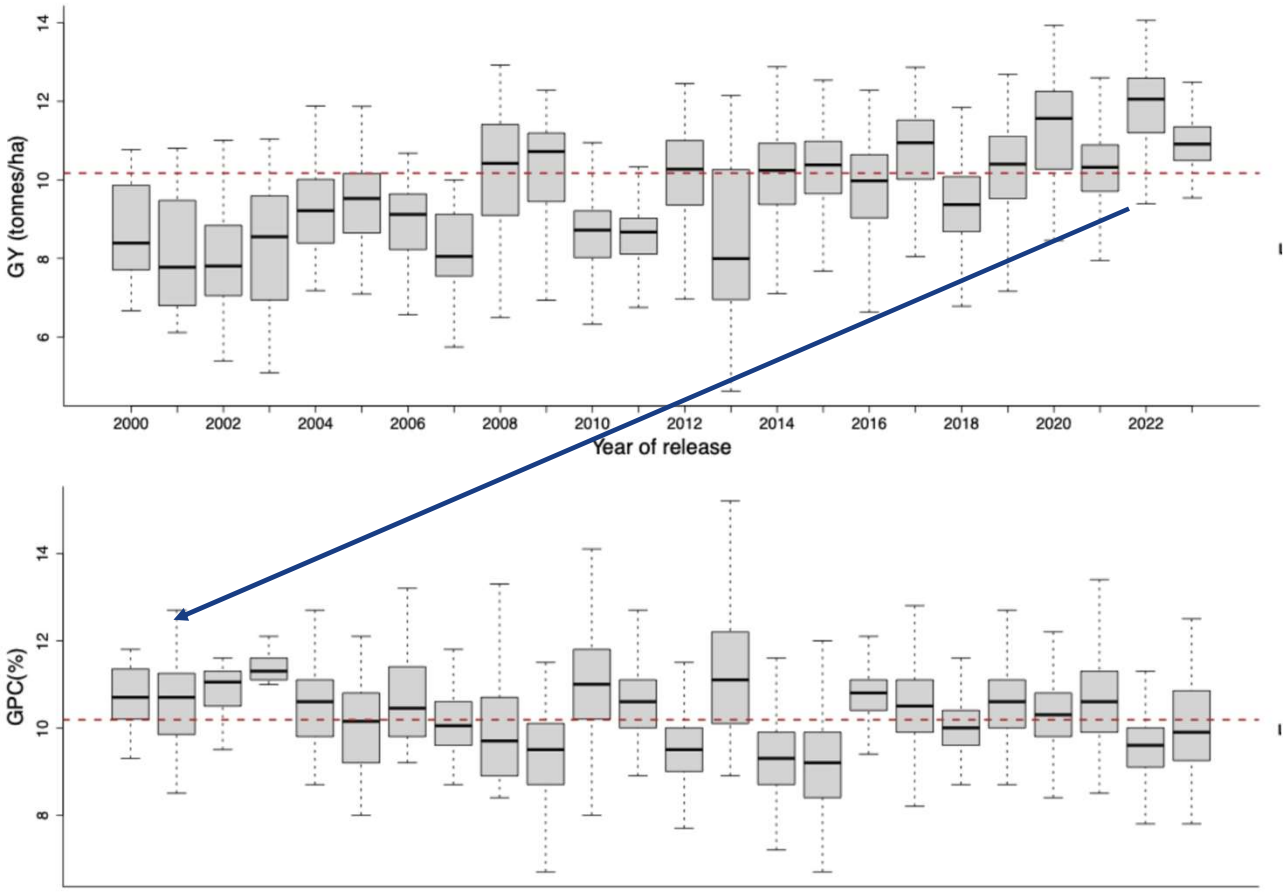
Wheat Grain Protein



Wheat Grain Yield (GY) & Grain Protein Content (GPC)







Increasing GPC

plant biology

Plant Biology ISSN 1435-8603

REVIEW ARTICLE

Recent advances in the genetics underlying wheat grain protein content and grain protein deviation in hexaploid wheat

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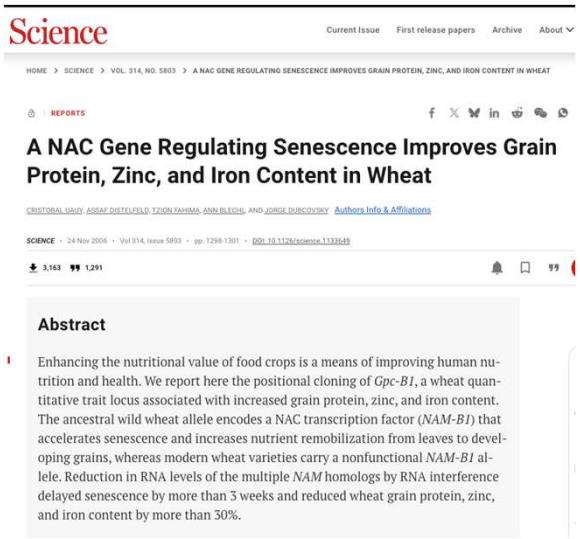


Science

Current Issue First release papers Archive About

HOME > SCIENCE > VOL. 314, NO. 5803 > A NAC GENE REGULATING SENESCENCE IMPROVES GRAIN PROTEIN, ZINC, AND IRON CONTENT IN WHEAT

REPORTS

A NAC Gene Regulating Senescence Improves Grain Protein, Zinc, and Iron Content in Wheat

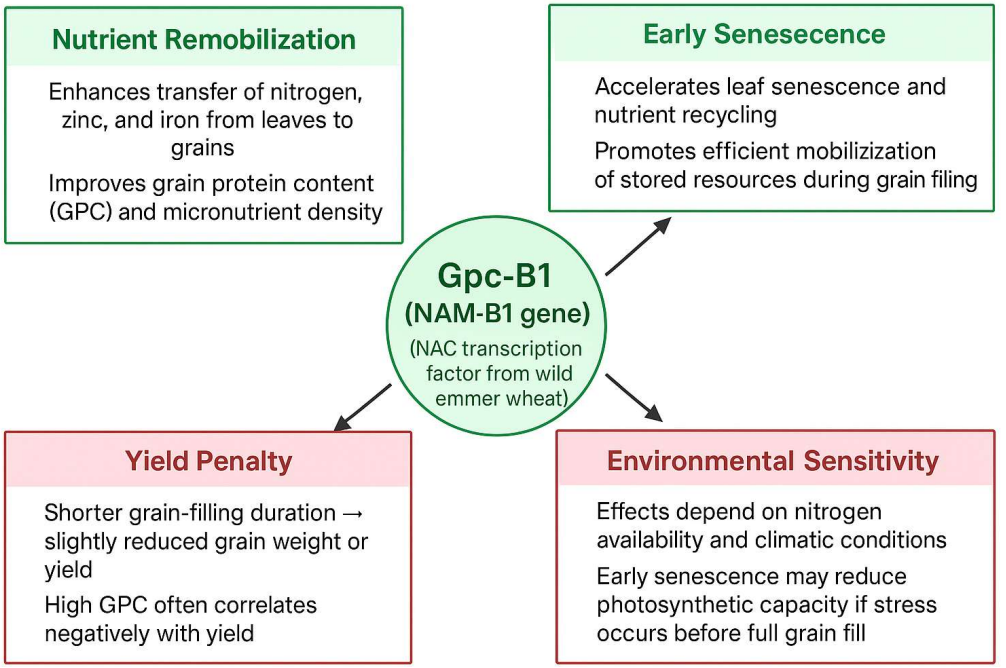
CRISTOBAL UAUY, ASSAF DISTELFELD, TZION FAHIMA, ANN BLECHL, AND JORGE DUBCOVSKY Authors Info & Affiliations

SCIENCE • 24 Nov 2006 • Vol 314, Issue 5803 • pp. 1298-1301 • DOI: 10.1126/science.1133649

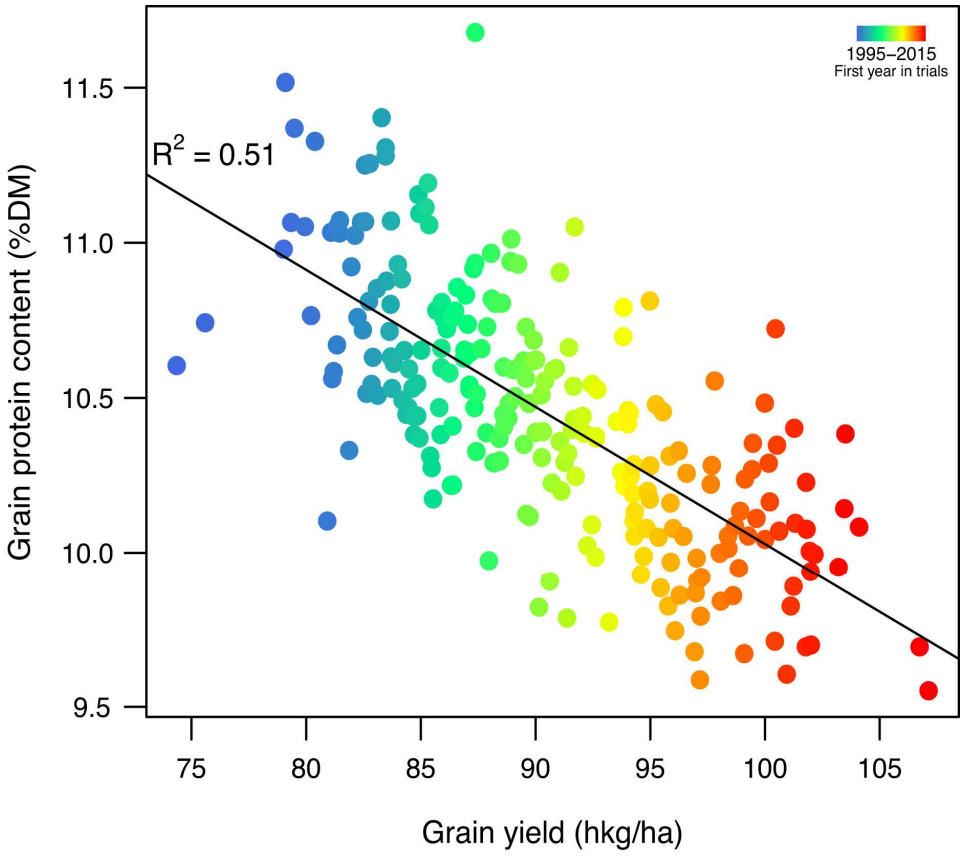
3,163 1,291

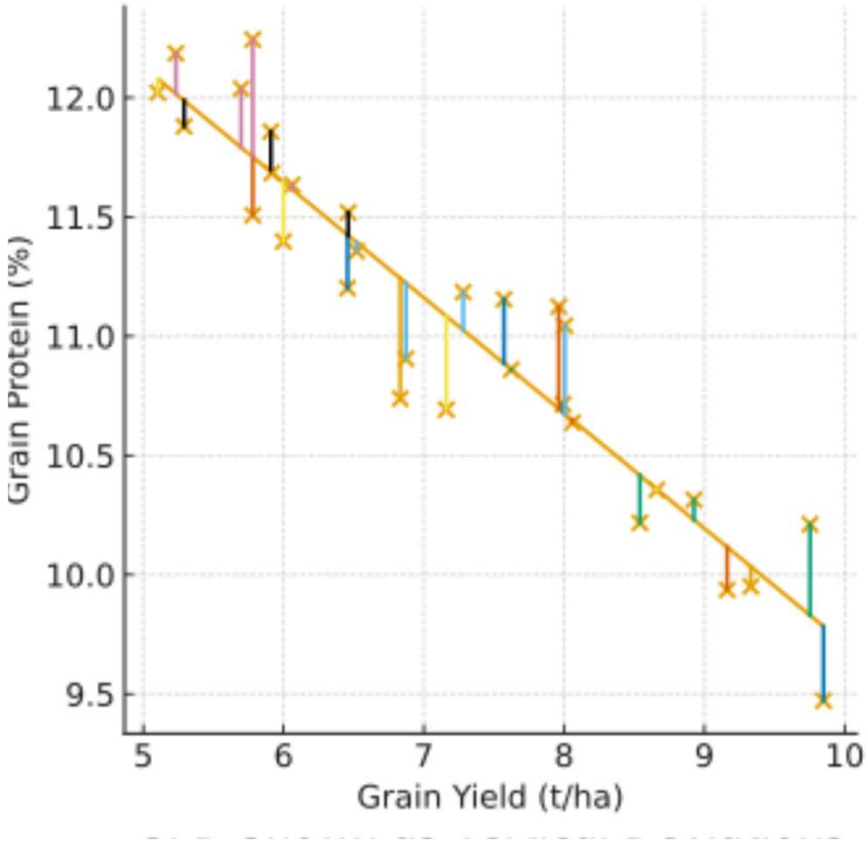
Abstract

Enhancing the nutritional value of food crops is a means of improving human nutrition and health. We report here the positional cloning of *Gpc-B1*, a wheat quantitative trait locus associated with increased grain protein, zinc, and iron content. The ancestral wild wheat allele encodes a NAC transcription factor (*NAM-B1*) that accelerates senescence and increases nutrient remobilization from leaves to developing grains, whereas modern wheat varieties carry a nonfunctional *NAM-B1* allele. Reduction in RNA levels of the multiple *NAM* homologs by RNA interference delayed senescence by more than 3 weeks and reduced wheat grain protein, zinc, and iron content by more than 30%.



Tackling negative relation in GPC & GY





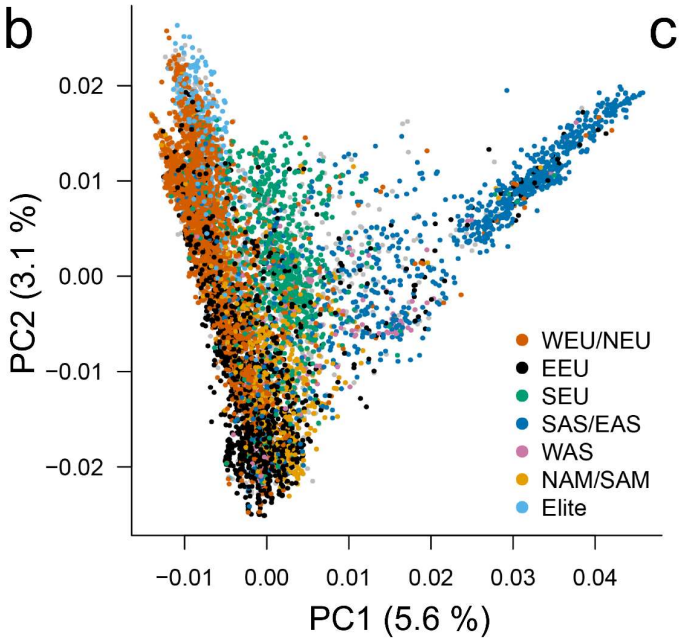
Datasets

1. Scandinavian winter wheat (SCAN-Wheat)
   - 255 Scandinavian cultivars
2. Elite European winter wheat panel (GABI)
   - 372 elite cultivars (*Gogna et al., 2022*)
3. European winter wheat collection
   - 9K winter wheat accessions (*Schulthess et al., 2022*)

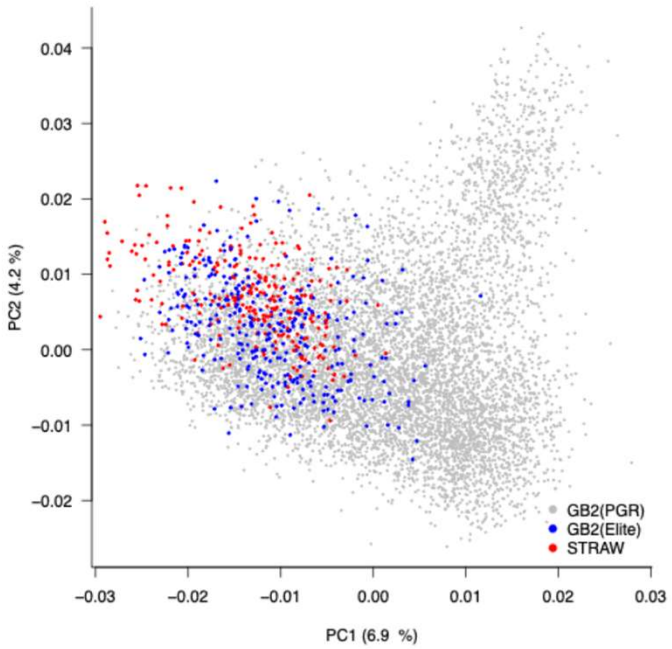
Scandinavian winter wheat (SCAN-WHEAT) cultivars

Number of cultivars=255

Array Name	#SNPs	#Samples	Company
7K	6731	41	Sejet
15K	13006	25	Sejet
20K	17267	23	Sejet
25K	24145	20	Sejet
25K	24145	146	NordicSeeds
Total		**255**	



PCA of 9K winter wheat (*Schulthess, 2022*)



SCAN-WHEAT diversity WRT entire diversity

nature genetics

Article https://doi.org/10.1038/s41588-022-01189-7

Genomics-informed prebreeding unlocks the diversity in genebanks for wheat improvement

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Check for updates

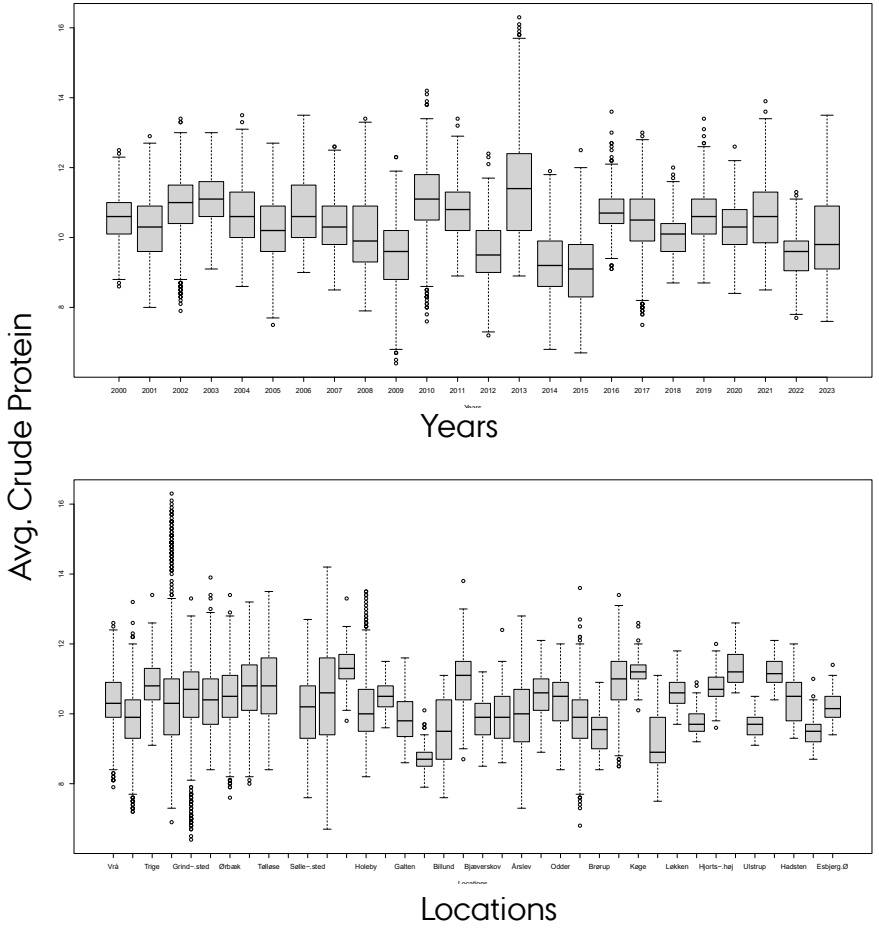
Albert W. Schulthess[1,11], Sandip M. Kale[1,9,11], Fang Liu[1,10,11], Yusheng Zhao[1], Norman Philipp[1], Maximilian Rembe[1], Yong Jiang[1], Ulrike Beukert[2], Albrecht Serfling[2], Axel Himmelbach[1], Jörg Fuchs[1], Markus Oppermann[1], Stephan Weise[1], Philipp H. G. Boeven[3], Johannes Schacht[3], C. Friedrich H. Longin[4], Sonja Kollers[5], Nina Pfeiffer[6], Viktor Korzun[5], Matthias Lange[1], Uwe Scholz[1], Nils Stein[1,7], Martin Mascher[1,8] and Jochen C. Reif[1]

Phenotypic Data

Downloaded from SortInfo from 2000- 2023

- Crude Protien
- Grain Yiled

	Showing 74 of 74 rows	Vrå	Horsens	Trige	Holste- bro	Grind- sted	Sønder- borg	Ørbæk	Nykøbing F	Tølløse	Avg.
2	02/09	-	10.7	11.3	9.8	10.6	9.3	10.9	10	10.7	10.4
3	01/06	-	11	10.2	9.6	10.3	9.5	10.7	10.7	11	10.4
4	Asketis	10.9	-	11.1	11.4	10.8	-	11.5	11.4	12.1	11.3
5	Askro	-	10.3	10.3	10.3	9.5	9.4	10.1	10.3	11.6	10.2
6	Aspect	11.2	-	11.5	11	10.6	-	11.3	11.9	12	11.4
7	Baltimor	10.7	-	11.1	9.7	10.8	-	11.2	10.9	11.5	10.8
8	Bauxit	-	10.4	10.6	9.9	10.5	9.5	10.3	10.3	11	10.3
9	Bill	10.6	-	10.5	9.3	10.6	-	10.8	11	11	10.5
10	Biscay	10.7	-	10.4	9.9	10.4	-	11.1	10.6	11.1	10.6
11	Blanding,vi-hved	10.8	10.6	10.5	9.8	10	9.4	10.5	10.6	11.2	10.4
12	Boston	10.9	-	10.5	11.1	10.5	-	10.5	11.2	11.4	10.9
13	Brandt	11	-	11	10	10.5	-	10.8	11.6	11.7	10.9
14	Buccaneer	11	-	10.8	8.9	10.5	-	10.1	10	10.7	10.3
15	CPB-T W63	10.4	-	11	9.4	10.5	-	10.8	10.7	11.1	10.6
16	Cardos	11.1	-	11.8	11.3	11.1	-	11.3	11.1	10.9	11.2
17	Claire	10.6	-	10.5	9.1	10.5	-	10.5	11.1	10.8	10.4
18	Classic	11.6	-	11.5	9.9	10.9	-	11.6	11.6	11.8	11.3
19	Cockpit	10.4	-	10.9	9.9	10.1	-	10.8	11.3	10.7	10.6
20	Comet	-	10.8	10.1	9.1	9.9	9.1	10.4	10.2	11.4	10.1
21	Complet	11.4	-	11.4	10.7	10.6	-	11.3	12.3	11.6	11.3
22	Cortez	10.1	-	10.1	9.1	9.9	-	10.2	10.7	11.8	10.3
23	Deben	10.9	-	10.3	9.4	10.1	-	10	10.8	11.3	10.4
24	Diabas	10.6	-	10.2	10.3	9.7	-	11.1	11.5	12.5	10.8
25	Dirigent	10.4	-	10.5	9.4	9.9	-	9.5	10	10.9	10.1
26	Efal	10.3	-	11.2	9.4	9.9	-	9.9	10.7	10.9	10.3
27	Excellenz	-	10.7	10.5	9.9	10.6	9.6	10.6	10.4	11.1	10.4
28	Flair	10.8	-	11.3	10.4	10.1	-	10.2	10.9	12.3	10.9
29	Flip	-	10.5	10.1	9.9	10.6	9.5	9.9	10.2	11.3	10.3

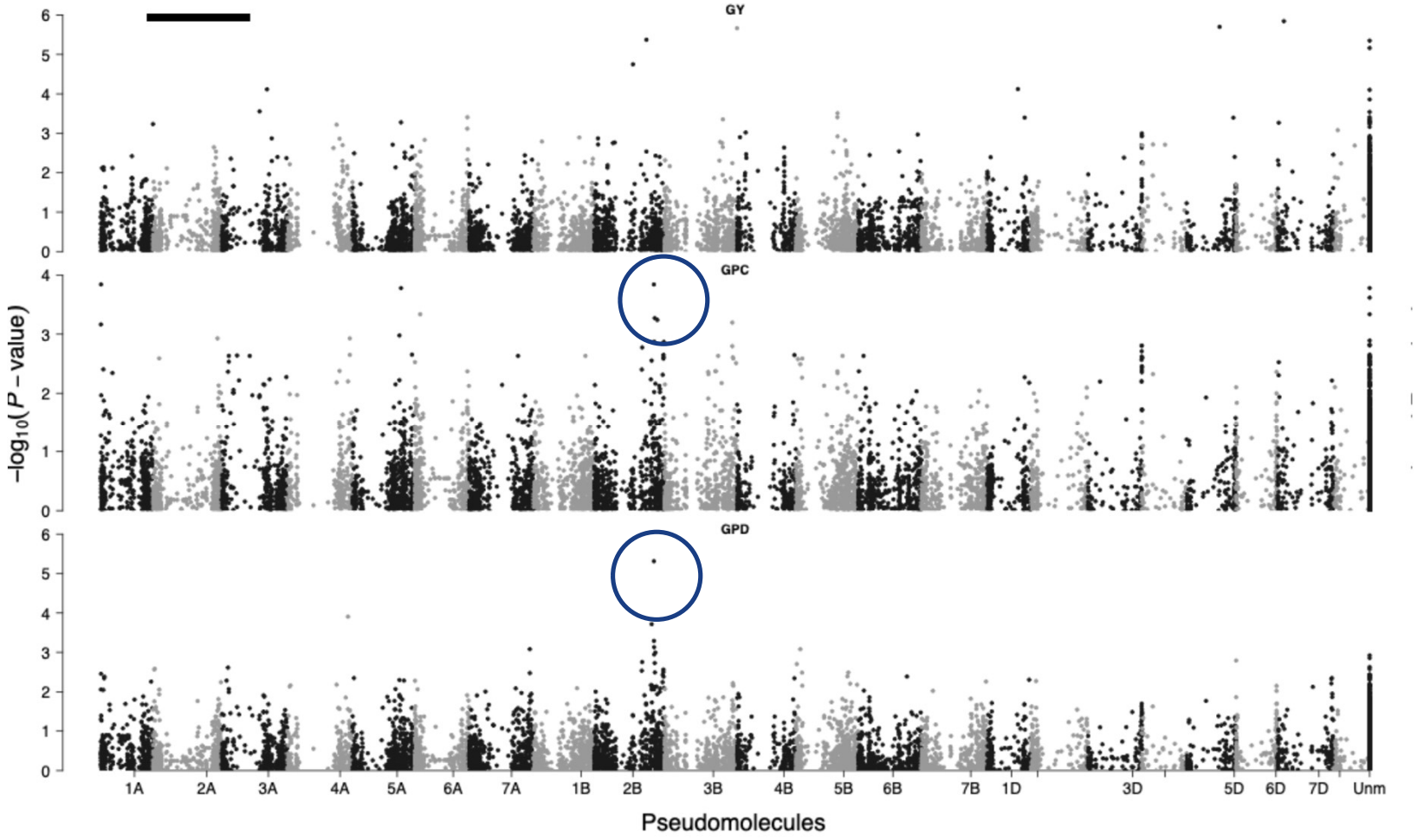


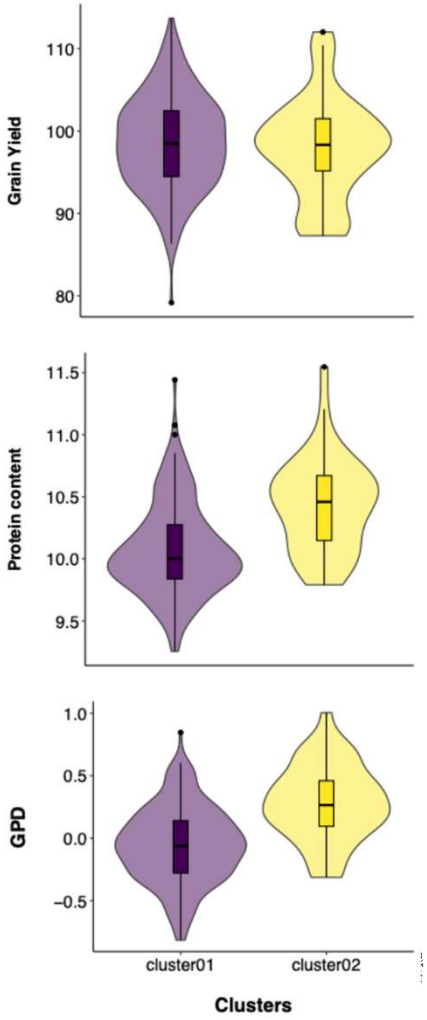
Download data from 2000 to 2023

Average the data by year and location

Pheno ~ (1|sample) + (1|location) + (1|year) + (1|sample:location)

GWAS-Linking Genotype with Phenotype



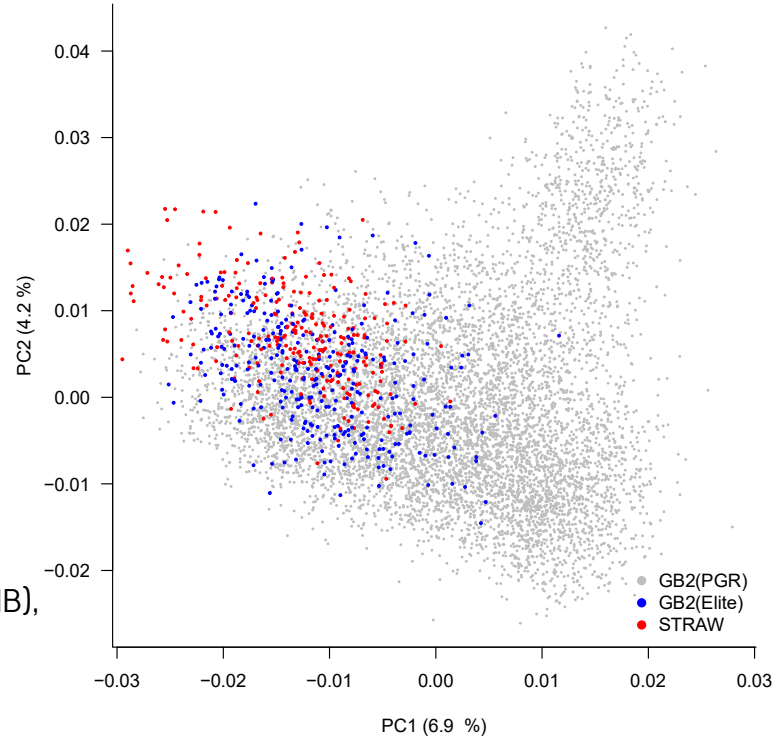


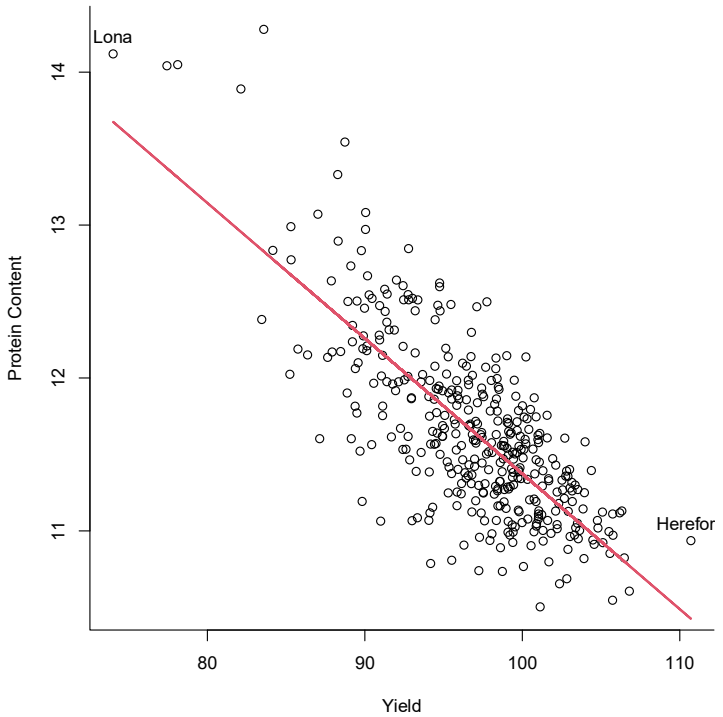
Elite European winter wheat panel (GABI)

Panel of 372 elite lines

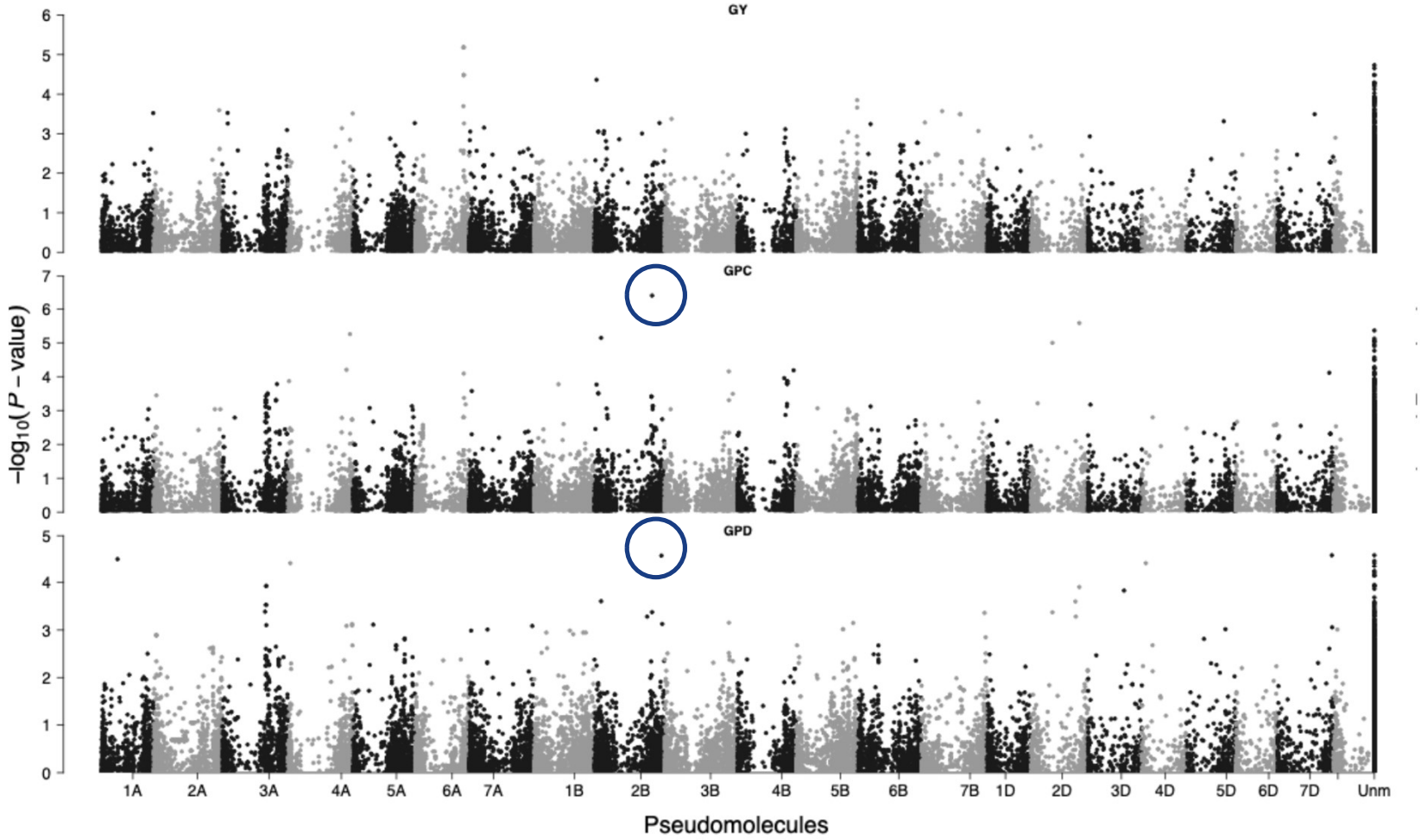
The phenotypic data :

- heading date (HD),
- plant height (PH),
- thousand grain weight (TGW),
- ear weight (EW),
- grains per ear (GPE),
- yield (YIE),
- specific weight (SW)],
- grain hardiness (GH),
- starch content (STC),
- protein content (PC),
- sedimentation index (SDS),
- Hagberg falling number (HAG),
- zeleny sedimentation index (ZEL)]
- resistance to fusarium head blight (FHB),
- resistance to septoria blotch (STB),
- resistance to tan spot (DTR)

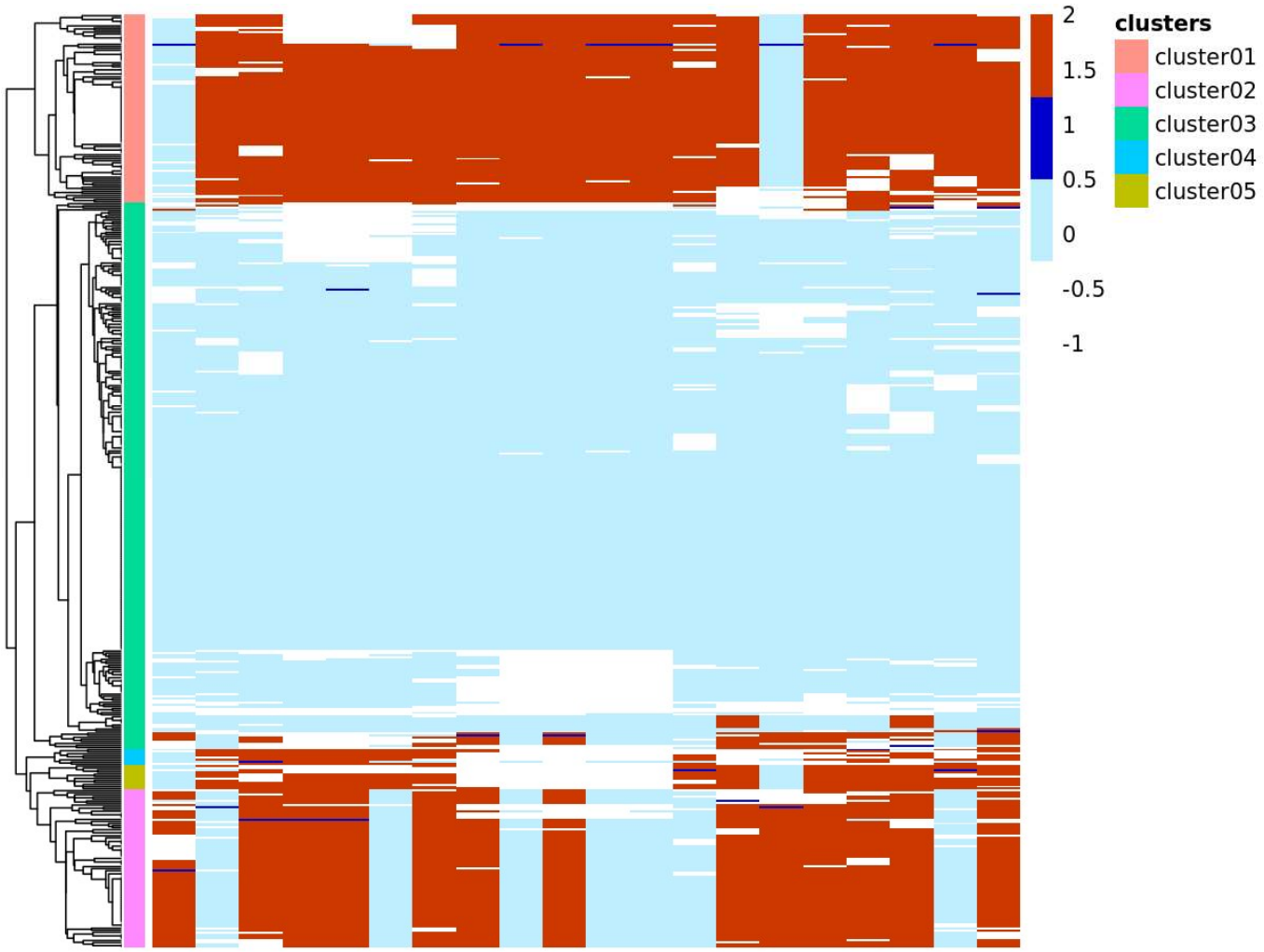


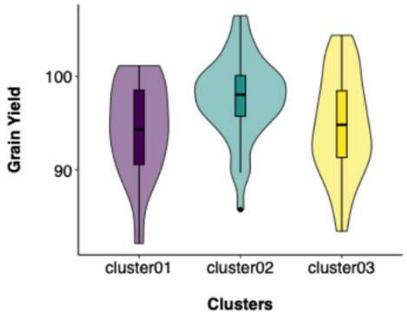


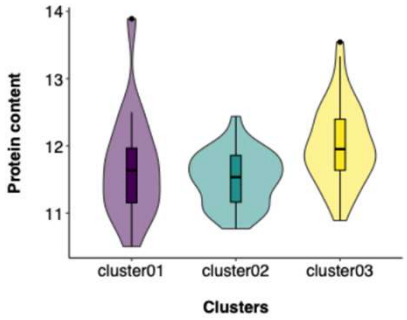
GWAS-GABI wheat panel

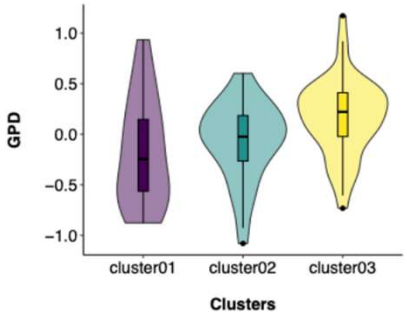


Haplotype Analysis – GABI wheat panel

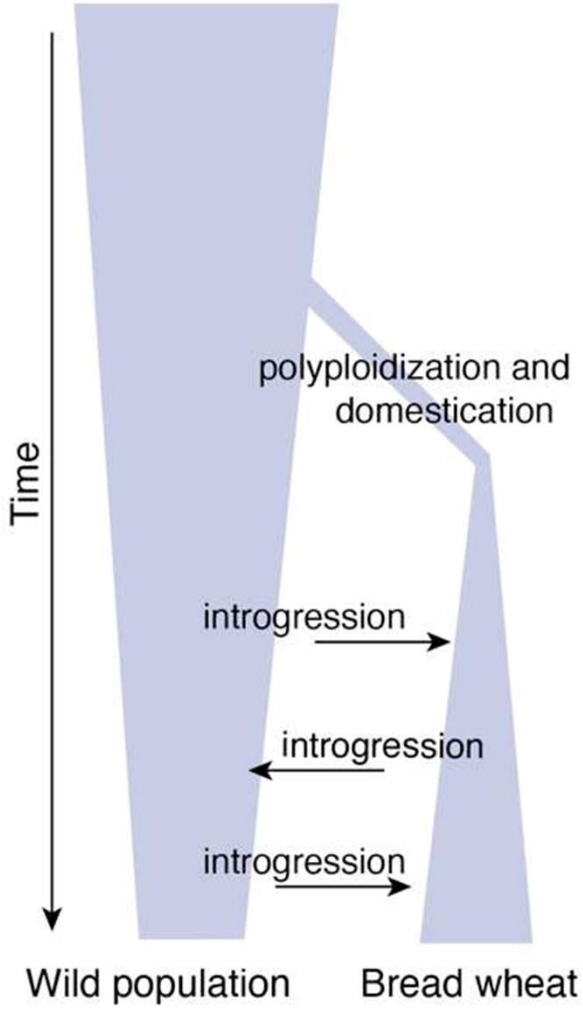




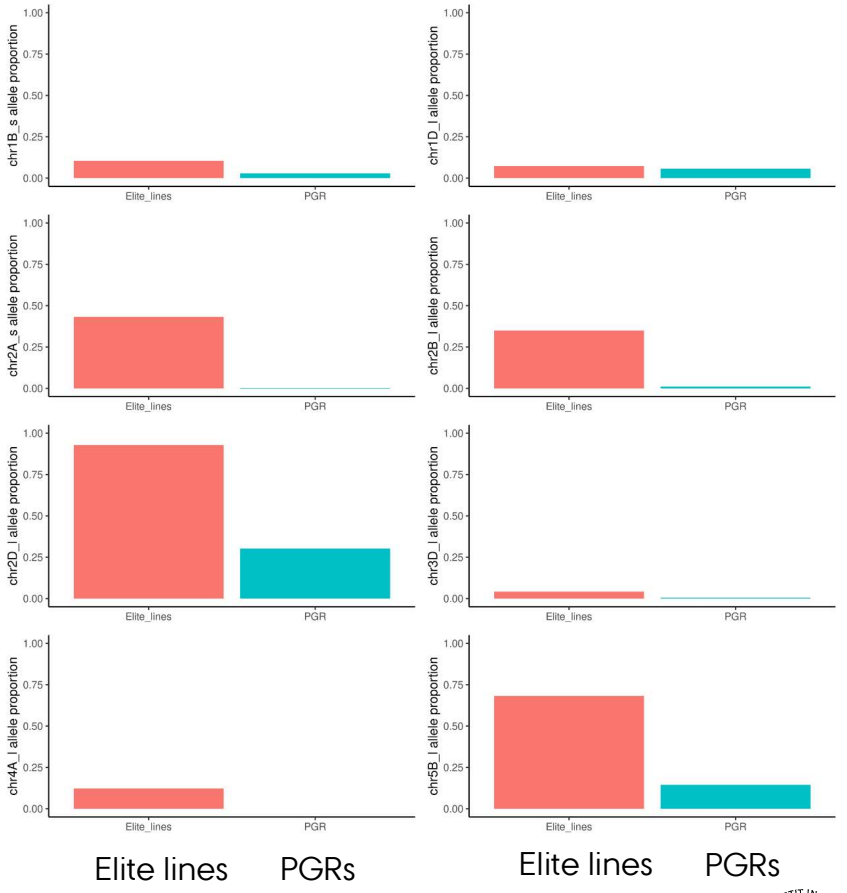




Introgressions/Translocations in bread wheat



Lr37–Yr17–Sr38–Pm4 locus on chr2A
From *Aegilops ventricosa*

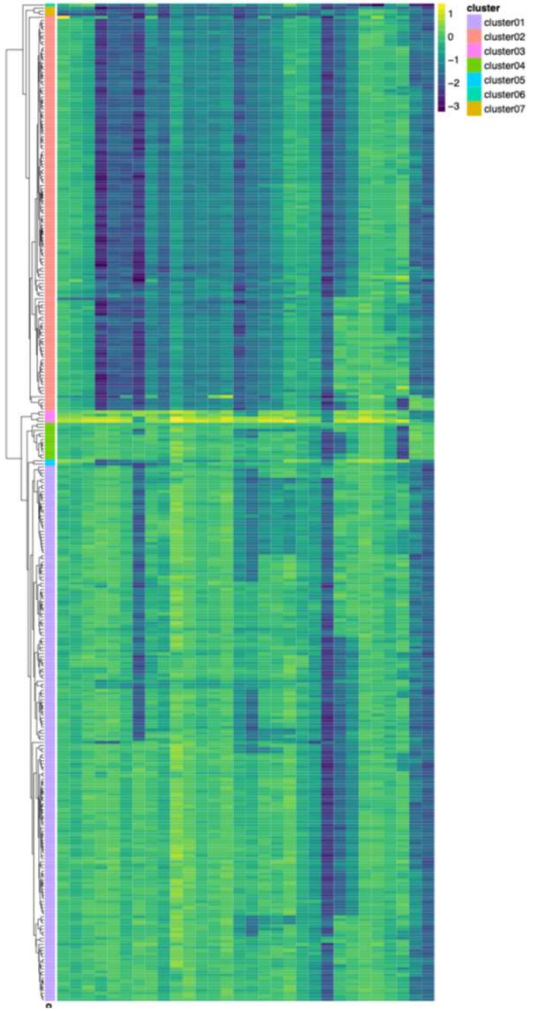


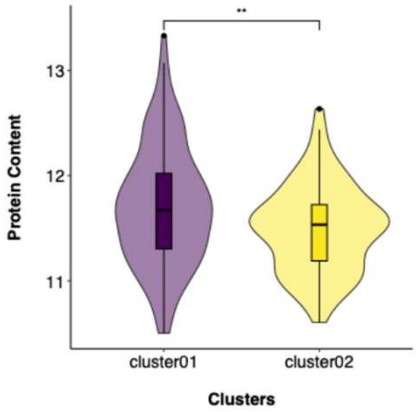
Frequent introgressions in
wheat cultivars

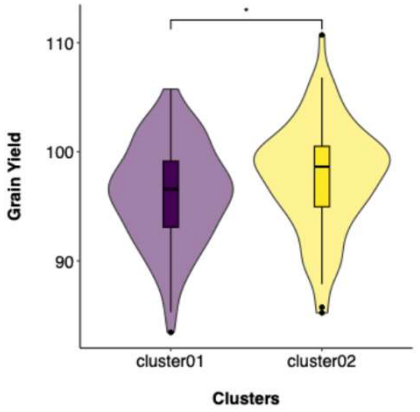
Introgression on Chr2B

GPC locus on chr2B
Falls within the introgressed region

Pm6 locus on chr2B
From *Triticum timopheevii*







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The Plant Genome

ORIGINAL ARTICLE

Special Section: Wheat Genomics and Genetics

An introgression from *Triticum timopheevii* reduces grain protein content in winter wheat populations

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Abstract

Improving grain protein content (GPC) in wheat (*Triticum aestivum* L.) is crucial for enhancing end-use quality and ensuring efficient nitrogen (N) utilization, thereby reducing environmental damage caused by excess N. However, progress in increasing GPC has been limited because of the strong negative correlation between GPC and grain yield (GY), as well as the scarcity of multi-location, multi-year phenotypic data. In this study, we analyzed the variation in GPC, GY, and grain protein deviation (GPD) using multi-location, multi-year phenotypic data from winter wheat varieties in Scandinavian regions. As reported previously, we observed a negative correlation between GY and GPC, with recent cultivars showing higher GY but lower GPC. Additionally, a genome-wide association study (GWAS) in two independent populations identified significant marker–trait associations (MTAs) for GPC and GPD, with key MTAs located on chromosome 2B (chr2B), highlighting its central role in the regulation of these traits. Interestingly, the MTA for GPD on chr2B coincided with an introgression from *Triticum timopheevii*, which was associated with reduced GPC and GPD in elite lines carrying this region. This introgression, which contains a powdery mildew resistance gene (*Pm6*), appears to negatively affect GPC, likely due to linkage drag. These findings emphasize the importance of chr2B in wheat breeding and suggest that advanced genomic techniques, such as mutagenesis and CRISPR-Cas, could be employed to mitigate negative pleiotropic effects and improve GPC and GPD. Overall, this study provides valuable insights into the genetic architecture underlying GPC in wheat and offers directions for future breeding strategies aimed at enhancing protein content.

Abbreviations: BLUE, best linear unbiased estimate; GBS, genotyping-by-sequencing; GPC, grain protein content; GPD, grain protein deviation; GWAS, genome-wide association study; GY, grain yield; IBS, identity-by-state; IWGSC, International Wheat Genome Sequencing Consortium; MTA, marker–trait association; NIR, near-infrared; NT, National Trial; OVT, Official Variety Testing; PM, powdery mildew; PCA, principal component analysis; QTL, quantitative trait locus; SNP, single nucleotide polymorphism; TILLING, targeting-induced local lesions in genomes; WGRS, whole-genome re-sequencing.

Summary & Future Prospective

- We identified a region on chr2B explaining 11.5% and 14.45% of the variation in GPC and GPD, respectively.
- It corresponds to a 0.5% increase in GPC.
- The region also harbor *Pm6* locus and negative effect on GPC.
- Breaking the linkage between *Pm6* and GPC is needed.
- New Breeding Techniques (NBTs) like mutation breeding, CRISPR-Cas9 can be used
- GWAS fixing the introgression

THANK YOU

Sejet plant breeding

Nordic Seed

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Konkurrencedygtig Planteproduktion

Promilleafgiftsfonden for landbrug