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Effect of Na-isocationic salt solutions on the activity dynamics of Q6PDH and DMDH enzymes in relation to wheat sprout development

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Q6PDH and the pentose phosphate pathway it regulates are widespread processes in nature and are found in al is a of one of the relatively well-

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Abstract: Adaptation of plants to the environment, including adverse environmental conditions, is accompanied by changes in metabolism, and NADPH is required for the implementation of these changes. There are four known enzymes (Q6PDH, 6PQDH, ISDH and DMDH) that generate NADPH in the cell, the main of which are the Q6PDH and DMDH enzymes. Of these two enzymes, Q6PDH is the most studied, while DMDH is the least studied.

Q6PDH and the pentose phosphate pathway it regulates are widespread processes in nature and are found in all primitive (except viruses) and higher organisms. The universality of the enzyme in terms of its distribution in living nature is apparently due to the importance of the function it performs in metabolism. Therefore, Q6PDH is a protein that has not escaped the attention of researchers and is actually one of the relatively well-studied enzymes.

Key words: Q6PDH, enzyme, oxidative, pentose phosphate pathway

İntroduction: The localization of the enzymes of the pentose phosphate pathway of glucose oxidation in plant cells is peculiar. All enzymes catalyzing the oxidative and reductive stages of the cycle have been found in plastids, including chloroplasts. Despite the discovery of all enzymes of the oxidative stage in the cytoplasmic fraction, it has not yet been possible to detect a number of enzymes of the reductive stage. Therefore, it is believed that the pentose phosphate pathway operates in a reduced (shortened) form in the cytosol. This allows us to speculate that the pentose phosphate pathway, including the Q6PDH enzyme that regulates its activity, serves different purposes (different purposes) in different compartments of plant cells.

NADPH is required for the synthesis of the reduced form of glutathione, which is considered one of the vital metabolites of the cell, and it performs the function of a coenzyme in the activity of the glutathione reductase enzyme that ensures its synthesis [3]. It is also a metabolite essential for the normal functioning of the enzyme catalase. Catalase, which is involved in many processes, is one of the components of the cell's defense system [2,7]. NADPH is also used in the synthesis of steroids, which are a component of the membrane and play an important role in its integrity and functional activity. One of the important places where it is used is the synthesis of fatty acids [3].

Analysis of the literature data shows that the Q6PDH enzyme plays an important role in the adaptation of various plants to adverse environmental conditions, in eliminating the effects of biotic (in the fight against various pathogens) and abiotic (in response to drought, extreme temperature conditions, salinity, etc.) stress [1,6]. Under the influence of biotic and abiotic stress factors, the amount of active metabolites of oxygen in the cell increases sharply. Q6PDH participates both in the formation of such metabolites and in eliminating their harmful effects. The first function is performed with the direct participation of NADPH-oxidase bound to the walls of the cell membrane, and the second - by maintaining glutathione in a reduced form with the help of glutathione reductase [5]. The second process involves the ascorbate cycle, which neutralizes the active metabolites of oxygen, especially the excess hydrogen peroxide, which is normally stored in the cell at a certain concentration. In addition, glutathione (GSH), which is stored in a reduced state with the participation of the Q6PDH enzyme, plays an important role in the neutralization of peroxides and drugs. The lack of NADPH leads to a decrease in the level of GSH in the cell below normal, which leads to cell death [1,4].

It is believed that Q6PDH is part of the defense response in plants against viruses and pathogenic fungi. The aging of plant tissues is accompanied by an increase in the amount of active metabolites

of oxygen in them. The enzyme Q6PDH acts to prevent this process. The NADPH it produces is used in the synthesis of lignin (a component of the cell wall) and fatty acids (a component of the membrane), which allows the enzyme to participate in the restoration of damaged areas of plant tissues [1]. In microorganisms, two forms of the Q6PDH enzyme are found, which are involved in different metabolic pathways. One of them is a component of the enzyme system of the pentose phosphate pathway of glucose oxidation, and the other is a component of the enzyme system that oxidizes glucose via the Etner-Dudorov pathway. In some bacteria (e.g., Leuconostos mesenteroides), the same enzyme is used in both pathways [1].

Materials and Methods:

One of the main points in determining the activity of enzymes is the correct selection of the extraction medium. For this purpose, in our experiments, a 0.1 M tris-HCI buffer solution containing 0.01 M β-mercaptoethanol as a reducing agent and 1% polyvinylpyrrolidone (molecular weight 24 kDa) dissolved in it to neutralize phenolic compounds was used as the extraction solution. Based on the literature data, buffer solutions with a pH value of 8.0 for the extraction of the Q6PDH enzyme and a pH value of 7.0 for the extraction of the DMDH enzyme were taken. In the preparation of the homogenate, 2 ml of the extraction solution was taken for 1 g of the biological object and crushed in a mortar and pestle in a cold environment using an ice bath. In both cases, the homogenate obtained was filtered through a double capron cloth, and the filtrate was centrifuged at 5,000 rpm for 10 min, the supernatant was collected and used for activity determination. The enzyme preparations prepared by this method had stable activity in a cold environment for several hours and did not cause any difficulties in carrying out measurements.

The activity of both enzymes was determined spectrophotometrically at a wavelength of 340 nm, based on the rate of NADP reduction. ΔE103340/min/g /min/g wet weight was taken as the enzyme unit.

Results and Discussion: Table 1 shows the changes in the activity dynamics of Q6PDH, a regulatory enzyme of the pentose phosphate pathway of glucose oxidation, and DMDH, a key enzyme of malate metabolism, and the activity ratio of these enzymes during the 7-day incubation period of wheat seedlings with solutions of different concentrations of Na-isocationic salts, in relation to the development of the root and stem system.

Table 1.

Effect of Na-isocationic salt solutions on the activity dynamics of Q6PDH and DMDH

enzymes in relation to the development of wheat seedlings

Various	Q6PDH activity			DMDH activity			Q6PDH/ DMDH		
	3 day	5 day	7 day	3 day	5 day	7 day	3 day	5 day	7 day
control	164	150	137	43	65	92	3.81	2.31	1.49
NaCl									
25 mM	185	170	161	48	76	121	3.85	2.24	1.33
50 mM	209	210	156	56	88	130	3.73	2.39	1.20
75 mM	235	208	131	59	92	126	3.98	2.26	1.04
100 mM	231	181	104	65	95	101	3.55	1.91	1.03
Na_2SO_4									
25 mM	188	177	163	52	80	132	3.61	2.21	1.23
50 mM	220	222	159	65	82	163	3.38	2.71	0.98
75 mM	156	133	101	69	93	104	2.26	1.43	0.97
100 mM	138	117	88	70	87	96	1.97	1.34	0.92
$NaHCO_3$									
25 mM	190	160	151	50	71	110	3.80	2.25	1.37
50 mM	174	141	92	56	61	63	3.11	2.31	1.46
75 mM	153	114	88	53	45	36	2.89	2.53	2.44
Na_2CO_3									
25 mM	185	165	156	47	67	103	3.94	2.46	1.51
50 mM	133	125	82	53	55	48	2.51	2.72	1.71
75 mM	130	102	71	49	43	35	2.65	2.37	2.03

As can be seen from the table, the activity of the Q6PDH enzyme in the control variant was characterized by a tendency to gradually decrease in relation to the cultivation period. Thus, the highest activity in the tissues of the root system of wheat seedlings cultivated in distilled water was observed at the beginning of the experiments, that is, in the roots of 3-day-old seedlings and was equal to 164 Δ103340/min/g wet weight. In the subsequent measurement stages, this figure decreased by 14 units in the root system tissues of 5-day-old seedlings compared to the root system tissues of 3-day-old seedlings, and by 24 units in the roots of 7-day-old seedlings, that is, 91% and 84% of the initial activity remained, respectively.

The high activity of the Q6PDH enzyme in the early stages of the cultivation process is apparently due to the specificity of the nutrition of seedlings at this stage. In a period when the stem and leaves are absent or poorly developed, the sprouts use the nutrients stored in the seeds to obtain the precursors of the necessary metabolites and energy. This function is mainly performed by starch molecules stored in the endosperm. Part of the starch, which has been hydrolyzed and converted into glucose, is oxidized via pentose phosphate, and the resulting NADPH, pentoses,

tetroses and trioses are used in the synthesis of substances necessary for the growth, development, division of newly formed cells and the initiation of other tissues. As the reserve substance is depleted, the meaning of maintaining the enzyme activity at a high level also disappears, and the sprouts move towards a free-living lifestyle, independent of reserve nutrients.

Table 1 also reflects the changes in the activity dynamics of the DMDH enzyme in the tissues of the root system of wheat seedlings in connection with the cultivation of Na-isocationic salt solutions at different concentrations. As can be seen from the table, in the control variant, unlike the Q6PDH enzyme, the activity of the DMDH enzyme increases significantly in connection with the growth of seedlings. That is, the activity is weakly detected in young root tissues, while the activity of the enzyme is activated in relatively grown root tissues. For example, if in 3-day-old root tissues DMDH activity was at the level of 43 Δ103340/min/g wet weight, in 5-day-old root tissues this figure already reaches 65 Δ103340/min/g wet weight, and in 7-day-old seedlings it reaches 92 Δ103340/min/g wet weight, that is, in the roots of 5- and 7-day-old seedlings, the enzyme activity increases by approximately 51.2 and 113.9% compared to the roots of 3-day-old seedlings, respectively. Based on the results obtained, it can be concluded that, apparently, in the early stages of wheat seedling development, the need for NADPH and metabolites is mainly provided by the activity of the pentose phosphate pathway, and later the DMDH enzyme also joins this process. Such a conclusion is also supported by the changes in the dynamics of the activity ratio of the Q6PDH and DMDH enzymes in connection with the growth dynamics of the seedlings of the control variant. Thus, while this ratio is 3.81 in 3-day-old sprouts, it is 2.31 in 5-day-old sprouts, and 1.49 in 7-day-old sprouts. In other words, this figure is gradually decreasing. This indicates that the role of the DMDH enzyme in the development of wheat sprouts is increasing.

Glucose, which is formed due to the hydrolysis of starch, which is accumulated as a reserve nutrient in seeds, allows metabolism to start in this direction and the process is regulated by the Q6PDH enzyme. Undoubtedly, the other part of the glucose formed from the breakdown of starch is also used to generate energy and metabolites necessary for the growth and development of cells, including glycolysis and then the Krebs cycle. The fact that the DMDH enzyme is weak in the early stages of sprout development, but active in the later stages, is apparently related to malate metabolism. Since malate is not synthesized and accumulated sufficiently in the early stages of development, there is no need for the enzyme to be actively active. Later, the accumulation of malate in the cell and reaching a certain level allows it to be used as an important metabolite and

participate in the metabolism, and participate in the formation of NADPH and other metabolites. One of the interesting facts is that in many cases, in old seeds, the Q6PDH and DMDH enzymes accompany each other and complement each other with their functions. In this "joint" activity, the function of the Q6PDH enzyme is more easily understood than that of DMDH. Although it is emphasized that the functions performed by both enzymes in cellular metabolism are important, some of which are common and others are different [2,4].

The effect of salt solutions on the germination and development of wheat seeds is also manifested in the level of activity of the Q6PDH enzyme. Under relatively mild stress conditions created by salts, the activity of the enzyme is significantly positively stimulated, and under severe stress conditions, it is negatively stimulated.

NaCl salt significantly stimulated the enzyme activity at all concentrations on days 3-5 of the germination process compared to the corresponding days of the control variant. An increase in the concentration of NaCl salt solution in the tissues of the root system of 3-day-old seedlings was accompanied by an increase in the degree of induction of enzyme activity. Thus, if the increase in the activity of the Q6PDH enzyme in the roots of seedlings cultivated at a concentration of 25 mM was 15.6% compared to the control variant of the corresponding period, then for the roots of seedlings cultivated at a concentration of 50 mM and 75 mM this figure was already 27.4 and 43.3%, respectively. At a concentration of 100 mM, the activity was at a level comparable to that of 75 mM. As can be seen from the figures presented, the relatively short-term effect of NaCl salt solution at all concentrations leads not only to inhibition, but also to induction of the activity of the Q6PDH enzyme in the root system tissues of wheat seedlings. A similar picture is observed at a relatively low level compared to the control, as well as in the activity of the Q6PDH enzyme in the root system of 5-day-old experimental seedlings. In 7-day-old seedlings, relatively low concentrations of salt solution (25 and 50 mM) produce a stimulating effect, and higher concentrations (75, 100 mM) produce an inhibitory effect.

As can be seen from the figures presented in the table, one of the factors affecting the dynamics of the activity of the Q6PDH enzyme in relation to the development of wheat seedlings is the duration of the stress created by NaCl salt solutions. A relatively short-term effect (3-5 days) leads to induction of the enzyme activity, while a long-term effect leads to a weakening of this induction. For example, the activity of Q6PDH in the root system seeds of 7-day-old seedlings cultivated in 75 mM and 100 mM NaCl salt solutions was lower by 6 Δ103340/min/g wet weight

and 33 Δ103340/min/g wet weight, respectively, compared to the control variant of the analogous period. Such an effect of different concentrations of NaCl salt solutions, depending on the incubation period, is apparently due to the fact that the stress factor created by the salt solution creates different types of stress factors at different periods. It seems that in the early periods of the experiments, the osmotic stress created by the salt solutions comes to the fore, and the response created by the root cells mainly serves to neutralize this factor and adapt to it. In the later periods, the accumulation of Na+ and CI- ions intracellularly leads to the addition of the toxic effect created by these ions to the osmotic stress. Towards the end of incubation, plant cells try to neutralize this second factor itself, so the defense response against salinity stress becomes more complex.

When the accumulation of NaCl salt ions in the cell exceeds a certain limit, their toxic effect on the cell occurs, the course of physiological processes in the cell is disrupted, metabolic processes are slowed down, and the activity of enzymes becomes difficult. This, in turn, leads to a disruption of the normal development dynamics of seedlings.

Low concentrations of Na2SO4 salt (25, 50 mM) stimulated the activity of the Q6PDH enzyme during all periods of cultivation. Therefore, the activity level of the Q6PDH enzyme in the root system tissues of wheat seedlings cultivated in these concentrations of Na2SO4 salt solutions was higher than the activity level in the root tissues of the control variant cultivated in distilled water. Moreover, this stimulation effect manifested itself in a slightly stronger form in the early stages of cultivation compared to the stimulation effect of NaCl salt. That is, the activity level characteristic of NaCl salt solutions could be created by relatively low concentrations of Na2SO4 salt. The above is also characteristic of the inhibitory effect of Na2SO4 salt on enzyme activity. Thus, if the enzyme activity in sprouts cultivated in a 75 mM NaCl salt solution was not only not inhibited, but rather stimulated, then Na2SO4 salt at a similar concentration inhibited the enzyme activity in all incubation periods compared to the control. For example, for the corresponding periods, this difference was 4.9% in 3-day-old sprouts compared to the control, 11.3% in 5-day-old sprouts, and 26.3% in 7-day-old sprouts. As can be seen from the presented figures, the inhibitory effect of a high concentration of Na2SO4 salt on enzyme activity also increases sharply in relation to the duration of its exposure.

This difference between the effects of NaCl and Na2SO4 salt solutions on enzyme activity is apparently related to their components. This effect is based on the intracellular concentration of SO4 ions along with Na ions. It is known that Na2SO4 salt creates higher osmotic stress than NaCl

salt. At the same time, high concentrations of Na, Cl, and SO4 ions have a toxic effect on cells, creating difficulties in the course of physiological and biochemical processes.

Solutions of NaHCO3 and Na2CO3 salts induce the activity of the Q6PDH enzyme at a low (25 mM) concentration in all incubation periods compared to the control. At other concentrations (50, 75 mM), a certain difference is observed between the effects of salt solutions. Thus, in 3-day-old seedlings, while a 50 mM NaHCO3 salt solution induces the activity of the enzyme, Na2CO3 salt solution, on the contrary, inhibits it. In subsequent periods, high concentrations of both salts resulted in inhibition of the activity of the enzyme. At similar concentrations, their inhibitory effect on the activity of the enzyme was higher in Na2CO3 salt solution than in NaHCO3 salt solution. It is believed that the fact that NaHCO3 and Na2CO3 salt solutions create more severe stress conditions than NaCl, Na2SO4 solutions, have a more severe negative effect on the growth dynamics of seedlings, and inhibit the activity of the G6PDH enzyme more strongly at similar concentrations is due to their ability to alkalize the incubation and intracellular environment. Thus, NaCl, Na2SO4, NaHCO3 and Na2CO3 isocationic salt solutions have a negative effect on the germination and root development of wheat seeds. The intensity of the effect of the listed salts on these processes increases in accordance with the transition from NaCl salt to Na2CO3 salt in the above-presented order of salts, depending on their anionic nature. Mild stress conditions created by relatively small concentrations of salt solutions significantly positively stimulate the activity of the cytoplasmic G6PDH enzyme, while acute stress conditions inhibit it. Perhaps the increase in enzyme activity is due to the adaptation of seedlings to the stress factor and the defense reaction aimed at eliminating the complications caused by extreme conditions. At high concentrations of salts, the performance of enzymes becomes more difficult.

Cultivation of wheat seedlings in different concentrations of Na-isocationic salts also leads to certain changes in the activity dynamics of the DMDH enzyme. The nature of the changes is mainly determined by the concentration of Na ions and, to some extent, the anion composition of the salt.

Analogous figures for the 50 and 75 mM NaCl salt solution variants were 30.2% and 37.2% for the root system of 3-day-old seedlings, and 35.4% and 41.5% for the root system of 5-day-old seedlings. As can be seen from the presented figures, in connection with the development of the root system of wheat seedlings, not only the activity of the DMDH enzyme, which is a regulatory enzyme of malate metabolism, increases, but also its participation in the stress created by salt

solution increases.

The stimulating effect of NaCl salt on the activity of the DMDH enzyme is better justified at low concentrations (25 and 50 mM). An increase in the salt concentration (75 and 100 mM) is accompanied by a weakening of this effect, but even in these variants the level of enzyme activity is maintained at a significantly higher level than in the control variant. It is precisely due to this feature (due to the 7-day effect of 75 and 100 mM NaCl salt solutions) that the DMDH enzyme of the root system of wheat seedlings differs from the Q6PDH enzyme. As already mentioned, the activity of the Q6PDH enzyme in the roots of 7-day seedlings was weaker than in the control at high concentrations of NaCl salt. The observation of such a difference may occur for various reasons:

First, it is possible that enzymes differ in their induction mechanisms under salt stress.

Second, it is possible that this difference is related to the sensitivity of enzyme molecules to Na+ and Cl– ions, i.e., in vitro, they are more resistant to NaCl salt than the Q6PDH enzyme.

Third, it is possible that the degree of participation of enzymes in the response of the root system of wheat seedlings to salt stress is different. In this case, it seems that the main function in the defense and adaptation reaction of the root system of wheat seedlings at the early stages is provided by the activity of the Q6PDH enzyme. The above idea is also clearly demonstrated by the ratio of Q6PDH and DMDH enzymes at different stages of development of the root system of wheat seedlings under normal and salt stress conditions. In the early stages of development, this ratio (Q6PDH/DMDH) is within 3-4, and at the end of the experiments it is within 1.0-1.5. This ratio takes on a more interesting form, especially at high concentrations of NaCl salt. This value, characterized by the number 3.5 in the roots of 3-day-old seedlings, approaches unity. It seems that with an increase in the incubation period and the exacerbation of salt stress, the role of the DMDH enzyme in neutralizing the negative effects of extreme environments and in the adaptation reaction to the environment increases.

Although Na2SO4 salt solutions resemble NaCl salt solutions in terms of the nature of their effect on the activity dynamics of the DMDH enzyme, they differ from it in certain features. This difference is mainly due to the fact that a lower concentration of Na2SO4 salt is required compared to NaCl salt to obtain a similar induction or inhibitory effect. In experiments with Na2SO4 salt solutions, the activity of the DMDH enzyme was positively stimulated at all stages of incubation at concentrations of 25-75 mM and a positive correlation was observed between the salt

concentration and the exposure time. At a concentration of 100 mM, the stimulating effect of Na2SO4 salt was relatively weakened, but the enzyme activity level remained higher than in the control. Such an effect is apparently related to the compositional nature of Na2SO4 salt. This salt may be related to both the anion and cation composition. Probably, SO ion has a more pronounced negative effect on the activity of Q6PDH enzyme than Cl–, and can denature it more easily. On the other hand, at an equimolar concentration, the amount of Na+ in Na2SO4 salt is twice as high as in NaCl salt solution. The entry of Na+ into the cell in excess of the norm leads to the development of a toxic effect, disruption of the metabolism of mineral and organic substances, and finally, the normal course of physiological processes becomes difficult.

As can be seen from the figures presented in the table, the value of the Q6PDH/DMDH activity indicator decreases with the increase in the concentrations of NaCl and Na2SO4 salt solutions in the incubation medium and the extension of their effect on the root system of seedlings. This means that as the stress created by salts intensifies, the role of the cytoplasmic form of the DMDH enzyme in eliminating its negative effect also increases.

From the comparative analysis of the effect of Na2SO4 salt solutions on the activity dynamics of Q6PDH and DMDH enzymes in the root system tissues of wheat seedlings, it is also possible to conclude that, as in NaCl salt solutions, in this case, the DMDH enzyme is more resistant to the negative effects of salt solutions than the Q6PDH enzyme. This means that under stress conditions created by high concentrations of NaCl and Na2SO4 salt solutions, when the activity of the Q6PDH enzyme becomes difficult, the DMDH enzyme takes on the main function in implementing the defense and adaptation reaction.

Perhaps one of the main reasons for the appearance of the cytoplasmic DMDH enzyme in evolution is precisely the adaptation of plants to extreme environmental conditions. Since the Q6PDH enzyme, which carries out one of the ancient pathways of glucose breakdown and regulates its activity, is more sensitive to extreme factors, a more resistant enzyme - DMDH - has emerged that can insure it.

NaHCO3 and Na2CO3 salt solutions differ significantly from NaCl and Na2SO4 salt solutions in terms of the nature of their effect on the cytoplasmic DMDH enzyme of the tissues of the root system of wheat seedlings. They inhibit the activity of the DMDH enzyme more sharply. Perhaps this difference is due to the effect of NaHCO3 and Na2CO3 salt solutions on the activity of the root system of wheat seedlings and the regulation of the enzyme activity at the transcriptional

and translational levels, as well as the effect of absorbed ions on the indicators of the cytosol itself.

The effect of NaHCO3 and Na2CO3 salt solutions on the activity of the cytoplasmic DMDH enzyme in the root system tissues of wheat seedlings is almost similar, if certain nuances are not taken into account. The relatively short-term effect of both salt solutions results in an increase in the activity of the enzyme at all concentrations. However, this induction effect is somewhat weaker than in the NaCl and Na2SO4 salt solutions. Increasing the concentration of NaHCO3 and Na2CO3 salt solutions and extending the incubation time results in the replacement of the induction with an inhibitory effect. For example, the activity in the root system tissues of 5-day-old seedlings cultivated at a concentration of 50-75 mM is significantly lower than the activity observed in the control seedlings of the corresponding period. In 7-day-old seedlings, this is more clearly and sharply manifested. Compared to the control variant of the same period, this difference increases to 39.1% in seedlings grown in 50 mM NaHCO3 solution. For Na2CO3 salt solutions, the corresponding figures are 52.2 and 38.0%.

This effect of NaHCO3 and Na2CO3 salt solutions on the dynamics of the DMDH enzyme of the root system seeds of wheat seedlings is also manifested in the ratio of Q6PDH and DMDH enzymes. The figures obtained from this ratio differ significantly from the figures obtained from NaCl and Na2SO4 salt solutions. For NaCl salt solutions, this ratio in 7-day-old seedlings is within the range of 1.33-1.03, and for Na2SO4 salt, it is within the range of 1.23-0.92, while for NaHCO3 and Na2CO3 salt solutions, the analogous figures are within the range of 1.37-2.44 and 1.51-2.03, respectively. That is, the main role in the response of wheat seedlings to stress conditions created by NaHCO3 and Na2CO3 salt solutions falls on the Q6PDH enzyme.

One of the main biochemical changes occurring under salt stress conditions is the formation of active metabolites of oxygen, including superoxide radical (O), hydrogen peroxide (H2O2) and hydroxide radicals (OH•). The formation of such active substances is used in the response of plants to biotic and abiotic stress, on the one hand, and on the other hand, it causes serious problems in the normal course of plant metabolism by oxidative damage to lipids, proteins and nucleic acids [6]. The NADPH-oxidase enzyme, which is considered to be the trigger for the formation of active metabolites of oxygen, uses NADPH as a coenzyme. On the other hand, according to modern concepts, it is emphasized that phytohormones also play an important role in the process of weakening the negative effects of stress factors, including salt stress, on plants. It is believed that they participate in the adaptation of plants to adverse environmental conditions by modulating

physiological responses.

4.Conclusion This effect of NaHCO3 and Na2CO3 salt solutions on the dynamics of the DMDH enzyme of the root system of wheat seedlings is also manifested in the ratio of Q6PDH and DMDH enzymes. The figures obtained from this ratio differ significantly from the figures obtained from NaCl and Na2SO4 salt solutions. For NaCl salt solutions, this ratio in 7-day-old seedlings is within the range of 1.33-1.03, and for Na2SO4 salt, it is within the range of 1.23-0.92, while for NaHCO3 and Na2CO3 salt solutions, the analogous figures are within the range of 1.37-2.44 and 1.51-2.03, respectively. That is, the main role in the response of wheat seedlings to stress conditions created by NaHCO3 and Na2CO3 salt solutions falls on the Q6PDH enzyme.

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