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RESEARCH GROUP ON CEREALS, RHEOLOGY AND FEED TECHNOLOGY

T. Hellemans[a], K. Dewitte[b], F. Van Bockstaele[a], P. Vermeir[c], G. Haesaert[b], and M. Eeckhout[a]

[a] Department of Food Technology, Safety and Health, Faculty of Bioscience Engineering, Ghent University, [b] Department of Plants and Crops, Faculty of Bioscience Engineering, Ghent University,
[c] Laboratory for Chemical analysis (LCA), Department of Green Chemistry and Technology, Faculty of Bioscience Engineering, Ghent University

PLANT DEVELOPMENT, YIELDING PROPERTIES AND KERNEL COMPOSITION OF WINTER WHEAT IN RELATION TO SOIL TYPE AND IRRIGATION TREATMENT UNDER AN ORGANICALLY ELEVATED TEMPERATURE

Introduction

- The **relation between soil type and kernel composition** of winter wheat (*Triticum aestivum L.*) is limitedly examined. [1]
- **Protein content** – especially polymeric proteins (glutenins) – is increased by drought stress while heat stress has the opposite effect resulting in a lowered dough strength. [2]
- Preliminary trials indicated that soils with an increased water retention capacity (i.e. clay) can **diminish effects of drought stress.**
- Earlier research seldom provided an in-depth look at how **protein composition on a molecular level is influenced** by soil type or drought and heath stress.

Fig. 1: setup of the greenhouse trial with tailor-made soil moisture registration system

Materials and methods

Three distinct winter wheat (*Triticum aestivum* L.) cultivars (**Table 1**), were grown in four replicates in 1.20 m high tubes (d = 15 cm) filled with coarse sand or heavy clay at a seeding rate of 350 seeds/m². From ear emergence (Zadoks GS 50) until harvest, half of the tubes (n = 24) were irrigated with 1/3rd of the water compared to the fully irrigated tubes to simulate drought stress conditions. (**Fig 1**).

Throughout the entire growth period, soil conditions and environmental parameters were registered as well as plant developmental attributes – e.g., plant height, no. of tillers, SPAD, etc. After harvest, yielding properties, kernel morphology, starch (enzymatic) and amylose content (HPLC), protein content (Dumas) and composition (RP-HPLC and SDS-PAGE) and concentrations of Fe, K and Zn (synchrotron XRF) were determined.

Table 1: overview of the starch type and the wheat high molecular weight glutenin composition (SDS-PAGE) for the three cultivars applied in the greenhouse trial

Cultivar	Starch type	Glu-A1	Glu-B1	Glu-D1
Gedser	Normal	0	7+9	2+12
KWS Ozon	Normal	1	7+9	5+10
WaxyDie	Waxy	2*	7+8	5+10

Plant development

- Plant height was not significantly affected (p=0.245) by treatment (**Fig. 2**) despite interactions with soil type and genotype were observed.
- Both soil type and treatment affected the number of tillers significantly with a slight increase for irrigated plots compared to plots with drought stress treatment.
- Number of kernels per ear and grain yield increased (r>0.65) with plant height as well as the number of tillers for plots under drought treatment.

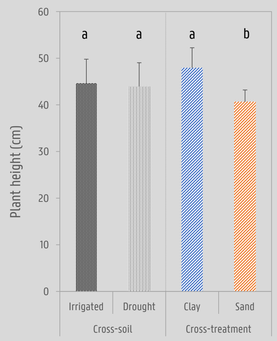


Fig. 2: plant height at harvest is solely affected by soil type, not by irrigation treatment

Kernel composition

Starch and protein content

- Soil type and genotype both influenced the starch content significantly (p<0.01), however, interaction effects between both factors could be observed (**Fig. 3**).
- Extremely high protein contents (16.5-28.5%) were obtained as a result of the high average day temperatures (21.7°C) during grain filling.
- Starch and protein content showed a weak but highly significant correlation (r=0.54).

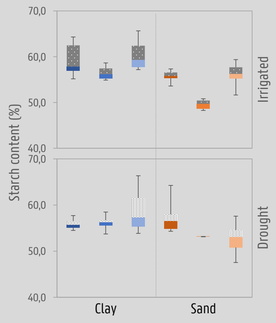
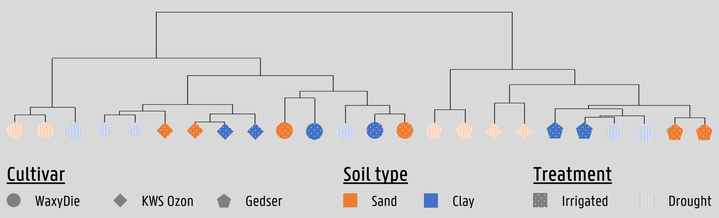


Fig. 3: grain starch content (n=12) per genotype, soil type and treatment

Protein composition

- Mainly glutenin composition was altered by drought stress conditions (**Fig. 4**).
- Prolamin:glutelin-ratio was significantly affected by all three factors and their mutual interactions, showing higher values for wheat grown on sandy soils under irrigated conditions. HMW:LMW-ratio, however, was not significantly influenced by soil type (p=0.765). Drought stress resulted in an increased ratio.
- Analyses indicated that cv. 'Gedser' will form a less elastic/rigid gluten network upon mixing with water.



Fi.g 4: dendrogram (ac=0.86) illustrating that glutenin composition, as determined by RP-HPLC, was affected by drought stress (on a sandy soil) (two biological replicates)

Principal Component Analysis

- On the basis of plant development parameters, yielding properties, kernel morphology, and compositional attributes, the different environment-treatment combinations could be partially distinguished in the score plot (**Fig. 5B**).
- Kernel morphology and thousand kernel weight were strongly correlated with protein *composition*. Plant height, number of ears or tillers, etc. showed a relation with starch and protein *content* (**Fig. 5A**).
- Severity of drought stress (sand drought > sand irrigated > clay drought > clay irrigated) results in an increase in the protein content and a drastic yield reduction.
- Due to the high water retention capacity of clay soils, effects of drought stress are diminished. However, retardation of plant development may also result in changes in the protein composition.

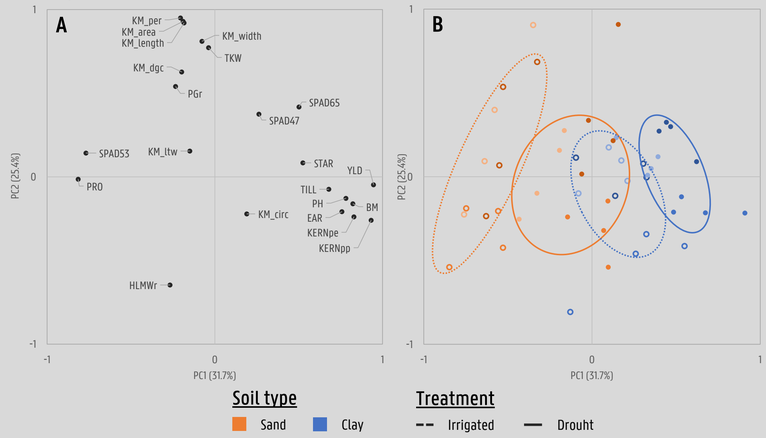


Fig. 5: loading (A) and score (B) plots from the two first principal components (PC) explaining 57.1% of the variability

Abbreviations: PH: plant height, TILL: # tillers, SPADi: SPAD-values per growth stage, EAR: # ears, BM: biomass, KERNpp/e: # kernels per plant/ear, TKW: thousand kernel weight, YLD: yield, KM: kernel morphology attributes [per: perimeter, ltw: length-to-width, circ: circularity, dtc: distance to geometric center] PRO: protein content, PGr: prolamin:glutelin ratio, HLMWr: ratio of high/low molecular weight glutenin subunits, STAR: total starch content

Conclusion

Grain compositional attributes are significantly affected by drought stress under organically elevated temperatures, mainly resulting in extremely high protein contents and deprived yields. Soil type can also contribute to similar effects due to its varying water retention capacities. These properties can on the other hand also be employed to diminish water stress related effects. However, fundamental research on the relationship between soil humidity and plant development and grain *composition* is required.

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[1] Hellemans, Tom, et al. "Impact of crop husbandry practices and environmental conditions on wheat composition and quality: a review." *Journal of agricultural and food chemistry* 66.11 (2018): 2491-2509.
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