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INFLUENCE OF STORAGE TIME ON QUALITY OF ENCRUSTED MAIZE SEEDS

Ala BOROVSKAIA[1], Elena LUTCAN[1], Raisa IVANOVA[1*], Nicolai VANICOVICI[2]

[1]Institute of Genetics, Physiology and Plant Protection, Moldova State University, Chisinau, Republic of Moldova
[2]Institute of Crop Science „Porumbeni", Pascani, r. Criuleni, Republic of Moldova
*Corresponding author: raisa.a.ivanova@gmail.com

ABSTRACT

The field germination of maize seeds is significantly affected by high soil moisture and suboptimal temperature, under adverse conditions it can decrease to 39%. Pre-sowing treatment of seeds by encrusting them with a conjugate based on biodegradable polymers and containing bioregulators increases the resistance of seeds to unfavourable conditions and promotes uniform germination and growth. The purpose of this study was to determine the changes in germination capacity, vigour and metabolic efficiency of encrusted maize seeds during 12 month of storage. The bioconjugate used for encrustation is based on sodium salt of carboxymethylcellulose containing genistifoliosides (iridoid glycosides extracted from *Linaria genistifolia*) as growth bioregulator. Seeds of P427 and P458 hybrids were encrusted and stored under laboratory condition. Their quality was compared with maize seeds of the same hybrids, commercially encrusted. Both vigour I and vigour II of P458 hybrid seeds were 1.15-1.54 and 1.28-1.94 times higher than those of P427 hybrid seeds, respectively. This regularity also persisted in seeds encrusted with the bioconjugate during the entire period of the investigation. High negative correlations between the biomass eliminated for respiration and the metabolic efficiency were revealed; the correlation coefficients were - 0.9557 (P427) and - 0.9457 (P458). The initial metabolic efficiency of seeds encrusted with the bioconjugate was reduced compared with intact seeds, but upon storage, it became higher than metabolic efficiency of intact seeds and commercially encrusted seeds. Thus, the encrustation with an environmentally friendly bioconjugate preserved the sowing qualities of maize seeds for a long storage time.

Keywords: *maize seed, bioconjugate, encrustation, seed quality.*

INTRODUCTION

The encrustation or coating of maize seeds contributes to elimination of significant variability existed in emergence and vigour at cold temperatures and high soil moisture for commercially produced hybrids (Ali *et al.,* 2018). Encrusting seeds with biodegradable polymers can help to protect seeds from environmental stress

and ensure a high percentage of seeds successfully germinate, which can ultimately lead to greater crop yields. Biopolymers, such as, starch, pectin, alginate, chitosan, gelatine gum arabic, cellulose and its derivatives (hydroxyethylcellulose, carboxymetylcellulose) have been used as substitutes to synthetic materials owing to their environment friendly and nontoxic characteristics, as well as good adherence to the seeds (Ren *et al.,* 2019; Pirzada *et al.,* 2020; Rahman *et al.,* 2021; Vinzant *et al.*, 2023).

The conjugate on biopolymer can help to retain moisture around the seed, preventing it from drying out and improving the seed's ability to absorb water. Additionally, some polymeric conjugate may contain fertilizers or other nutrients that can also enhance the early growth of plants, their good development and ultimately lead to greater crop yields. Carboxymethylcellulose is one of the most promising biopolymers due to its characteristic surface properties, mechanical strength, viscous properties, availability and low-cost synthesis process, and likewise many contrasting aspects (Rahman *et al.,* 2021). Carboxymethylcellulose-based seed coat has developed and tested for soybean (de Camargo *et al.,* 2017), wheat (Ren *et al*., 2019) and sweet corn (Mahisanon *et al.,* 2021) seeds using various fungicides and additives, and showed the effect of seed encrusting on germination, root/shoot growth and vigour. The incorporation of plant growth regulators with suitable concentrations in compositions of coating mixture improved seed germination of sweet corn (Suo *et al.,* 2017). Earlier it was showed that genistifolioside (plant extract), natural growth regulator, contributed to an increase in the metabolic efficiency of maize seeds subjected to heat stress (Ivanova *et al.,* 2021). A bioconjugate containing the sodium salt of carboxymethylcellulose and genistifolioside was developed at the IGFPP. Its effect was studied on seed pre-sowing encrustation of vegetable crops, such as cucumbers and white cabbage, as well as on the parental form of maize with a low germination (Borovskaia *et al*., 2022). The positive effect of seed encrustation with this bioconjugate, determined in laboratory conditions, consisted in increasing the germination energy up to 19% and germination by 14-35% of vegetable and cereal seeds. The positive effect of pre-sowing seed encrustation of maize parental form was confirmed by experimental data obtained in the field, which was expressed in improving the development of the root system and increasing the mass of both the green aerial part of plants and 1000 grains (Borovskaia *et al*., 2022). This study is a continuation of the ongoing research concerning the influence of seed encrustation with the developed bio-conjugate containing genistifolioside on the bio-morphological and physiological characters of maize. The purpose was to determine the modification of vigour and metabolic efficiency of encrusted maize seeds of different hybrids during the storage.

MATERIALS AND METHODS

The experiments were carried out in 2022-2023 years in laboratory conditions in the Institute of Genetics, Physiology and Plant Protection (IGFPP), Moldova State University, Republic of Moldova.

Seed materials. Maize seeds of hybrids Porumbeni 427 (P427), FAO 420, mid-late ripening, medium drought-resistant hybrid, and the Porumbeni 458 (P458) hybrid, FAO 450, late-ripening, resistant to drought, were generously contributed by the Institute of Crop Science „Porumbeni".

Composition of conjugate. The tested bioconjugate has the following composition: sodium salt of carboxymethylcellulose 1.0% as base, biodegradable polymer, and genistifolioside 0.1% as natural growth regulator, dry extract containing iridoid glycosides from *Linaria genistifolia*. An industrial conjugate containing fungicide Insure Perform (BASF) and colorant Peridiam (Solvay) was applied for commercially encrusting of maize seeds, which served as the object of comparison.

Laboratory testing. Each experiment consisted of 100 seeds (25 seeds on 4 replicates). Vigour and metabolic efficiency determination procedure included following steps:

a) germination of intact and encrusted seeds in optimal conditions. Index of total germination was determined on the seventh day as prescribed by the standard method of International Seed Testing Association (ISTA) (ISTA, 2019);
b) measure of roots and seedlings length of germinated seeds;
c) vigour I of roots and vigour II of seedlings were determined as the common value of the germination percentage and the length of roots and seedlings, respectively (Kerecki *et al.,* 2021; Khan *et al*., 2022);
d) separation of roots and seedlings from seeds;
e) drying of biomass (separated roots, seedlings, seeds);
f) determination of dry biomass weight;
g) calculation of reserve substances (SMR, g/unit) eliminated from seeds for respiration as follows:

SMR = SMU- (RMU + EMU + SMG)

where: SMU - dry weight of seeds before germination, g/unit; RMU - dry mass of roots, g/unit;

EMU - dry weight of seedlings, g/unit; SMG - dry weight of seeds after germination, g/unit.

h) seed metabolic efficiency (SME) was determined as the ratio of the sum of roots and seedlings dry weight (g) to the reserve substances spent on respiration, according to equation, described by (Sikder *et al.,* 2009, Dascaliuc *et al*., 2020):

SME = (RMU + EMU) / SMR

Vigour and metabolic efficiency indices were determined in intact seeds and in seeds encrusted by two procedures (bioconjugate and commercially) before and after 4 and 12 months of storage at room conditions.

Statistical analysis. The obtained experimental data were processed by the statistical methods using the software package Statgraphics Plus 5.0. The ANOVA test was applied for variance analysis of characters, Student test in assessment of statistically significant differences between plots (Raudonius, 2017).

RESULTS AND DISCUSSION

The initial overall germination of maize seeds was 96.0 and 98.0%, respectively in the hybrid P427 and P458. Intact seeds (control) of these two hybrids differed significantly ($p \leq 0.001$) in characters of roots and seedlings vigour. Vigour I of intact seeds of the P458 hybrid for the entire storage period was 1.15-1.54 times higher than of P427 hybrid seeds. Vigour II of control seeds was also 1.28-1.94 times higher in P458 seeds (Table 1).

Encrustation of P427 seeds with both the bioconjugate and commercially did not affect their germination and the growth of roots and seedlings, but the seeds of the P458 hybrid showed a statistically significant ($p \leq 0.001$) decrease in vigour values compared to the control. This fact indicated the specific physiological responce of different hybrids on encrustation prior to storage. No differences in studied characters were found between the seeds of the same hybrid encrusted with the bioconjugate and those encrusted commercially. Between the hybrids, the values of vigour I did not differ in the seeds both encrusted with bioconjugate and commercially, but vigour II significantly differed between the seeds encrusted with bioconjugate ($p \leq 0.05$) and commercially ($p \leq 0.001$). Thus, encrustation significantly reduced the vigour of roots and seedlings, as well as the metabolic efficiency in the seeds of the P458 hybrid. However, vigour I encrusted seeds of the P458 hybrid maintained comparable with those of P427, and vigour II was significantly higher (Table 1). The similar results of changes in physiological characters of encrusted seeds depending on types of cover and plant cultivars (de Camargo *et al.,* 2017) as well as on concentration of incorporated growth regulator (Suo *et al*., 2021).

After 4 months of storage, in seeds encrusted commercially, there were significant ($p \leq 0.001$) changes in both vigour I and vigour II. In the hybrid P427 these indices increased, but in the P458 hybrid decreased compared to the control seeds (Table 1). There was established the specific response reaction of different hybrids on encrustation with the same concentration of CMC and growth regulator. Suo *et al.* (2017) reported that different concentrations of growth regulators incorporated in encrustation complex could influenced significantly on germination and vigour indices, as well as on length of roots and seedlings of sweet corn. Seeds encrusted with the bioconjugate after 4 months of storage had no differences in vigour I compared to control, and vigour II was increased compared to seeds germinated before storage. Storage of encrusted seeds with the bioconjugate during 12 months did not affect the physiological potential of maize seeds, keeping the values of vigour and metabolic efficiency within the control seeds.

Table 1. Vigour values and metabolic efficiency of intact (control) and encrusted maize seeds during the storage

Storage time	Variant	Number of seeds	Vigour I	Vigour II	Metabolic efficiency
P427					
Before of storage	Control	98	772.73±28.10	417.56±16.72	0.9211
	Bioconjugate	97	853.92±28.25*	382.61±16.82	0.7897
	Commercially	97	819.18±28.25	375.12±16.82	0.8916
4 months	Control	98	738.61±24.94	394.96±13.85	0.7470
	Bioconjugate	96	781.26±25.20	484.12±13.98***	0.8581
	Commercially	98	1151.49±24.94***	561.48±13.84***	0.7462
12 months	Control	88	727.99±29.22	375.93±19.25	0.6708
	Bioconjugate	85	689.32±29.73	404.31±19.58	0.7445
P458					
Before of storage	Control	99	1038.20±27.96	583.06±16.65	0.8933
	Bioconjugate	95	872.08±28.55***	439.98±16.99***	0.7946
	Commercially	88	803.77±29.66***	472.92±17.65***	0.7179
4 months	Control	97	1129.28±29.65	651.06±17.57	0.8395
	Bioconjugate	84	1044.69±31.86	581.89±18.88**	0.8563
	Commercially	85	765.58±31.67***	500.82±18.77***	0.7994
12 months	Control	97	846.44±27.83	643.01±18.33	0.7871
	Bioconjugate	88	792.98±29.22	596.39±19.25	0.8221

Note: *; **; *** - statistically significant difference of encrusted seeds with control at $p \leq 0.05$; $p \leq 0.01$ and $p \leq 0.001$, respectivelly

The physiological characters of maize seeds encrusted with the bioconjugate improved after 4 months of storage. In our opinion, an increase in storage time of encrusted seeds of studied maize hybrids should have biological and economic justifications.

During storage, the metabolic efficiency of intact seeds of both hybrids decreased, indicating the need to expend more energy for seed germination. Bioconjugate encrustation did not affect on metabolic efficiency of maize seeds on long-term storage, that can be appreciate as positive influence of this encrustation. Having the weights of biomass separated components (seeds, roots, seedlings and reserve substances consumed to respiration) of germinated seeds the correlations between determined biomass and metabolic efficiency were calculated. High negative correlations between the biomass eliminated for respiration and the metabolic efficiency were revealed; the correlation coefficients were - 0.9557 and - 0.9457, respectively for seeds of the P427 and P458 hybrids (Figure 1).

Despite the fact that the two hybrids P427 and P458 reacted differently to encrustation some regularity also remained. The metabolic efficiency of all seeds (control, encrusted by two procedures (bioconjugate and commercially) increased when they mobilized less reserve substances for respiration. Influence of encrustation procedures on physiological characters of seeds need to be continued,

in special the impact of growth regulators incorporated in conjugate could be evaluated.

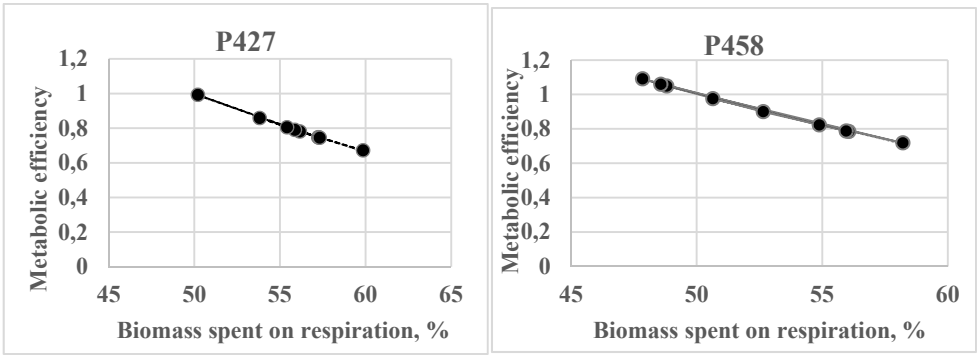

Figure 1. Dependence of metabolic efficiency on the fraction (%) of biomass spent on respiration from the total biomass of reserve substances consumed in the process of seed germination

CONCLUSION

Encrustation of maize seeds with the bioconjugate containing biologically active substances of natural origin, genistifoliosides, and biodegradable polymer, sodium salt of carboxymethylcellulose, contributes to preserve the physiological characters and sowing qualities of maize seeds, which changed during storage depending on hybrids. According to analyzed data, the maize seeds of the P427 hybrid were more sensitive to long-time storage and the influence of the bioconjugate.

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