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WATER BASED FREE ENERGY AS IMPORTANT FACTOR OF MAIZE GRAIN FILLING

V. Dragičević, M. Simić, B. Kresović and M. Brankov

Maize Research Institute "Zemun Polje", Slobodana Bajića 1, 1185 Zemun Polje, Serbia. (vdragicevic@mrizp.rs)

ABSTRACT
Kernel filling is important for achieving yield height and stability. It is firstly followed by the intensive accumulation of nutrients and water, up to the moment when polymerisation takes advantage, and added water tends to be loosed to the full ripening stage. The fluctuations of free energy of free, bulk and chemically boned water were measured in grains of different maize hybrids, grown at distinct densities, during grain filling. Free water gradually decreases during whole period, indicating that proper hydration is important for process continuity. Whereas bulk and chemically boned water are important for polymeriation phase. Maize growing at higher density enables higher water retention in kernels, with slower polymerisation.

INTRODUCTION
Kernel filling is important phase in maize lifecycle, defining yield height and stability. It is firstly followed by the intensive accumulation of assimilates and water, up to the moment when polymerisation takes advantage, when added water tends to be loosed to the full ripening stage. The dynamics of water fluctuation in kernel depends on genotype characteristics and agro-ecological conditions [1, 2]. One of the important factors that influence kernel moisture, and yield is crop density.

Besides the carrying of nutrients into kernels, water enables source (solute) for chemical reactions in kernels. Based on the water status, it could be assumed which processes take advantage, monomer accumulation or polymerization, i.e. endergonic over exergonic reactions [3]. Free energy presents the work necessary to make the sorption sites available, and so the higher the moisture content is, the number of available sites are lower [4].

The aim of this experiment was to test reaction of different maize hybrids, grown at distinct densities, based on fluctuations of free energy of free, bulk and chemically boned water in maize kernels, during grain filling.

EXPERIMENTAL

The experiment was performed with the aim to study how low and high crop density: 59523 plants ha^{-1} (D1) and 89286 plants ha^{-1} (D2) affects moisture fluctuation in kernel of ZP 366 (H1), ZP 555 (H2) and ZP 606 (H3) during vegetative season of 2017. After cob measuring, grains were sampled every 10 days (phase I to phase VI), starting from the 15th day after full pollination. The moisture was determined after drying at 60°C (free water), 105°C (bulk) and 130°C (chemically boned water). Free energy (ΔGFW – free water; ΔGBW-bulk water; ΔGBonW-boned water) was calculated using sorption isotherm [5]:

$$\Delta G = -RT\ln(a_w)$$

where a_w is the relative water content achieved after drying at T (60, 105 and 130 °C), R is the gas constant (8.3145 J mol^{-1} K^{-1}) and ΔG is differential free energy. The experimental data were statistically processed by standard deviation.

RESULTS AND DISCUSSION

Grain filling is characterised by gradual accumulation of assimilates in the form of monomers and their further polymerisation, to the composition characteristic for each plant species (genotype). It is specific that ΔHFW increased mainly continually from phase I to phase VI (Table 1), indicating the presence of endergonic over exergonic reactions [3].

Lesser continuality in ΔHFW was present at H3. In grain of the same hybrid ΔHFW finished its increase in phase V at D1, meaning that lower density induces drop in available sorption sites, i.e water retention in grain, opposite to results obtained by Farnham [6].

ΔGBW and ΔGBonW expressed lesser gradation during grain filling, particularly ΔGBW at D1. The highest difference was present between phase I and II, when greater amounts of nutrients enter into kernels [2]. The further variations in ΔGBW were generally lower. This means that available sorption sites for bulk water reached their maximum and remained stable. Only for H3 at D2, increase in ΔGBW was somewhat continual, up to phase VI. In general, ΔGBonW had the highest values, since this kind of energy is the strongest one, bonding water to macromolecules [4, 7]. Similarly to ΔGBW, ΔGBonW rapidly increases between phase I and II and then slowly, up to phase VI. This could indicate that from phase II to VI saturation of sorption sites for water is present, so the polymerisation of storage molecules takes domination in regard to nutrients entering into kernel. Only H3 exhibits difference at D2, with stability of ΔGBonW reached in phase III. This indicates slower accumulation of storage substances.

Table 1. Fluctuations in free energy of free water (ΔGFW), bulk water (ΔGBW) and bound water (ΔGBonW) in maize grain during grain filling period of three maize hybrids (H1-H3) grown at twoi densities (D1 and D2)

	Dens.	Phase	ΔGFW (J mol^{-1})	ΔGBW (J mol^{-1})	ΔGBonW (J mol^{-1})
H1	D1	I	0.40 ± 0.15	4.07 ± 1.35	6.65 ± 1.09
		II	1.00 ± 0.22	10.98 ± 0.10	14.38 ± 0.16
		III	1.86 ± 0.20	11.20 ± 0.07	14.08 ± 0.18
		IV	3.17 ± 0.37	11.58 ± 0.07	15.28 ± 0.07
		V	3.87 ± 0.39	11.47 ± 0.10	15.32 ± 0.08
		VI	6.66 ± 0.89	11.89 ± 1.67	15.75 ± 1.47
	D2	I	0.39 ± 0.06	4.82 ± 1.38	7.43 ± 0.92
		II	0.79 ± 0.16	10.69 ± 1.19	12.65 ± 0.85
		III	1.93 ± 0.20	11.27 ± 0.13	13.85 ± 0.22
		IV	2.79 ± 0.28	11.46 ± 0.13	14.33 ± 0.25
		V	4.66 ± 0.35	12.02 ± 0.12	15.75 ± 0.45
		VI	6.27 ± 0.23	11.36 ± 0.15	17.92 ± 0.38
H2	D1	I	0.35 ± 0.16	3.96 ± 1.39	6.45 ± 0.96
		II	0.72 ± 0.23	10.11 ± 0.31	12.49 ± 0.33
		III	1.87 ± 0.28	11.89 ± 0.11	13.55 ± 0.25
		IV	3.01 ± 0.34	11.42 ± 0.08	15.13 ± 0.05
		V	4.67 ± 0.24	11.27 ± 0.11	15.39 ± 0.03
		VI	6.37 ± 0.85	11.72 ± 1.43	15.56 ± 1.41
	D2	I	0.40 ± 0.10	5.67 ± 1.14	7.60 ± 1.18
		II	1.11 ± 0.15	10.49 ± 1.02	14.30 ± 0.92
		III	1.85 ± 0.19	11.34 ± 0.17	13.66 ± 0.31
		IV	3.03 ± 0.29	11.36 ± 0.11	16.06 ± 0.31
		V	4.73 ± 0.26	11.94 ± 0.10	15.44 ± 0.08
		VI	5.63 ± 0.13	11.69 ± 0.06	15.86 ± 0.08
H3	D1	I	0.39 ± 0.12	4.44 ± 1.17	5.72 ± 1.03
		II	0.62 ± 0.18	9.50 ± 0.34	11.98 ± 0.46
		III	1.56 ± 0.27	11.16 ± 0.06	13.53 ± 0.28
		IV	2.41 ± 0.21	11.37 ± 0.02	15.66 ± 0.06
		V	4.20 ± 0.01	11.50 ± 0.02	15.22 ± 0.05
		VI	4.27 ± 0.55	11.41 ± 1.57	15.49 ± 1.74
	D2	I	0.40 ± 0.01	4.73 ± 0.92	5.67 ± 0.91
		II	0.48 ± 0.09	8.64 ± 0.94	10.80 ± 1.09

III	1.18 ± 0.20	10.20 ± 0.44	14.34 ± 0.57
IV	2.47 ± 0.23	11.26 ± 0.23	15.03 ± 0.09
V	3.49 ± 0.31	11.49 ± 0.07	14.45 ± 0.16
VI	5.55 ± 0.29	11.66 ± 0.04	15.76 ± 0.23

CONCLUSION

It could be concluded that maize grain filling is complex process, depending highly on grain water and its free energy. Free water is category with gradual decrease during whole period, indicating that proper hydration is important for process continuity. Whereas bulk and chemically boned water are important for polymerisation phase. In this study, growing at higher density enables higher water retention in kernels, with slower polymerisation, particularly for H3 (ZP 606). All these could contribute to greater yielding capacity.

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