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VARIABILITY OF MAIN NUTRIENTS IN MAIZE INBRED LINES CAUSED BY APPLICATION OF ORGANIC PEROXIDES

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ABSTRACT

Exogenous application of chemical elicitors to plants can be successfully used to reduce damage caused by abiotic stresses and consequently to enhance productivity. Different organic peroxides, applied foliarly as DMSO solution, were used in this study with the aim to examine variations in grain yield and main nutrient status, i.e. protein, starch and oil contents, of four maize inbred lines. Results showed that two genotypes reacted positively on applied treatments, achieving higher grain yields than control group, with differences up to 2-3 t ha⁻¹. In total, one of the applied peroxides expressed the highest impact on yield enhance. In terms of nutritive quality, the same treatment mostly increased the starch content. With regard to protein content, higher value was achieved by the same genotype which had higher grain yield, and for oil content, variations in results among treatments were insignificant and irregular. This indicates that synthetic elicitors, such as organic peroxides, could be used not only to increase grain yield, but also to modify grain nutritional quality in regard to genotype variability.

Keywords: foliar treatment, chemical elicitors, grain, yield, nutritional quality

INTRODUCTION

Maize belongs to the three most widely grown crops and it is ranked first among the cereal crops grown throughout the world (WU *et al.*, 2019; VANCETOVIĆ *et al.*, 2014). It is one of the most important crops due to its wide uses as food, feed and as industrial material. Consequently, the main objective of the breeding program is to create hybrids, i.e. lines with improved properties, both in terms of quality and yield potential. From the quality characteristics, main nutrients in maize grain are starch, oil and protein. Starch is energy source, while protein and oil content are especially important traits at the maize market (MLADENOVIĆ DRINIĆ *et al.*, 2013a; YANG *et al.*, 2013; MLADENOVIC-DRINIC *et al.*, 2013b; AL-NAGGAR *et al.*, 2016).

According to PUNJ and HARYANA (2012) abiotic stresses such as drought, temperature, salinity, etc. that induce oxidative stress affect plant growth, productivity and quality. Maize mitigates induced damage through various mechanisms: activating enzymatic and nonenzymatic antioxidants, growth regulators and osmoprotectants. Many studies (AHMAD *et al.*, 2014; TRIVEDI *et al.*, 2018; AHMAD *et al.*, 2013) involved foliar application of different elicitors with the aim to overcome negative environmental impacts by stimulating one of these mechanisms. Exogenous treatment enhances maize antioxidant defense system, positively affecting the productivity and nutrient quality of grain as a result of lower degree of stress on the plant (CHATTHA *et al.*, 2015). It is reported that plant growth regulators improve photosynthate partitioning and grain development, thereby increasing plant tolerance to stress (WAQAS *et al.*, 2017). This research was aimed to examine elicitor effect of organic peroxides, with structure similar to plant growth hormones (MESAROVIC *et al.*, 2015), on yield and main nutrient status of four different maize inbred lines.

MATERIALS AND METHODS

The experiment was carried out to investigate elicitor effect of synthetic organic peroxides (belonging to mixed tetraoxanes) on grain yield and status of protein, starch and total oil in different maize inbred lines. Seeds of four maize inbred lines: L 355/99 (G1), L 76 B004 (G2), L 76 B036 (G3) and L 73 B003 (G4) were sown in randomized block design at field of Maize Research Institute „Zemun Polje“, Serbia. Each line was sown in two rows of 5 m in length, with four replications. In 5-8 leaves stage lines were treated foliarly with four organic peroxides (T1-T4), dissolved in DMSO solution, to assure their absorption by foliage. Two control groups had also been set up, one without spraying (C) and one treated with DMSO only (D).

After harvesting, grain yield was measured and calculated to 14% of moisture. The content of protein, starch and oil was determined on infrared analyzer (Infraneo, Chopin Technologies, France) and expressed as percentage of grain dry matter.

Results were analyzed using analysis of variance (ANOVA) and the significance of the treatments effect were determined by the Fisher's least significant difference (LSD) test at $p = 0.05$. Evaluation of interdependence between genotypes and treatments was analyzed using principal component analysis (PCA). Statistical data were processed by SPSS 15.0 (IBM Corporation, Armonk, New York, USA) for Windows Evaluation version.

RESULTS AND DISCUSSION

G1 line provided higher yield in comparison to the other three lines (Table 1). However, treatments haven't expressed effectiveness because treatment with DMSO, as

control, gave the highest yield. Foliar application of peroxides expressed good results in lines G2 and G3, achieving yields of 2-3 tons higher than control. One of the applied peroxides (T3) showed the highest impact on yield enhance. Results obtained in this research are in accordance with results obtained by AHMAD *et al.* (2014) in which mixture of ascorbic acid, salicylic acid and hydrogen peroxide applied on grain increase yield under stressful conditions. They explained observed effect through increased antioxidant activity which helped the maize crop to maintain relatively optimal photosynthesis under abiotic stress.

Table 1. Effect of different genotypes (G1-G4) and exogenous treatments (T1-T4) on grain yield (t ha⁻¹) of maize inbred lines

	G1	G2	G3	G4	Average
C	10.41	4.58	6.51	6.56	7.02
D	11.31	6.25	6.10	6.24	7.47
T1	10.01	6.57	6.06	6.39	7.26
T2	9.08	8.10	6.99	6.28	7.61
T3	10.88	7.24	7.35	5.87	7.83
T4	9.00	7.11	7.18	6.54	7.46
Average	10.12	6.64	6.70	6.31	7.44
LSD_{0.05}	T 1.44, G 0.75, T x G 1.68				

In terms of nutritive value, significant variability in starch and protein content was observed. Taking into account, genotype by treatment interaction, results for protein content (Table 2) showed that elicitors had positive influence only in G3, while in G1, G2 and G4 lines maximum values were recorded in control groups (C or D).

Table 2. Effect of different genotypes (G1-G4) and exogenous treatments (T1-T4) on protein content (expressed as % of grain DM).

	G1	G2	G3	G4	Average
C	10.29	10.98	9.92	9.54	10.18
D	10.61	10.94	10.23	9.46	10.31
T1	10.55	10.95	10.07	9.31	10.22
T2	10.10	10.47	10.32	9.27	10.04
T3	10.17	10.19	10.00	9.19	9.89
T4	10.22	10.23	10.32	9.13	9.98
Average	10.32	10.63	10.14	9.32	10.10
LSD_{0.05}	T 0.47, G 0.20, T x G 0.38				

Concerning the starch content (Table 3), one of applied peroxides (T3) raised starch level in three genotypes (up to the 0.54, 0.07 and 0.53%, for G1, G3 and G4, respectively). The same treatment also expressed the greatest influence on yield enhance (Table 1). Similarly, CHATTHA *et al.* (2015) reported greater yield and starch content by applying some of growth promoting substances, as well as enhanced protein content, which is opposite to our results. Exogenous treatments affect the tested parameters in different ways, depending on the type of applied elicitor and environmental conditions (TRIVEDI *et al.*, 2018; WAQUAS *et al.*, 2017), which is also confirmed in this research.

Table 3. Effect of different genotypes (G1-G4) and exogenous treatments (T1-T4) on starch and oil content of maize grain.

	Starch (%) ^a					Oil (%) ^a				
	G1	G2	G3	G4	Average	G1	G2	G3	G4	Average
C	68.93	70.15	69.70	71.50	70.07	3.67	3.57	3.93	3.50	3.67
D	69.00	68.17	68.97	71.27	69.35	3.67	3.63	3.83	3.23	3.59
T1	69.03	67.70	69.23	71.47	69.36	3.47	3.63	4.00	3.37	3.62
T2	69.10	69.37	69.47	71.53	69.87	3.60	3.70	3.87	3.30	3.62
T3	69.47	69.47	69.77	72.03	70.18	3.50	3.63	3.73	3.43	3.58
T4	69.30	69.53	69.53	71.50	69.97	3.50	3.90	3.93	3.37	3.68
Average	69.14	69.06	69.44	71.55	69.80	3.57	3.68	3.88	3.37	3.62
LSD_{0.05}	T 0.98, G 0.43, T x G 0.83					T 0.19, G 0.09, T x G 0.20				

^aValues are expressed as a percentage of grain dry matter.

In contrast, T1 peroxide adversely affected content of starch in almost all maize inbred lines (Table 3). Among tested genotypes, G4 is the line with the highest starch level in all treatments and control groups, too.

For total oil content, differences at a significant level were obtained only among genotypes, whereas variations in results due to foliar treatment were insignificant and irregular (Table 3). This indicates that applied peroxides were ineffective for modification of oil content.

PCA

In order to evaluate the interaction among maize inbred lines, applied treatments and nutrient content, the PCA was used and indicated that first two axes were explained by 59.9% and 25.6% of total variability for examined parameters, respectively. Projection of variables are shown in Figure 1. and pointed that protein and starch content contributed mainly to PC1 (90.6% positively and 96.4% negatively, respectively), while grain yield to PC2 (86.4%). These results are in line with previous studies, where a negative correlation between starch content on the one side and protein and oil content

on the other side are confirmed (MLADENOVIĆ DRINIĆ *et al.*, 2013a; YANG *et al.*, 2013). All treatments applied on G1, as well as T2 application on G2, affected the yield, while starch content was altered by all applied treatments on G4. Similarly, applied foliar treatments influenced the oil content in G3, while in G2 line, protein and oil content varied mainly, depending on the treatments.

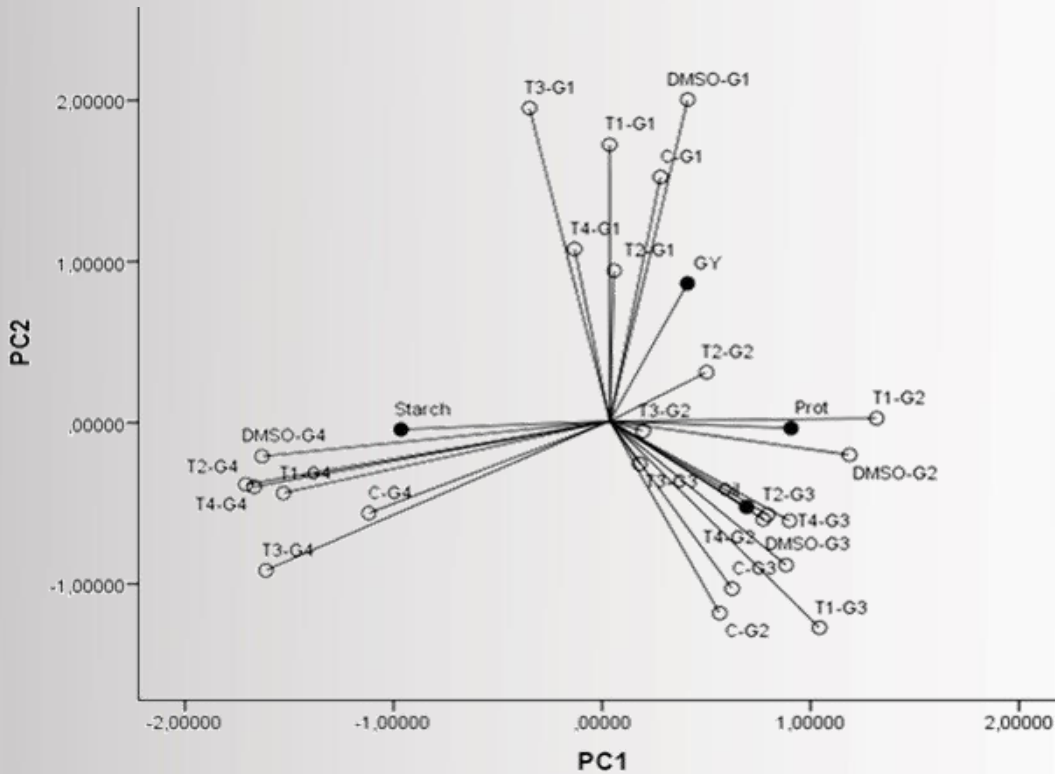


Figure 1. The obtained PCA plot for PC1 and PC2 components, showing the interaction among genotypes, elicitors and main nutrients.

CONCLUSION

Significant differences among genotypes were present for the yield, as well as content of main nutrients. G1 and G4 were genotypes with the highest average yield and starch content, respectively, whereas significant variations in protein and oil content were present among all genotypes.

According to the obtained results, exogenous treatment increased grain yield with differences up to 2-3 t ha⁻¹ in G2 maize line. Foliar application of T3 peroxide provided the highest yield and starch content increase. Accordingly, T3 elicitor should be tested on a larger number of maize genotypes in order to confirm its benefits. In terms of protein content, elicitors have had positive influence only in G3 line, the same one with a higher grain yield. Applied peroxides didn't express significant impact on oil content.

This indicates that various elicitors, such as organic peroxides, could be used not only to increase grain yield, but also to modify grain nutritional quality, including variability among genotypes.

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