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Behavior of some Hungarian wheat varieties to seed soaking in gibberellic acid under salt stress

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SUMMARY

Various abiotic stresses including high salinity strongly affect seed germination. Three Hungarian wheat landraces Gamási, Fóti and Kartali have been tested for seed germination, seedling growth and chemicals parameters when seeds were soaked in gibberellic acid (GA_3) at the concentrations of 0, 75 and 150 ppm and at four levels of salinity stress 0, 5, 10 and 15 dSm^{-1}. A laboratory experiment took place at Research Institute of Nyíregyháza. Factorial Experiment based on Randomized Complete Block Design (RCBD) in four replications has been conducted. Seed soaking in GA_3 before sowing significantly affected germination characteristics, seedling properties and the results of chemical analysis. The highest germination as well as K^+ content of seeds were observed at seed soaking into 150 ppm GA_3. However, Na^+ and proline contents in seedling were decreased. The behavior of the tested Hungarian wheat varieties was genotype-dependent. Increasing salinity stress up to 15 dSm^{-1} significantly affected germination characteristics, seedlings parameters and chemical analysis. Fóti variety turned out to be the best at 150 ppm GA_3 compared to the other two varieties. Moreover, it had the lowest Na^+ and proline contents and highest K^+ content.

Keywords: *wheat, seed soaking, GA_3, salt stress, germination, proline, sodium and potassium*

INTRODUCTION

Wheat (*Triticum aestivum* var. vulgare L.) is cultivated as a major cereal crop in several parts of the world; it is considered the king of cereal crops in global ranking followed by maize and rice. It has a major importance in global consumption and it is also a strategic commodity. The total cultivated area of wheat according to FAO reached about 221.61 million hectares in 2015 and the total production exceeded 728.96 million tons. However, the total cultivated area in Hungary was about 1.11 million hectares and the total production was approximately 5.26 million tons. The total cultivated area in Egypt was approximately 1.42 million hectares with a total production of 9.27 million tons. In general, there is a large gap in Egypt between consumption and production of wheat due to the continuously growing human population and additionally the limited cultivated area.

Gibberellic acid (GA_3) is considered one of the most important exogenous phytohormones, which markedly improves the processes of germination, hypocotyls growth and cell division, increases the size of leaves and reduces the rapid decline of physiological and biochemical activities in roots and shoots. Phytohormones, in general have been found to control the transport of ions in plants (Karmoker 1984). So, phytohormone-induced alleviation of the inhibitory effect of salinity may be due to the induced changes in ionic balance in shoot and roots (Akbarimoghaddam et al. 2011). In addition, GA_3 stimulates hydrolytic enzymes that are needed for the degradation of cells surrounding the radicle and thus speeds germination by promoting seedling elongation growth of cereal seeds. In this connection Ghobadi et al. (2012) reported that GA_3 caused significant increases in shoot and root length, shoot and root fresh & dry weight, final germination percentage, germination rate, mean germination time and seedling vigor index. On the other hand, Chauhan et al. (2009) showed that seeds treated with GA_3 showed significant difference compared with control; they also indicated that the germination percentage decreases when the concentration is increased, which shows that higher concentration inhibits germination and the longest radicle length was observed under GA_3 50 ppm. Furthermore, GA_3 was recorded to overcome the inhibitory effect of salinity stress on germination. In this connection, Samad and Karmoker (2012) indicated that increased salinity stress resulted in the increased accumulation of Na^+ in shoot and roots, furthermore the inhibition of that of K^+, however, GA_3 reduced the rate of Na^+, proline accumulation and increased K^+ accumulation in the seedlings.

Wheat cultivars showed a great variation in germination and seedling characteristics due to salinity stress (Sadat and McNeilly 2000, El-Hendawy et al. 2005). The maximum germination was found in the HD2689 cultivar and maximum inhibition was found to be in the case of the HOW234 cultivar at 150 mM salinity level. Moreover, proline content increased with increasing salinity level for all of the studied wheat cultivars (Datta et al. 2009). Kandil et al. (2012) showed that Egyptian cultivars i.e. Sakha 93 and Sakha 94 had positive effects in most of germination and seedling characteristics. Wheat cultivars can be classified to three groups in terms of salinity stress i.e. salt tolerant, moderately salt-tolerant and salt-sensitive. In addition, HD–2160 cultivars recorded as good stand even at a salinity level of 16 dSm^{-1} Kandil et al. (2013). Oproi and Madosa (2014) showed that the increased salinity stress of NaCl solution resulted in gradual reduction in seed germination in all analyzed wheat genotypes.

According to the FAO Land and Plant Nutrition Management Service, over 6% of the world's land is affected by either salinity or sodicity. Moreover, limited water quality and poor drainage systems are the reason of these stress factors and the problem is even more serious in areas of higher evaporation, especially in arid and semi-arid zones. Germination phase is considered the most sensitive stage of the plant life cycle, this stage of growth is severely influenced by environmental factors, especially the degree of temperature, salinity tension and humidity (Soltani et al. 2008). Increasing salinity levels in irrigation water results in a gradual and significant decrease of germination parameters i.e. germination percentage, shoot and root length, shoot and root fresh and dry weight (Mujeeb-ur-Rahman et al. 2008), plant metabolism, it disrupts cellular homeostasis and uncouples major physiological and biochemical processes. Proline, sodium and potassium contents also influenced by salinity stress (Ahmad et al. 2010, Masoudi Khorasani et al. 2014, Al-Saady 2015, Chernane et al. 2015). Moreover, salinity stress causes an osmotic pressure on cells that prevents water uptake or reduces water potential and increases the concentration of certain toxic elements such as Na^+, Cl^-. It also reduces the amount of essential nutritives (calcium and potassium) which has a negative influence on seed germination and increases the amount of toxic elements, influences enzyme activity and seed hormones during the germination phase (Othman et al. 2006, Akbarimoghaddam et al. 2011).

Free proline has a role in plants under stress conditions. A several-fold increase of the proline content under physiological and pathological stress conditions has been reported by numerous authors. Hence, the analysis of proline in plants has become a routine practice within the pathology and physiology division of agricultural sciences. Thus, proline content in tissue plants plays an important role as protective composite. Higher potassium levels provided protection during salinity stress and they should be used as physiological indicators for the evaluation of salt tolerance in wheat plants. Proline content in shoots and roots also increases with increasing salinity stress (Kumar et al. 2012).

Currently, there is insufficient information about the interaction between seed soaking in GA_3, salt stress and Hungarian wheat cultivars. Therefore, the aim of this study was to assess the possible method of interaction between exogenous GA_3 and salinity stress on various germination and seedling characteristics as well as some biochemical parameters of three Hungarian wheat cultivars.

MATERIAL AND METHODS

Site description

A laboratory experiment under controlled condition has been conducted in a phytotron at the temperature of 20±1 ºC and relative humidity of 70% for 18/6 h day/night illumination for germination at the Research Institute of Nyíregyháza, Hungary in November 2016.

Experimental Design, Treatments, and Measurements

The experiment was arranged in Factorial Experiment based on Randomized Complete Block Design (RCBD) with four replicates. Factor A: included three Hungarian wheat landraces i.e. (Gamási, Fóti and Kartali), which were obtained from the Hungarian Research Institute for wheat. Wheat landraces are defined as a variety developed over many years by one or more farmers using simple selection methods for local adaptation, and a wide variety of quality traits. Generally they provide low yield but they are highly stable in the agro-ecology of selection and all of them have been stored under normal conditions in paper bags. Factor B: contained three treatments of seed soaking on exogenous phytohormone concentrations i.e. (control (distilled water), 75 and 150 ppm GA_3) hormone solutions of the suitable concentrations have been prepared, 250 g of seeds from each cultivar have been soaked in 500 ml of each solution and retired near to original weight with forced air under shade (Sundstrom et al. 1987). Factor C: included four salinity stress levels i.e. (control (distilled water), 5, 10 and 15 dSm^{-1}) a salty mixture of 50.2% NaCl, 6.6% $NaSO_4$, 30.4% $CaSO_4$ and 12.8% $MgCl_2$ have been prepared to simulate natural salinity; according to Bazilivitch and Pankova (1971), this mixture represents a sulphate-chloride type of salinity at a $Cl:SO_4$ ratio equal to 2:1 Thus, the whole experiment included 144 Petri dishes.

Before cultivation, seeds were externally sterilized with 2% sodium hypochloride for 10 minute; after that they have been rinsed with distilled water and have been air dried (Basra et al. 2003). Then 25 healthy seeds of each treatment for each cultivar have been allowed to germinate on a filter paper in 11 cm diameter in sterile petri dishes. Each filter paper was moistened with 10 ml distilled water (control) or a water solution at different salinity stress levels. The Petri dishes were labeled and incubated in a germinator (Phytotron) at 20±1 ºC and relative humidity of 70% for 18/6 h day/night illumination for germination. Radicle protrusion of 5 mm was recorded as germination. Germinated seeds have been recorded daily and the first and final account has been done after 4 and 8 days, respectively according to the International Rules of Seed Testing Association (ISTA 2015).

Studied Characteristics

A: Germination characteristics

1. Germination percentage (GP%): it was calculated according to ISTA by using the following equation: GP=A/B×100, where A is the number of germinated seeds after 8 days and B is the total number of germinated seeds.
2. Germination speed (GS): it was estimated according to Maguire (1962) by using the following equation: GS=A/D, where A is the number of germinated seeds after 8 days and D is the total number of germination days.
3. Mean Daily Germination (MDG): it was calculated according to Rubio-Casal et al. (2003) by using the following equation: GP%/number of days to final germination.

B: Seedling parameters

12 days following sowing, ten plants have been randomly selected from each treatment and the following seedling parameters have been estimated:

1. Shoot and root length (cm),
2. Seedling vigor: it was estimated by multiplying GP% by (mean shoot length plus mean root length) according to Abdul-Baki and Anderson (1973),
3. Shoot and root fresh weight (g),
4. Shoot and root dry weight (g).

C: Chemical analysis

1. Sodium (Na^+) and Potassium (K^+) contents: Na^+ and K^+ contents have been estimated by means of the following methods described by Karmoker and Van Steveninck (1978): 0.2 gm seedlings washed in 0.1 mM $CaSO_4$ contained in a small beaker (50 ml each) for two minutes to remove free space ions and have been dried in an oven at 70 ºC to a constant weight. Then, Na^+ and K^+ have been extracted by means of hot water and then measured by means of a flame photometer (Jenway PEP-7, UK) at a wavelength of 767 and 589 nm, respectively.
2. Proline content: it has been determined according the procedures of Bates et al. (1973). Fresh 0.250 g of seedling samples have been homogenized and ground with 10 ml of 3% sulpho-salicylic acid using a mortar and pestle, then the crude extract has been centrifuged at 3000 RP for 10 minutes. Approximately 2 ml of extract has been taken into a fresh test tube and 2 ml of glacial acetic acid and 2 ml of ninhydrin reagent have been added to it. The mixture has been boiled in a water bath at 100 °C for 30 min. After cooling the reaction mixture, 4 ml of toluene was added. After thorough mixing, the chromophore containing toluene has been separated and absorbance of red color developed was read at 520 nm against toluene black on UV-visible spectrophotometer (Chemito, UV-2600). Proline concentration has been determined using calibration curve and expressed as mg proline per g fresh weight of tissue.

Statistical Analysis

The obtained data have been statistically analyzed for differences between treatment means using the technique of analysis of variance (ANOVA) for the Factorial Experiment based on Randomized Complete Block Design (RCBD) design as published by Gomez and Gomez (1984) using MSTAT statistical package (MSTAT-C with MGRAPH version 2.10, Crop and Soil Sciences Department, Michigan State University, USA). Least Significant Difference (LSD) method was used to test the differences between treatment means at 5% level of probability as defined by Snedcor and Cochran (1980).

RESULTS AND DISCUSSION

Seed soaking in GA_3 effect

Seed soaking in GA_3 concentrations had significantly positive effect on different aspects of the germination characteristics, seedling properties and chemical analysis as showed in *Table 1–2*. Seed soaking in GA_3 significantly increased wheat germination characteristics and seedling properties as compared to the control treatment (untreated seeds). The highest germination percentage (86.79%), germination speed (2.71), mean daily germination (7.23), shoot length (11.16 cm), root length (6.57 cm), seedling vigor (1591.4), shoot fresh weight (0.273 g), shoot dry weight (0.072 g), root fresh weight (0.143 g) and root dry weight (0.049 g) have been recorded from soaking wheat seeds before sowing in GA_3 at the concentration of 150 ppm. Soaking seeds in GA_3 at the concentration of 75 followed the above mentioned treatment concerning germination and seedling parameters growth and yield attributes. The lowest values of germination characteristics and seedling parameters have been obtained in the case of the control treatment (without seed soaking in GA_3).

It could be noticed that GP%, GS, MDG, shoot and root length, SV, shoot fresh weight, shoot dry weight, root fresh weight and root dry weight were increased by (9.8 and 4.7%), (9.8 and 4.6%), (9.8 and 4.7%), (23.7 and 12.6%), (25.9 and 11.3%), (31.1 and 15.6%), (23.4 and 5.9%), (50.0 and 16.7%), (25.2 and 7.0%) and (40.8 and 24.5%) with using the highest concentration of GA_3 compared to the control treatment and seed soaking in GA_3 at 75 ppm, respectively. These results may be ascribed to the beneficial role of GA_3 during germination stage through improving the processes of germination, hypocotyls growth and cell division and increasing the size of leaves and controlled in the transport of ions in tissues plants and decreasing the high decline of physiological and biochemical activities in roots and shoots (Karmoker 1984). Moreover, GA_3 stimulates hydrolytic enzymes that are needed for the degradation of the cells surrounding the radicle and thus speeds germination by promoting seedling elongation growth of cereal seeds. These results are in a good harmony with those stated by Ghobadi et al. (2012). In contrast, Chauhan et al. (2009) indicated that germination % decreases with increasing GA_3 concentration, which shows that higher concentration inhibits germination and the longest radicle length was observed under GA_3 50 ppm.

There were significant differences among studied seed soaking treatments on chemical analysis i.e. Na^+, K^+ and proline contents in seedlings as showed in *Table 2*. Soaking seeds before sowing in GA_3 at the concentration of 150 ppm significantly decreased both Na^+ and proline contents in seedling which were (1954.4 ppm and 112.5 mg g^{-1} fresh). On the other hand, K^+ content (872.3 ppm) was increased compared with control treatment (seed without soaking). It could be noticed that Na^+ and proline contents have been reduced by (16.51 and 5.33%) and (19.97 and 11.18%) with seed soaking in 150 ppm GA_3 compared with the control and 75 ppm, respectively. On the other hand, K^+ content in seedlings was increased with using 150 ppm GA_3 by (28.87 and 15.16%) compared with the control and 75 ppm, respectively. These results are in line with those reported by Samad and Karmoker (2012) indicating that GA_3 reduced the rate of Na^+ and proline accumulation and increased K^+ accumulation in the seedlings.

Hungarian wheat varieties behavior

Data presented in *Tables 1* and *2* clearly showed that the tested varieties of wheat significantly varied for germination characteristics and seedling properties.

Table 1.

Means of germination percentage (GP%), germination speed (GS), mean daily germination (MDG), shoot length (cm), shoot length (cm) and seedling vigor (SV) as affected by seed soaking in GA_3, wheat varieties, salinity stress as well as their interactions (n=144)

	Characteristics					
Treatments	Germination percentage (GP%)	Germination speed (GS)	Mean daily germination (MDG)	Shoot length (cm)	Root length (cm)	Seedling vigor (SV)
			Seed soaking in GA_3 (PPM) effects			
Control (without)	78.28	2.446	6.52	8.51	4.87	1096.73
75	82.74	2.586	6.89	9.75	5.83	1343.19
150	86.79	2.712	7.23	11.16	6.57	1591.40
$LSD_{5\%}$	0.06	0.02	0.05	0.29	0.16	22.03
			Hungarian varieties behaviors			
Gamási	81.84	2.55	6.82	9.28	5.14	1229.58
Fóti	85.11	2.66	7.09	10.28	6.55	1493.46
Kartali	80.86	2.52	6.73	9.87	5.58	1308.27
$LSD_{5\%}$	0.75	0.02	0.06	0.30	0.13	27.86
			Salinity stress (dSm^{-1}) effects			
Control (distilled water)	98.56	3.08	8.21	14.14	7.01	2087.67
5	89.43	2.79	7.45	11.71	6.11	1602.22
10	79.26	2.47	6.60	7.01	5.40	989.45
15	63.16	1.97	5.26	6.38	4.51	695.75
$LSD_{5\%}$	0.87	0.03	0.07	0.34	0.15	29.17
			Interactions effects			
A×B (F. test)	*	*	*	*	*	*
A×C (F. test)	*	*	*	*	*	*
B×C (F. test)	*	*	*	*	*	*
A×B×C (F. test)	*	*	*	*	*	*

Table 2.

Means of shoot and root fresh and dry weight (g), Na^+ and K^+ contents (PPM) and proline content (mg g^{-1} fresh weight) as affected by seed soaking in GA_3, wheat varieties, salinity stress as well as their interactions (n=144)

	Characteristics						
Treatments	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)	Na^+ content (PPM)	K^+ content (PPM)	Proline content (mg g^{-1})
				Seed soaking in GA_3 (PPM) effects			
Control (without)	0.209	0.036	0.107	0.029	2341.00	620.44	140.60
75	0.257	0.060	0.133	0.037	2064.47	740.05	126.69
150	0.273	0.072	0.143	0.049	1954.41	872.30	112.52
$LSD_{5\%}$	0.009	0.006	0.008	0.004	23.84	13.78	3.88
				Hungarian varieties behaviors			
Gamási	0.218	0.050	0.122	0.033	2211.27	642.63	136.21
Fóti	0.291	0.064	0.132	0.044	2039.27	876.55	118.13
Kartali	0.230	0.053	0.129	0.038	2109.33	713.61	125.47
$LSD_{5\%}$	0.006	0.003	0.004	0.003	25.21	13.77	1.87
				Salinity stress (dSm^{-1}) effects			
Control (distilled water)	0.304	0.074	0.180	0.061	1386.74	850.926	100.58
5	0.272	0.063	0.152	0.044	2231.22	765.037	117.93
10	0.224	0.048	0.095	0.028	2364.92	699.074	138.37
15	0.185	0.038	0.084	0.021	2496.96	662.037	149.53
$LSD_{5\%}$	0.007	0.003	0.004	0.004	29.11	15.440	2.17
				Interactions effects			
A×B (F. test)	*	*	*	*	NS	*	*
A×C (F. test)	*	*	*	*	*	*	*
B×C (F. test)	*	*	*	NS	*	*	*
A×B×C (F. test)	*	*	*	*	*	*	*

On the basis of the results obtained from this study, it could be detected that the Foti variety significantly exceeded other studied varieties (Gamási and Kartali) and recorded the maximum averages of all studied characteristics. While the Kartali variety turned out to be the second after Fóti variety followed by the Gamási variety with respect of all studied traits. It could be noticed that Fóti variety significantly exceeded other studied varieties (Gamási and Kartali) in terms of GP%, GS, MDG, shoot length, root length, SV, shoot fresh weight, shoot dry weight and shoot dry weight and root dry weight were increased by (3.84 and 4.99%), (4.13 and 5.26%), (3.80 and 5.07%), (9.72 and 3.98%), (21.52 and 14.80%), (17.67 and 12.40%), (25.08 and 20.96%), (21.87 and 17.18%), (7.57 and 2.27%) and (25.00 and 13.63%), respectively. Regarding to chemical analysis i.e. Na^+ and K^+ and proline contents, Gamási variety surpassed the other two varieties in Na^+ and proline contents followed by Kartali variety then Fóti variety recorded the lowest values. On the other hand, Fóti variety recorded the highest values of K^+ content. These findings might be attributed to the differences of these varieties in terms of their genetic constitution and genetic factors makeup. These results are in perfect harmony with those stated by (El-Hendawy et al. 2005, Datta et al. 2009, Kandil et al. 2012, Kandil et al. 2013, Oproi and Madosa 2014).

The performance of Fóti variety dominated almost every studied characteristic over the other two varieties and it might be recommended.

Salinity stress effect

Concerning the effect of salinity stress on germination characteristics, seedlings parameters and chemical analysis as showed in *Tables 1* and *2*. Results showed a gradual and significant decrease in germination characteristics, seedlings parameters and the optimum reduction was recorded under the highest salinity stress 15 dSm^{-1}. It could be noticed that GP%, GS, MDG, shoot length, root length, SV, shoot fresh weight, shoot dry weight and shoot dry weight and root dry weight were decreased by (9.26, 19.58 and 35.58%), (9.41, 19.80 and 36.03%), (9.25, 19.61 and 35.93%), (17.18, 50.42 and 54.87%), (12.83, 22.96 and 35.66%), (23.25, 52.60 and 66.67%), (10.52, 26.31 and 39.14%), (14.86, 35.13 and 48.64%), (15.55, 47.22 and 53.33%) and (27.86, 54.09 and 65.57%) under 5, 10 and 15 dSm^{-1}, respectively compared to control treatment. The reduced germination characteristics and seedling parameters due to increasing salinity stress might be ascribed to salinity stress caused an osmotic pressure on the cells that prevents water uptake or reducing of water potential and special poisonous ions such as: Na^+, Cl^- and reducing of its necessary nutrition calcium and potassium has negative influence on seed germination and increase ions poisonous, changing enzymes activation and seeds hormones in germination phases (Othman et al. 2006, Akbarimoghaddam et al. 2011). These results are in agreement with those reported by (Mujeeb-ur-Rahman et al. 2008, Al-Saady 2015). Increasing salinity stress up to 15 dSm^{-1} significantly increased Na^+ and proline contents by (37.84, 41.36 and 44.46%) and (14.75, 27.33 and 32.77%) under 5, 10 and 15 dSm^{-1}, respectively compared to control treatment. On the other hand, K^+ content was decreased by (10.09, 17.85 and 22.20%) respectively compared to control treatment. These results are comprehensive with those found by (Ahmad et al. 2010, Masoudi Khorasani et al. 2014, Chernane et al. 2015) indicated that plant metabolism, disrupting cellular homeostasis and uncoupling major physiological and biochemical processes such as proline, sodium and potassium contents also due to salinity stress.

Interactions effect

There are many significant effects of the interactions among studied factors on studied characteristics as showed in *Table 1–2*. Therefore, the significant triple interactions only among studied factors were focused herein. As revealed from data graphically illustrated in *Figures 1–13*, the highest values of GP% *(Figure 1)*, GS *(Figure 2)*, MDG *(Figure 3)*, shoot length *(Figure 4)*, root length *(Figure 5)*, SV *(Figure 6)*, shoot fresh weight *(Figure 7)*, shoot dry weight *(Figure 8)* and shoot dry weight *(Figure 9)*, root dry weight *(Figure 10)* and K^+ *(Figure 12)* content were obtained from sowing Fóti variety, with seed soaking in 150 ppm GA_3 under the control treatment, followed by Kartali variety, with seed soaking in 150 ppm GA_3 under the lowest levels of salinity stress, then Gamási variety, with seed soaking in 150 ppm GA_3 under the lowest levels of salinity stress came in the third rank. On the other hand, the lowest values of these characteristics were recorded with Gamási variety, without seed soaking under the highest levels of salinity stress. Vice versa, the highest Na^+ *(Figure 11)* and proline *(Figure 13)* contents were recorded with Gamási variety, without seed soaking in GA_3 under the highest salinity stress, while the lowest values of Na^+ and proline were produced from sowing Fóti variety and seed soaking on 150 ppm GA_3 under the lowest levels of salinity stress. These results are in concurrence with those stated by Sadat and McNeilly (2000), El-Hendawy et al. (2005) and Oproi and Madosa (2014).

CONCLUSIONS

In general, increasing salinity stress up to 15 dSm^{-1} is associated with decrease in germination characteristics and seedling parameters. In terms of optimizing wheat germination characteristics and seedling parameters under high salinity stress, the Fóti variety turned out to be the best at 150 ppm GA_3 compared with other two varieties. Moreover, it produced the lowest Na^+ and proline contents and highest values of K^+ content. Thus, Fóti variety was more tolerant to salinity up to 15 dSm^{-1} and may be suggested to be sown for enhancing wheat production under saline soil conditions of Hungary.

ACKNOWLEDGEMENT

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Figure 1: **Means of germination percentage (GP%) as affected by the interaction between seed soaking in GA_3**

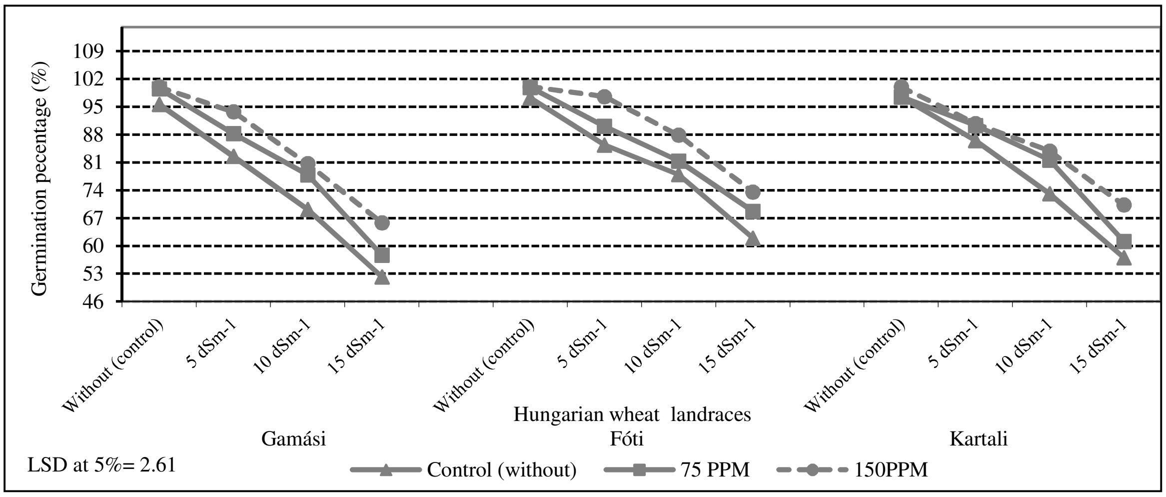


Figure 2: **Means of germination speed (GS) as affected by the interaction between seed soaking in GA_3**

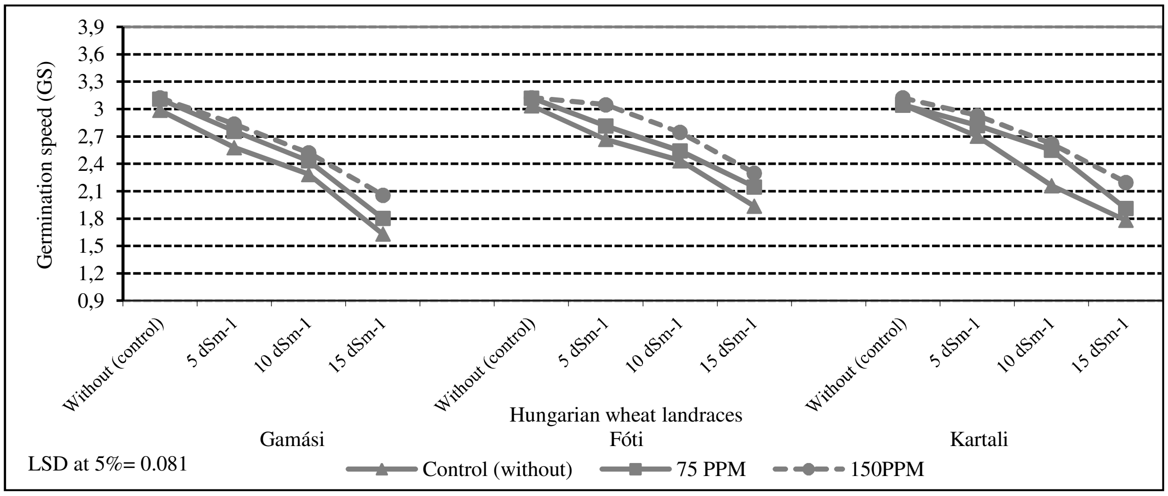


Figure 3: **Means of mean daily germination (MDG) as affected by the interaction between seed soaking in GA_3**

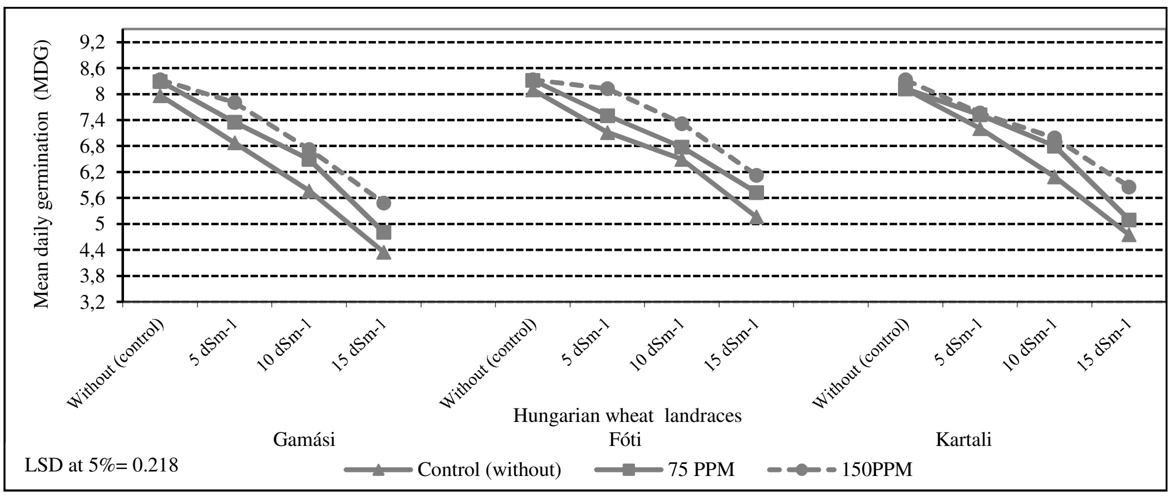


Figure 4: **Means of shoot length (cm) as affected by the interaction between seed soaking in GA_3**

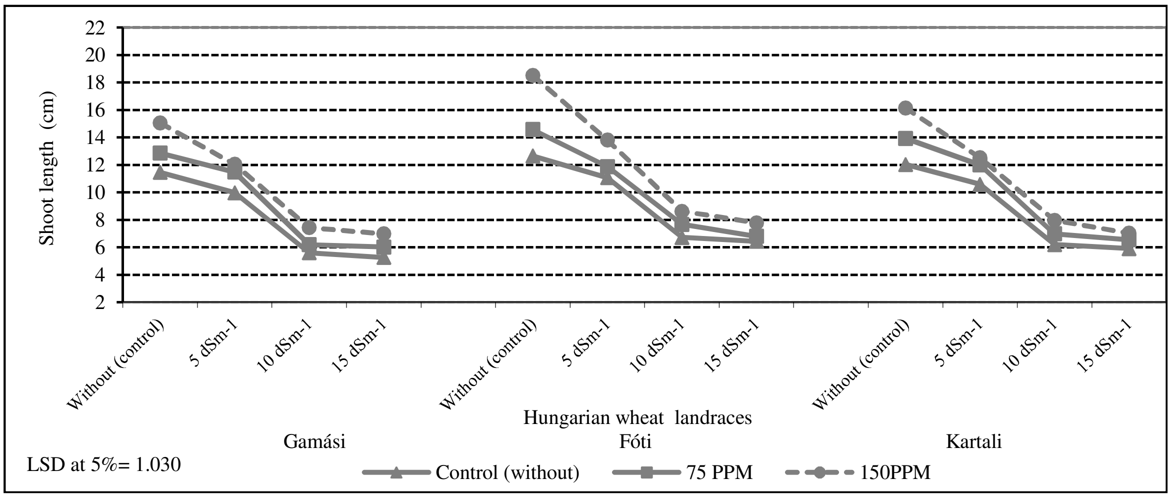


Figure 5: **Means of root length (cm) as affected by the interaction between seed soaking in GA_3**

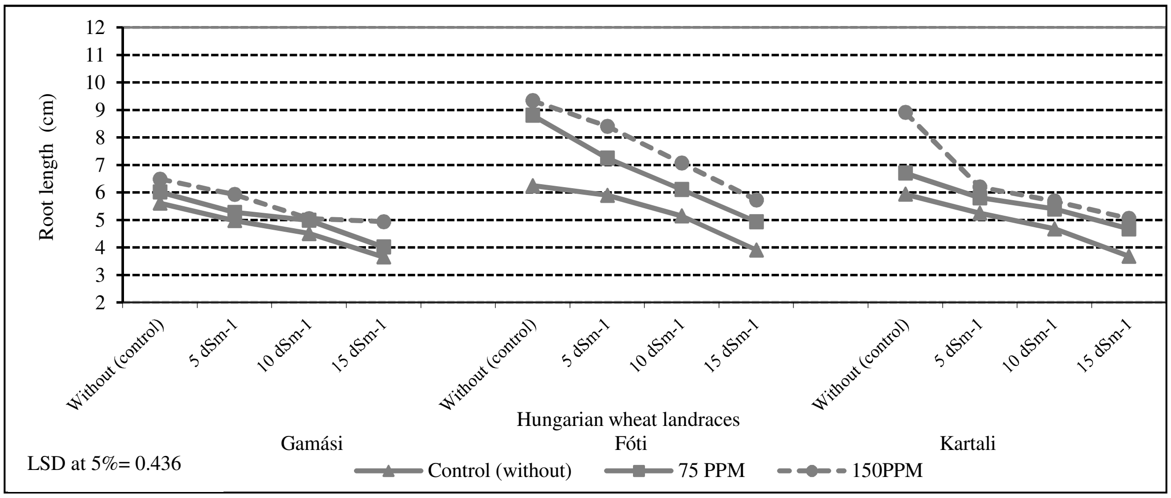


Figure 6: **Means of seedlings vigor (SV) as affected by the interaction between seed soaking in GA_3**

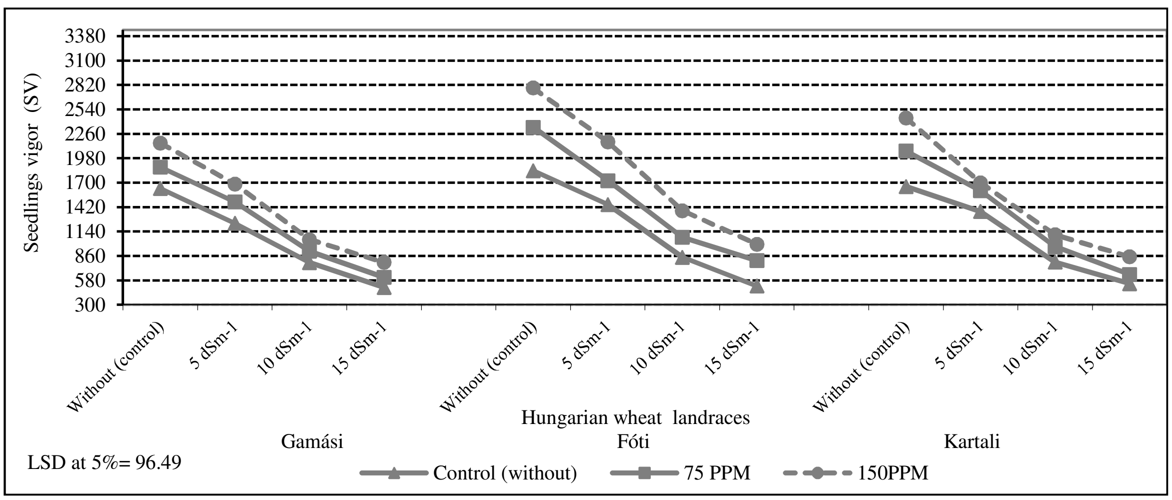


Figure 7: **Means of shoot fresh weight (g) as affected by the interaction between seed soaking in GA_3**

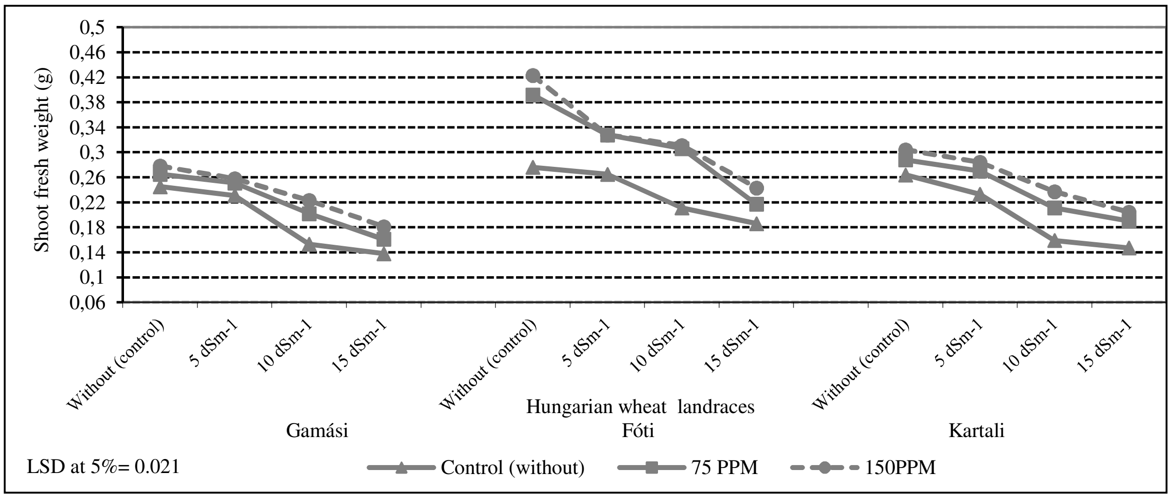


Figure 8: **Means of shoot dry weight (g) as affected by the interaction between seed soaking in GA_3**

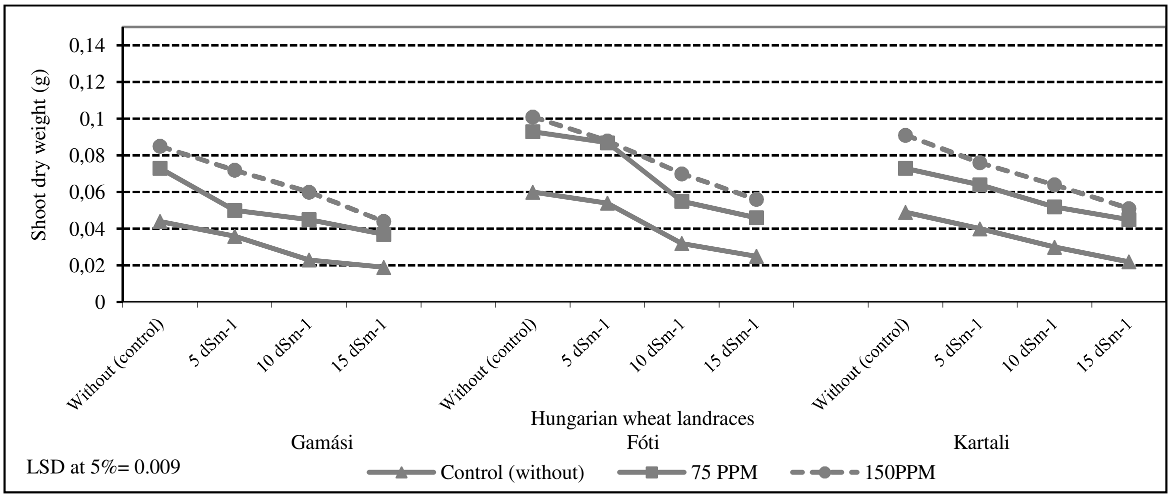


Figure 9: **Means of root fresh weight (g) as affected by the interaction between seed soaking in GA_3**

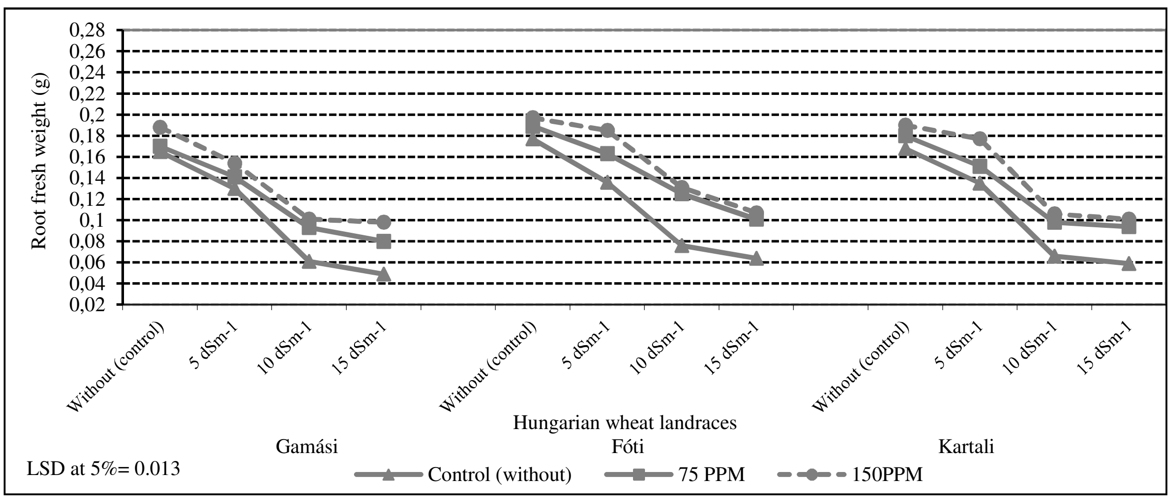


Figure 10: **Means of root dry weight (g) as affected by the interaction between seed soaking in GA_3**

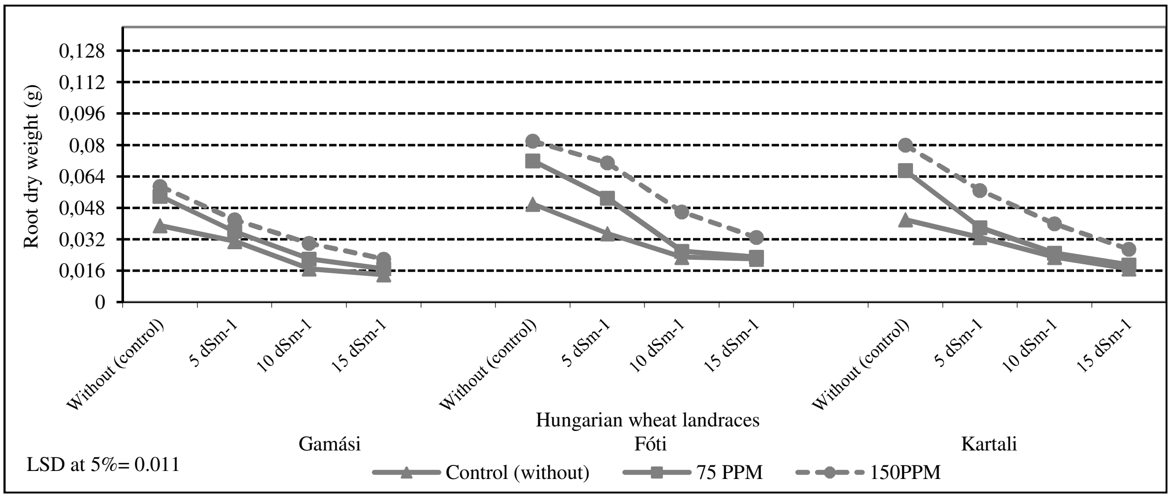


Figure 11: **Means of Na^+ content (ppm) as affected by the interaction between seed soaking in GA_3**

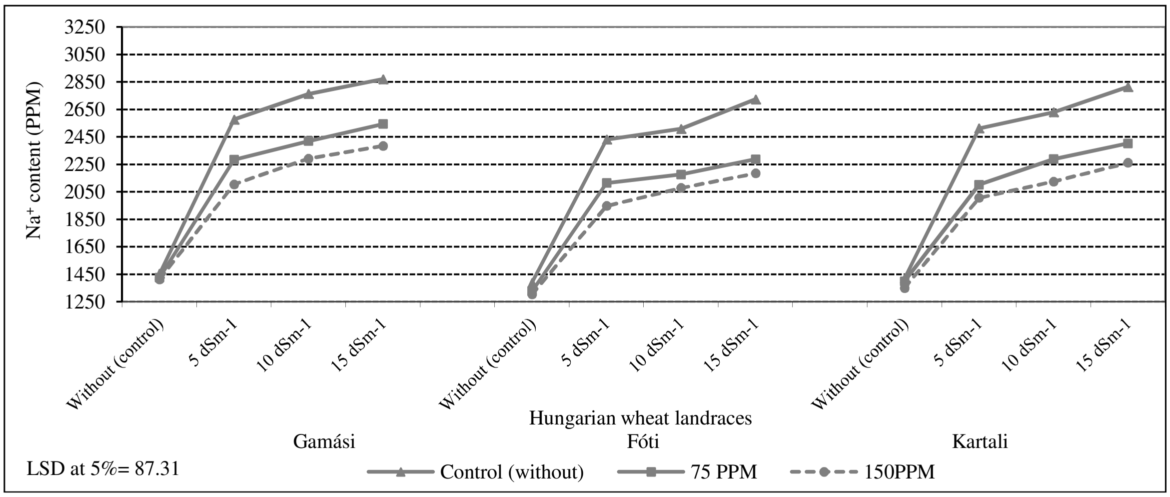


Figure 12: **Means of K^+ content (ppm) as affected by the interaction between seed soaking in GA_3**

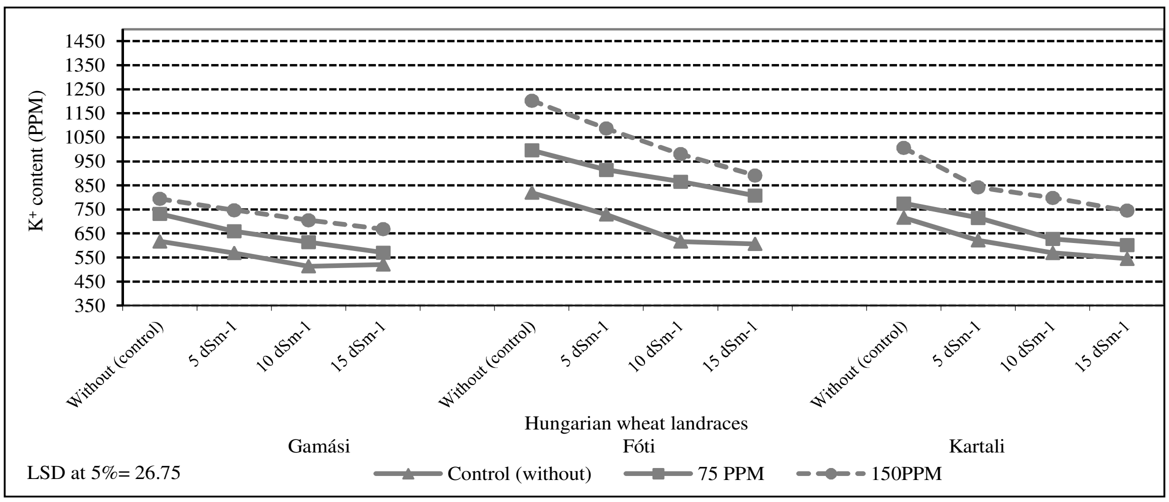
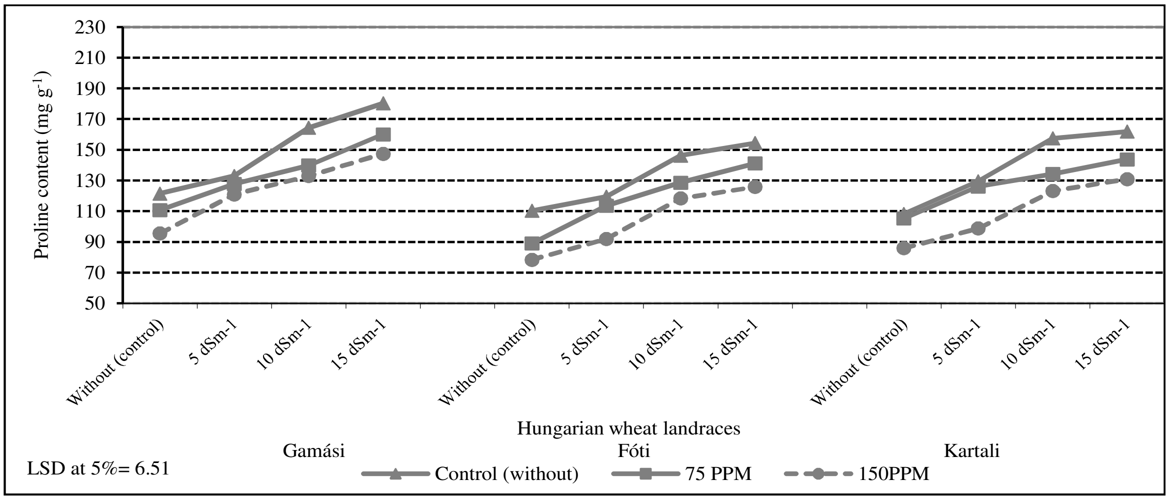


Figure 13: **Means of proline content (mg/g) as affected by the interaction between seed soaking in GA_3**



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