THE IMPACT OF THE VANADATE IONS ON THE GERMINATION OF THE WHEAT SEEDS AND THE GROWTH OF THE SEEDLINGS IN THE FIRST DAYS OF LIFE

Petrehele Anda Ioana*, Morgovan Claudia*, Fodor Alexandrina*, Mureşan Ioana*

*University of Oradea, Faculty of Science, 1 University St., 410048, Oradea, Romania, e-mail: andapetrehele@yahoo.com

Abstract

The influence of vanadate ions in both germination of wheat seeds and growth of seedlings in first sixth days of life were studied. Vanadate solution by concentration from 0.01 to 100 mg% were prepared and used to watering of wheat seeds in comparison with distilled water as blank. The germination yield, length of embryonic roots, adventitious roots, coleoptile and leaflet and the quantitative percentage of biomass were determined for each wheat seedling. The germination took place in vitro at 25 °C, in the dim light. The germination yield of wheat seeds not appeared to be influenced by the presence of vanadate ions in solutions and not presented a clear dependence but their concentration, but touched the maximum value at 0.01 mg%. The length of roots was inhibited by the presence of vanadate ions in whole range of concentration, especially at 10-100 mg%. The growth of both coleoptile and leaflet was negative influenced at the highest concentration too. The biomass accumulation was stopped and inhibited significantly at all values of concentration, but more at 0.1 mg%. This behavior of wheat seedlings in the presence of vanadate ions not recommended using of this as essential trace elements in development of wheat plants in the first days of life in the light absence.

Key words: wheat, vanadate, germination, seedlings

INTRODUCTION

Evidences that Vanadium is essential for the growth of higher plants are not conclusive (Dieter, 2008, Panichev et al., 2006, Serra et al., 1989). Its essential role in the development of micro-organisms (Jakobs et al., 1980, Kao., 1996), seems also to be questioned only possible exception being its involvement in the growth of green algae, Scenedesmus obliquus (Chung-Yi et al, 2014, Terasaka et al., 2003). However, the growth rates of the various micro-organisms higher plants (Haiou et al, 2013, Welch et al., 1973), and animals (Huang C et al, 2013) were increased even by small additions of Vanadium (Gondek, 2003, Maity et al., 2010). The experiments reported here were performed to see whether Vanadium is involved in germination and growth of seedlings of wheat in the first days of life (Amodeo et al., 1992, Prasad, 2003, Zhang et al., 2004).

In this paper, we intend to follow the influence of Vanadium salts by seed germination and growth of wheat seedlings in the first six days of life in vitro. The concentrations of Vanadium solutions used were ranged in

0.01-100 mg%. The seeds were germinated in germinators under laboratory conditions with constant value of the temperature, humidity and light (Bowden , 2008). Degree of seed germination in the fourth and sixth day were determined during the experiments and for seedlings were measured the length of roots, coleoptile and first leaflets were measured and the biomass was determined quantitatively (Bîlteanu et al., 1991). Interpretation of results was accomplished using data from processing statistical of analyzes (Măruşteri, 2006).

MATERIAL AND METHOD

Five solutions of different sodium vanadate concentration ($NaVO_3 \cdot 3H_2O$) were prepared: 0.01mg%; 0.1 mg%; 1.0 mg%; 10 mg% and 100 mg%. Distilled water was used as a reference solution (blank). Healthy wheat seeds organic and environmentally friendly, from 2015 production, kept in optimal conditions were taken in our study (Bowden, 2008). The seeds were hand-selected by size, integrity, color and appearance, were washed twice with distilled water and then were placed on a filter paper for drying. It has prepared six germinators, five for each vanadate solution and one for control. The counted seeds were placed in first germinator on two filter paper socked with control solution. In the same manner, the next germinators were prepared, each with seeds watering with another vanadate solution. Germinators were closed and kept for four days at room temperature (25 °C) in the dim light. In the fourth day, each germinator was opened and germinating seeds were counted. On the sixth day, germinators were reopened, seedlings were counted again and then, the length of embryonic root, the adventitious roots, coleoptile and first leaflet were determined for each plant (Petcu et al. 2007). For biomass determination, seedlings were dried in oven at 105°C until reaching a constant weight.

After the measurements, the results were statistically analyzed and interpreted using 2016 Excel program. We determined the following values for each parameter studied: minimum (MIN), maximum (MAX), median, average and standard deviation (STDEV) of values. It was applied Student test (TTEST) and the percentage differences were calculated using the mathematical relationship (1):

$$percentage\ differences\ (\%) = (\bar{x}_{sample} - \bar{x}_{blank}) \cdot 100 / \bar{x}_{blank} \quad (1)$$

where $\bar{x}_{sample}$ was average of values for one of studied parameters after using someone of vanadate solution, while $\bar{x}_{blank}$ average of values of the same parameter after using of distilled water (blank).

RESULTS AND DISCUSSION

In Table 1, germination yields for wheat seeds obtained after the fourth day, respectively the sixth day were recorded. On the fourth day of germination the highest yield was touched for seeds soaked with 0.01 mg% vanadate (yield 100%). In the sixth day, germination yields were unmodified and were up to 95% in all vanadate (0.01-100 mg%).

Table 1

Germination yields of wheat seeds after watering with vanadate solutions by different concentration

Sample	Germination Yields (%)	
	4th day	6th day
Vanadate 0.01 mg %	100	100
Vanadate 0.1 mg %	98	98
Vanadate 1 mg %	96	96
Vanadate 10 mg%	95	95
Vanadate 100 mg %	97	97
Blank (distilled water)	97	97

Table 2

Statistical parameters of wheat seedlings after watering with 0.01mg% vanadate solution

0.01 mg%	Embryonic root (mm)	Adventitious roots (mm)	Coleoptile (mm)	Leaflet (mm)	Biomass (%)
Average	45.73±22.35	33.72±12.53	33.6±6.19	50.83±13.08	30.40±2.4
STDEV	22.3546167	12.5357378	6.1892379	13.0845541	2.3977513
MAX	80	66	42	70	33.98
MIN	2	2	15	15	25.76
Median	50	32.75	35	55	30.07
TTEST	0.00010061	0.00518079	0.2454254	0.37427699	0.0004880

Table 3

Statistical parameters of wheat seedlings after watering with 0.1mg% vanadate solution

0.1 mg%	Embryonic root (mm)	Adventitious roots (mm)	Coleoptile (mm)	Leaflet (mm)	Biomass (%)
Average	58.48±22.45	41±16.22	34.79±6.42	50.86±13.25	25.24±4.52
STDEV	22.4493617	16.2236524	6.41861146	13.2553805	4.51645832
MAX	91	80	54	69	40.77
MIN	12	10	18	5	21.95
Median	60	37.5	35	54	24.19
TTEST	0.02052728	0.15485845	0.48528137	0.37874327	2.8213E-06

The whole experimental lot of seedlings treated with 0.01 mg% vanadate proved to be representative and results were translatable because the standard deviation values were found under 15% for the most parameters and it was between 15-30% only for embryonic roots (Table 2).

So how resulted from TTEST, p parameter found under 0.05 only for embryonic and adventitious roots and biomass corresponding to significantly different between 0.01 mg% vanadate and blank.

A very high homogeneity resulted from standard deviation for seedlings watering with 0.1 mg% vanadate solutions (Table 3). Average values remain very close to the median like in 0.01 mg% vanadate. Following TTEST ($p < 0.05$), the significant variations from blank were obtained for biomass and embryonic roots.

Table 4

Statistical parameters of wheat seedlings after watering with 1.0 mg% vanadate solution

1.0 mg%	Embryonic root (mm)	Adventitious roots (mm	Coleoptile (mm)	Leaflet (mm)	Biomass (%)
Average	67.6±19.63	40.4±12.56	34.79±5.51	49.1±10.03	31.52±2.51
STDEV	19.6330237	12.5597738	5.51098784	10.028734	2.50575599
MAX	97	68	45	65	36.27
MIN	17	6	18	18	28.54
Median	70	42.5	42.5	50	31.54
TTEST	0.07511694	0.11090352	0.48438798	0.19673906	0.00146444

Table 5

Statistical parameters of wheat seedlings after watering with 10 mg% vanadate solution

10 mg%	Embryonic root (mm)	Adventitious roots (mm	Coleoptile (mm)	Leaflet (mm)	Biomass (%)
Average	28.68±8.14	21.09±5.23	22.86±7.01	23.04±7.15	37.47±3.33
STDEV	8.14183891	5.22537349	7.0087409	7.14883678	3.32995587
MAX	50	32	37	37	44.3
MIN	10	7	7	7	30.63
Median	28	21	22.5	22.5	37.62
TTEST	2.5229E-09	5.3962E-07	4.5891E-08	8.5083E-12	0.15505983

Table 6

Statistical parameters of wheat seedlings after watering with 100 mg% vanadate solution

100 mg%	Embryonic root (mm)	Adventitious roots (mm	Coleoptile (mm)	Leaflet (mm)	Biomass (%)
Average	13,32±5,29	13,9±5,34	12,93±4,37	13,62±4,63	39,2±5,92
STDEV	5,29482048	5,34228416	4,37020503	4,63430829	5,9196127
MAX	22	26	23	23	47,6
MIN	2	2	7	7	29,15
Median	14,5	14	13	13	37,84
TTEST	3,5959E-12	4,2935E-09	1,1415E-17	7,0178E-15	0,35386852

The standard deviations of all studied parameters of wheat seedlings were under 15% after using of 1 mg% vanadate (Table 4). On the other hand, parameters from TTEST had values under 0.05 only for biomass.

In both Table 5 and 6, values of standard deviation were under 15% for all parameters, corresponding to a high homogeneity of seedlings at using of 10 mg% and 100 mg% vanadate solutions. TTEST analysis confirmed significant differences for length of roots, coleoptile and leaflets of seedlings after soaking with both 10 mg% and 100 mg% vanadate.

The percentage differences for embryonic roots determined in vanadate solutions were negative values in whole concentration range (0.01-100 mg%) (Fig. 1). The shortest embryonic roots were found in the highest vanadate concentrations (10-100 mg%), corresponding to a significant inhibitory action of this in growing of embryonic roots. Only 1 mg% vanadate solution was not aggressive with embryonic roots, its inhibitory action was insignificantly, so could see in Fig. 1.

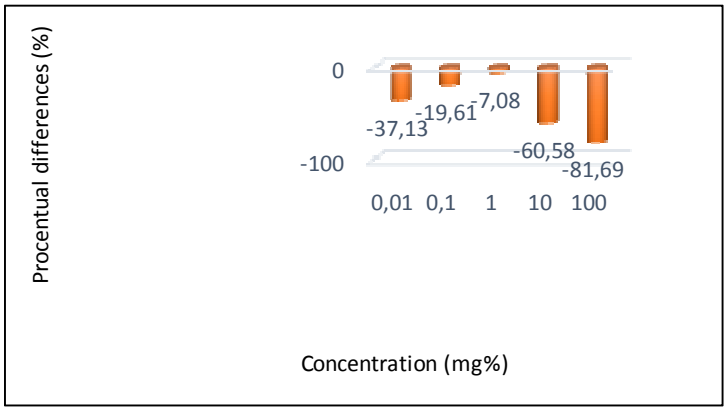

Fig. 1. Percentage differences between embryonic roots of wheat seedlings at different vanadate concentrations

The growth of adventitious roots was inhibited by the presence of vanadate solutions, especially in high concentration from 10 to 100 mg% (Fig. 2). In both Fig. 1 and Fig. 2 the behavior of embryonic and adventitious roots was very similar.

In Fig. 3, the influence of vanadate solutions in growth of coleoptile was significantly at high concentration (10-100 mg%) when the length of coleoptile was shorter than in blank. This difference was striking at soaking of seeds with 100 mg% vanadate.

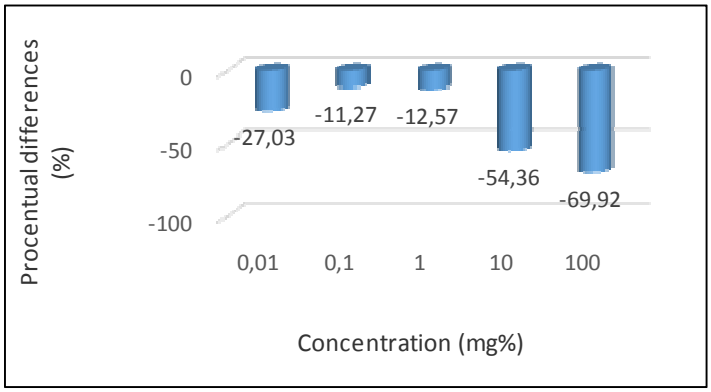

Fig. 2. Percentage differences between adventitious roots of wheat seedlings at different vanadate concentration

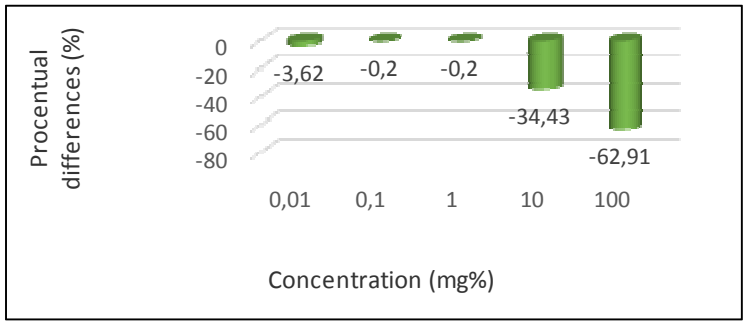

Fig. 3. Percentage differences between coleoptiles of wheat seedlings at different vanadate concentration

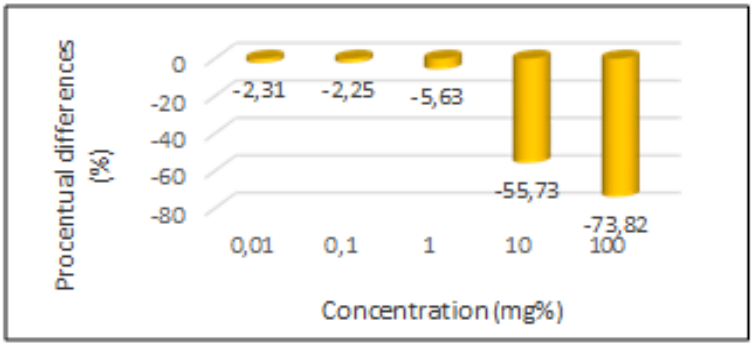

Fig..4. Percentage differences between leaflets of wheat seedlings at different vanadate concentration

Solutions with vanadate concentration between 0.01-1.0 mg% had an insignificantly negative influence in the growth of leaflet. Instead, solution with higher vanadate concentrations, 10-100 mg% expressed a very aggressive inhibitory action in develop of the leaflets, so can saw in Fig. 4.

Leaflets from seedlings watering with 10-100 mg% vanadate solution were stunted, shorter, than those from distilled water.

The variation of biomass with vanadate concentration had a very interesting evolution. In Fig. 5, the increasing of biomass was inhibited significantly at low concentration (0.1-1.0 mg%), especially at watering with 0.1 mg% vanadate solution when biomass touched at minimum values of percentage differences by 37.37%.

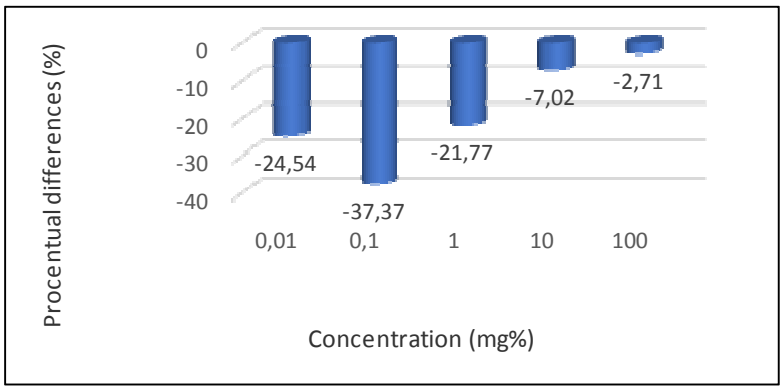

Fig. 5. Percentage differences between biomass of wheat seedlings at different vanadate concentration

CONCLUSIONS

The study relieved an inhibitory action of vanadate solutions, with a characteristic evolution for each studied parameter. The growth of embryonic and adventitious roots from wheat seedlings was inhibited especially by the presence of vanadate in higher concentrations, 10-100 mg%, but also the inhibitory action proved to be high enough at 0.01 mg%.

The situation became more clear for growth of coleoptile and leaflet from wheat seedlings. A negative influence in growth of coleoptile and leaflet of wheat seedlings became significantly to the highest concentration, 10-100 mg%. Despite, the biomass increasing in wheat seedlings showed to be seriously inhibited at little concentration, mainly at 0.1 mg%. A water retention at lower concentration of vanadate was observed.

This behavior of wheat seedlings after treatment with vanadate solutions exposed an unfriendly character of this ion in the first days of seedlings development. Vanadate ions had not recommended as essential trace element in the first day of life of wheat plants, at the dim light.

REFERENCES

1. Amodeo G., Srivastava A., Zeiger E., 1992, Vanadate Inhibits Blue Light-Stimulated Swelling of Vicia Guard Cell Protoplasts, Plant Physiol., 100, pp.1567-1570
2. Bîlteanu Gh., Salontai Al., Vasilică C., Bîrnaure V., Borcean I., 1991, Fitotehnie., Ed. Did. Ped., Bucureşti pp. 115-273.
3. Bowden P., 2008, Wheat growth and development, NSW Department of Primary Industries, pp.11-70.
4. Dieter R., 2008, Bioinorganic Vanadium Chemistry, John Wiley & Sons, Ltd. ISBN: 978-0-470-06509-9, pp. 1-51
5. Gondek K., Filipek-Mazur B., 2003, Biomass yields of shoots and roots of plants cultivated in soil amended by vermicomposts based on tannery sludge and content of heavy metals in plant tissues, Plant Soil Environ., 49(9), pp.402–409
6. Haiou W., You L., Zhong G., Shi G., 2013, Effects of vanadate supply on plant growth, Cu accumulation, and antioxidant capacities in *Triticum aestivum* L, Environmental Geochemistry and Health, 35 (5), pp. 585–592
7. Huang C., J.-J.Zhong, 2013, Elicitation of ginsenoside biosynthesis in cell cultures of *Panax ginseng* by vanadate, Process Biochemistry, 48(8), pp.1227–1234.
8. Jakobs M., Taiz L., 1980, Vanadate inhibition of auxin-enhanced H^+ secretion and elongation in pea epicotyls and oat coleoptiles, Proceedins of the National Academy of Sciences of the United States of America, 77(2), pp. 7242–7246
9. Kao C-H., 1996, Stimulation of ethylene production in detached rice leaves by vanadate, Plant Growth Regulation, 18(3), pp. 161-164.
10. Lin C-Y., Huang L-Y, Chi W-C, Huang T-L, Kakimoto T., Tsai C-R, Huang H-J., , 2014, Pathways involved in vanadate-induced root hair formation in Arabidopsis, Physiologia Plantarium, 153(1), pp.137-148.
11. Maity J. P. Kar S., Chakraborty A, 2010, Study on trace elements (using energy dispersive X-ray fluorescence technique) of edible seeds from Cicer arietinum L. plants developed from gamma irradiated seeds and variation of yielding capacity, J Radioanal Nucl Chem., 283, pp.225–230.
12. Mandiwana K., Panichev N., 2006, Distribution of Vanadium(V) species between soil and plants in the vicinity of Vanadium mine, Journal of Hazardous Materials A137 pp. 649–653
13. Măruşteri, Şt. M, 2006, Noţiuni fundamentale de biostatistică: note de curs, University Press, Târgu Mureş, pp. 28-35.
14. Petcu E., Ţerbea M., Lazăr C., 2007, Fiziologia plantelor, I.N.C.D.A. Fundulea, LXXV, pp.23-68.
15. Prasad M. N. V., 2003, Phytoremediation of Metal-Polluted Ecosystems: Hype for Commercialization, Russian Journal of Plant Physiology, 50(5), pp. 686–700.
16. Serra M. A. & al., 1989, Vanadate as an inhibitor of plant and mammalian peroxidases, Biological Trace Element Research, 23 (1), pp 151–164.
17. Terasaka K., Shitan N., Sato F., Maniwa F., Ueda K., Yazaki K., 2003, Application of Vanadate-Induced Nucleotide Trapping to Plant Cells for Detection of ABC Proteins, Plant Cell Physiol., 44(2), pp.198-200.
18. Welch R. M., Huffman E. W. D., 1973, The Growth of Lettuce (Lactuca Sativa L.) and Tomato (Lycopersicon Esculentum Mill.) Plants in Nutrient Solutions Low in Vanadium, Plant Physiol., 52, pp.183-185.
19. Zhang S., Wang S., Shan X., Mu H., 2004, Influences of lignin from paper mill sludge on soil properties and metal accumulation in wheat, Biol Fertil Soils, 40, pp. 237–242.