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Effect of foliar application of some organic compounds with magnetic and tap water on wheat *(Triticum aestivum L.)* yield

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Abstract
The effect of foliar application of organic compounds with magnetically treated water was studied on yield and yield components of bread wheat in a factorial trial based on a Randomized Complete Block Design in Research Farm of Urmia in 2016 growing season. The first factor was devoted to organic compounds including Aminolforte (2:1000), Kadostim (0.5:1000), urban compost and cattle manure (both with the ratio of 5%) and the second factor was devoted to irrigation water type including tap water and magnetically treated water (both at the rate of 20 l m^{-2}) in three replications. Results showed that organic compounds and water type significantly influenced the number of fertile spikes, 1000-grain weight, grain yield, days to spike emergence, days to physiological maturity, plant height, and the number of grains per spike. Means comparison showed that among organic compounds, Aminolforte had the strongest effect so that it was associated with the highest grain yield of 5758 kg ha^{-1} that was about 29% higher than that of control. The application of magnetically treated water vs. tap water changed all traits significantly. The interaction between organic compounds and water type was significant for days to spike emergence and days to physiological maturity.
Keywords: wheat, Kadostim, Aminolforte, magnetically treated water

INTRODUCTION

Extensive efforts have been triggered in recent years to find optimum methods for enhancing agricultural soil quality. Environmental risks and grave concerns for the sustainability of the current agricultural systems have increased the interests to use protein compounds (including amino acids) for the regulation of plant growth and biosynthesis. As organic nitrogenous compounds, amino acids are the building blocks of protein synthesis [1] The importance of amino acids lies in their extensive application in the biosynthesis of protein-free nitrogenous compounds like pigments, vitamins, coenzymes, and purine and pyrimidine bases [2].

It has been proven that amino acids can directly or indirectly influence the physiological activities of plant growth and development. Aminolforte and Kadostim are examples of amino acid-containing compounds. They are liquid biostimulators that contain free amino acids and bio-oligopeptides as well as useful nutrients for the application at flowering stage to induce grain formation. They are applied to improve the quality of such crops as rice, wheat, and barley (Hassanpanah, 2009). Kadostim induces germination, activates root meristem formation, accelerates leaf formation, regulates moisture, light and temperature, and mitigates stress [3]. The acids existing in these biostimulators play a crucial role in the biosynthesis of secondary metabolic and hormonal compounds. The physiological need for the uptake of nutrients peaks at specific stages for running the metabolic activities. However, plants cannot usually enjoy adequate nutrients at these stages due to some constraints on their uptake from soil. Even managerial actions like fertilization at optimum time cannot work to meet plant requirements because of the relatively long temporal gap between the uptake of nutrients and their conversion to compounds (e.g. amino acids) required by plants. So, the growth-stunted plants lose their optimum yield. Biostimulators (that contain amino acids) make it possible for plants to meet their own requirements in the shortest possible time without suffering stress and yield loss [4].

Overall, biostimulators are compounds that stimulate the metabolism and metabolic activities to improve plant efficiency. The formulations of biostimulator and growth stimulators are based on new inputs of amino acids and/or amino acids mixed with nutrients, hydrolyzed proteins of humic acid, the extracts of algae and marine organisms and other metabolites [5].

Amino acids are bipolar molecules with common formula ($C_2H_4O_2NR$) and function as biomolecules and life precursors in forming proteins and lipids that are responsible for all major functions of the plant including structural, enzymatic, metabolic, and mobilization functions. They are usually the precursors of a lot of micro-molecules that have vital biological roles. The strategy of the dissolution of amino acids is the formation of intermediate metabolites that are converted to glucose or are oxidized in citric acid cycle.In this respect, some researchers have reported that the foliar application of Aminolforte and Kadostim biostimulators on the basis of free amino acid containing formulation could greatly improve the physiological parameters and the yield of tea [6].

It has been reported that amino acids of Kadostim formulation may activate the hormones affecting the reproductive growth by enhancing mRNA transcription, thereby improving the uptake and mobilization of nutrients. In addition, the application of organic stimulators for environmentally-adapted biological production in collaboration with modern agriculture can improve the quantitative and qualitative growth of the plants [7]. Research shows that the foliar application of Aminolforten and Kadostim can lead to yield gain in plants like allfaalfa, corn and fixwed [8, 9, 10].

Applied findings reveal the significant role of organic biological products in the regulation of plant growth (including seeding, germination, rooting, maturity, senescence, and fruit formation and evolution). On the other hand, the formation of resistance to environmental stresses (like low and high temperatures, drought, and water deficit) reflects the high importance of the application organic biological products and amino acids in plants [11].

With foliar application of organic matter, the nutrients become directly available to plants in the shortest possible time. This practice can meet the nutritional requirements of the plants quickly and improve their nutrients use efficiency when there is a need for rapid plant response, the risk of the fixation of nutrients in soil, or the risk of leaching by heavy rainfall and flooding. The application of magnetic field for plant stimulation to improve plant quantity and quality has been recently attracted the attentions [12 ; 13].

Magnetically treated water – or, simply put, magnetic water – is a kind of water that is passed through a magnetic field generated by specific calculations to change its physical and chemical properties [14]. The major advantage of magnetic water application in agriculture is to amend soil with least amount of chemicals and acids. Physical refinement of water changes its physical properties like surface tension, viscosity and density and gradually loosens soil lime making it possible for root system to grow and develop. The amendment of magnetic water allows the dissolution of even lime stone that do not normally dissolve in water or hard water. Then, Na exchange with soil facilitates water penetration into soil and acts as a mediator between micron particles of clay and organic matter, helping the formation of soil aggregates which finally improves soil fertility, porosity, and aeration. In addition to the changes in the physical and chemical features of water, this technology enhances its purification and solubility so that the plants can readily absorb the essential elements for their growth and the remaining minerals and compounds are directed towards the drainage systems. Then, the pores easily allow the flow of these broken minerals to the drains in lower layers of soil [15].

Wheat is a strategic crop in Iran and supplies over 45% of protein and 55% of calorie requirements of the population. Global wheat production amounts to 621 million t per annum with the growing rate of 1.6%. It is projected that it will reach 900 million t by 2050. Wheat is an important crop, and fertilization is one of the main aspects of its production [15].

Organic fertilizers are the best substitutes for chemical fertilizers and can significantly improve the physical and chemical properties of soil so that they can enhance the activity of microorganisms and soil texture in addition to increasing soil organic content [16]. On the other hand, huge organic residues of industrial, agricultural, and urban activities have placed an enormous pressure on their disposal and have posed short- and long-term negative consequences to the health of environment. It is imperative to use all organic sources including agricultural wastes and urban sewage and wastes for increasing soil organic content in order to help sustainable development along with the improvement of agricultural production [17].

The incorporation of organic residuals to agricultural soil is the best and appropriate way for their disposal to environment [18]. However, the low price and ease of application of chemical fertilizers, unfortunately, hinder the extensive use of organic sources by agricultural sector. Nowadays, soil fertility is conserved mostly by chemical fertilizers [19].

Overexploitation of chemical fertilizers accompanied with the inappropriate cultivation practices like the burning of straw suppresses soil organic content and poses fatal risks to soil. Iran has mostly arid and semi-arid climate and the lack of adequate vegetative cover results in the return of just a small part of plant residues to soils making them deficient in organic matter so that most soils in Iran possess less than 1% organic matter [20].

On the other hand, given the constraints on manure resources, it is imperative to conduct a comprehensive investigation into the use of other organic sources like sewage mud and urban waste compost. Therefore, given the limitation of organic matter and adverse conditions in most parts of Iran, research on organic residues can pave the way for their application as a suitable, inexpensive amendment of agricultural lands. Extensive studies have been conducted on the use of urban sewage mud and its impact on soil features and crop yield throughout the world [21].

Therefore, the present study aimed to investigate the impact of foliar application of organic compounds including Aminolforte, Kadostim, compost extract, cattle manure, and magnetic water on yield and yield components of bread wheat in the climatic conditions of Urmia, Iran.

MATERIALS AND METHODS

The present study was carried in Research Farm of Urmia University (Lat. 37°32' N., Long. 45°41 E., Alt. 1320 m) in 2016 growing season. The soil texture was loam-clay (Table 1). The study was a two-factor factorial trial based on a Randomized Complete Block Design with 11 treatments and three replications. The first factor was devoted to foliar application of Aminolforte, Kadostim, cattle manure, and compost at three rates and the second factor was devoted to water type including magnetic and conventional water (tap water). Kadostim (0.5:1000), Aminolforte (2:1000), urban compost and cattle manure each at 5% ratio, and tap water and magnetic water (each at the rate of 20 l m^{-1}) were applied at three phases of tiller initiation, spikelet emergence, and grain formation once 25 days. For the preparation of organic fertilizer spray extract, a 1:10 mixture of water and organic fertilizer was prepared and was kept at room temperature for 48 hours. Then, it was mixed and infiltrated from a two-layer thin cloth. Afterwards, it was applied with a sprayer (0.2 bars pressure) at tiller initiation, spikelet emergence, and grain formation stages. Magnetic water was produced by flowing tap water through a magnetic field using a magnetic device. The quantities and types of amino acids and minerals of protein organic fertilizer are summarized in Table 2.

After leveling and building the plots in the farm, wheat cv. Zarin was planted in a ridge and furrow system at the depth of 3-4 cm with the density of 450 plants m^{-2} in October. Each plot was composed of six 4-m-long rows spaced by 50 cm. The replications were spaced by 2 m. Treatments related to production operations were carried out in a uniform manner on all plots, based on local custom. An area of 4 m^2 was harvested from each plot for yield assessment and the grain yield was estimated on the basis of 14% moisture content. The studied traits included the number of fertile spikes, 1000-grain weight, grain yield, days to spike emergence, days to physiological maturity, plant height, and the number of grains per spike.

The variance of the data was analyzed by SAS 9.2 statistical package (SAS Institute, Cary, NC, US) and the means were compared by LSD test at the 5% probability level.

RESULTS AND DISCUSSION

The number of fertile spikes

Analysis of variance revealed that the effect of organic compounds and irrigation water type was significant on the number of fertile spikes at the 1% probability level (Table 3).

The application of magnetic water was associated with the production of 441.33 fertile spikes, which was about 3% higher than that associated with tap water (429.53) (Table 4).

Means comparison showed that the highest number of fertile spikes (448.6) was related to application of Aminolforte, which was 6% higher than that of control (422.83%). As well, the application of Kadostim increased fertile spikes by 4% as compared to control. The increased yield of the foliar application of amino acids may be associated, in addition to more rapid availability of nutrients, to appropriateness of the ratios of amino acids and its compounds that further induced the metabolism of the plant and the allocation of more photosynthates to reproductive parts like fertile spikes. Cattle manure and compost did not differ significantly.

Thousand-grain weight

According to the results of analysis of variance, 1000-grain weight varied with the types of organic compounds and irrigation water significantly at the 1% probability level (Table 3).

Thousand-grain weight was found to be 35 g when the plants were irrigated with magnetically treated water; 9% higher than that under the application of tap water (32 g) (Table 3). Plants have Fe-containing cells which are specifically important to plant growth. The last magnetic orbit of Fe atom which is engaged with exogenously applied magnetic field induces a vibration in system. Then, they generate force. The vibration uses its own energy and finally, settles down in the magnetic field directionNot only are the different plant responses to the magnetic field resulted from the strength of magnetic field, but they also depend on growth physiological stage of the studied plants. It can be concluded that magnetic field can improve the growth by increasing such elements as Ca and Mg. These findings are consistent with some authors. Means comparison suggests that the highest 1000-grain weight (36 g) was obtained from the application of Aminolforte, which had no significant difference with that obtained from Kadostim (35 g). These two treatments differed from control (31.5 g) by 14% and 11%, respectively. Foliar application of amino acids increases the growth and 1000-grain weight, as two important grain yield components, through improving the uptake of N, P, k and micronutrients.There was no statistically significant difference between cattle manure and compost. Nonetheless, these two treatments improved 1000-grain weight by 5% and 8% as compared to control, respectively.

Grain yield

As analysis of variance revealed, organic compounds and water type influenced grain yield significant at the 1% probability level (Table 3). Grain yield was 5308.2 kg ha^{-1} in plots irrigated with magnetic water; about 5% higher than grain yield (5062.2 kg ha^{-1}) in plots irrigated with tap water (Table 4). Higher quantities of ions can enhance the nutritional value of the plants. Magnetic field affects the diffusion of biological particles in solvent by Lorentz and Maxwell force. Lorentz force influences the diffusion and charging of particles like plasma proteins. The orientation of ferromagnetic particles and fluctuations of paired radicals are considered as the mechanism for magnetic field effectiveness. The application of magnetic field increased grain yield through increasing the number of fertile spikes and 1000-grain weight.

Means comparison revealed that the highest grain yield (5758 kg ha^{-1}) was obtained from the application of Aminolforte and that it was 29% higher than that of control (4461.5 kg ha^{-1}). Kadostim (5401.5 kg ha^{-1}) increased grain yield by about 6% as compared to cattle manure application (5086 kg ha^{-1}). Increased activity of enzymes and protein synthesis in plant cells improves total biomass rapidly and sharply which results in higher grain yield. Foliar application of organic compounds and macro- and micro-nutrients required by plants can play a significant role in improving the morphological traits, yield and yield components of crops [22].

Compost application resulted in nearly 3% higher grain yield (5219 kg ha^{-1}) than cattle manure. This improvement can be related to the positive impact of organic fertilizers on soil organic content and the physical, chemical and biological improvement of soil.

Biological yield

Analysis of variance suggested the insignificant effect of organic compounds and water type on biological yield at the 1% probability level (Table 3).

Days to spike emergence

According to the results of analysis of variance, organic compounds and water type changed days to spike emergence significantly at the 1% probability level (Table 3).

Spikes were emerged in 212.8 days when plants were irrigated with magnetic water; about 1% longer than that of tap water (211 days) (Table 4).

The shortest time to spike emergence was obtained from the application of Kadostim and Aminolforte, which was 3% shorter than that of control not significant differences were observed between the application of compost and cattle manure. A significant interaction was observed between organic compounds and water type (Table 3). Means comparison indicated that the lowest number of days to spike emergence (207.67 days) was related to Aminolforte-treated plants irrigated with tap water, which was 5% lower than that of plots which were not treated with organic compounds and irrigated with tap water (Figure 1).

Days to physiological maturity

Analysis of variance showed the significant impact of organic compounds and water type on days to physiological maturity at the 1% probability level (Table 3). Physiological maturity was reached in 233.8 days when plants were irrigated with magnetic water, which was about 2% longer than that of tap water (229.7 days) (Table 4). The shortest time to physiological maturity (224.8 days) was obtained from the application of Kadostim so that it was 8% shorter than that of control (244 days). Foliar application of amino acid-containing compounds may accelerate maturity by helping more rapid vegetative growth, which is beneficial in avoiding the encounter of grain filling stage with late-season high temperatures. When compost was applied, plants reached physiological maturity in 227.3 days which was 7% shorter than that in control. There was a significant interaction between organic compounds and water type (Table 3) so that the treatment of Kadosim and magnetic water reduced days to physiological maturity by 13% as compared to control (220 and 248.67 days, respectively) (Figure 2).

Plant height

According to the results of analysis of variance, the effect of organic compounds and water type was significant on plant height at the 1% probability level (Table 3). Plant height was 100.4 cm in plants irrigated with magnetic water. It was 3% higher than that of plants irrigated with tap water (97.7 cm) (Table 4). Irrigation with magnetic field improves plant growth and development by free radicals involved in chemical reactions and the increased activity of proteins and enzymes. The increase in plant height is accounted for by the increased growth and development of cells. Research shows that magnetic field increases the number of ions and consequently, improves nutritional value and plant growth. This phenomenon can be a justification for the replacement of chemical treatments.

The highest plant height was obtained from the application of Aminolforte and Kadostim (101.75 and 101.05 cm, respectively). Both were about 9% higher than the plant height of control (92.9 cm). It is possible for the amino acids used in Kadostim formulation to be involved by enhancing mRNA transcription in the activation of hormones affecting reproductive growth, the activation of fatty acid formation, and the increase in the uptake and translocation of nutrients, resulting in growth improvement [23]. Cattle manure and compost did not cause statistically significant differences in plant height. However, they resulted in 2% taller plants than control.

The number of grains per spike

Analysis of variance revealed that the impact of organic compounds and water type was significant on the number of grains per spike at the 1% probability level (Table 3). Plants produced 15.04 grains per spike when they were irrigated with magnetic water. Those irrigated with tap water yielded 9% less grains (13.8) (Table 4). The application of Aminolforte resulted in 11% gain in grain number per spike (15.2) as compared to control (13.6). Amino acids influence soil N uptake and improve vegetative and reproductive growth, thereby increase the uptake of nitrogen and other trace elements and improve growth and finally, yield. No significant difference was observed between cattle fertilizer and compost. But, compost produced 6% more grains per spike (14.4) than control.

CONCLUSION

We found that the application of magnetic water and organic fertilizers improved yield and yield components of wheat as compared to control. Among organic compounds, Aminolforte and Cadostim had the strongest impact. It appears that the application of biological products including amino acids, compost and cattle manure can be taken into consideration given their consequences for optimum nutrition for yield gain, crop health and higher economic efficiency of wheat as a strategic crop.

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Table 1. Soil characteristics in the research site

Soil depth	Texture	EC	Saturation %	Lime	Clay (%)	Silt (%)	Sand (%)	Organic C (%)	N (%)	Absorbable P (ppm)	Absorbable K (ppm)
0-30	Loam-slit	1.1	43	13	26	35	39	0.6	6	10.4	250

Table 2. The formulation of organic fertilizers used in the trial

Fertilizer	Compound formulation
Aminolforte	3750 mg l^{-1} free amino acids, 2% organic matter, 1.1% total nitrogen, 0.8% urea nitrogen, 0.3% organic nitrogen
Kadostim	3750 mg l^{-1} free amino acids, 2% organic matter, 1.6% ammonia nitrogen, 3.1% nitric nitrogen, 0.3% organic nitrogen, 6% potassium
Cattle manure	2.14% nitrogen, 065% phosphorous, 3.01% potassium, 2.57% calcium, 0.67% magnesium
Compost	1.4% nitrogen, 0.61% phosphorous, 0.62% potassium, 27.3% carbon, 85.1 mg kg^{-1} lead, 5.4 mg kg^{-1} cadmium

Table 3. Analysis of variance of the wheat traits as affected by the studied treatments

S.O.V.	df	Means of squares							
		FS	**TKW**	**GY**	**BY**	**DSE**	**DPM**	**PH**	**NGS**
Replication	2	2.43^{ns}	6.3^{ns}	15936^{ns}	5408176^{ns}	1.3^{ns}	2.2^{ns}	0.063^{ns}	2.7^{ns}
Organic compounds	4	523^{**}	18.3^{**}	1364615^{**}	840160^{ns}	34.3^{**}	336.7^{**}	0.6^{**}	21^{**}
Water type	1	1044^{**}	36.3^{**}	45378^{**}	21048711^{ns}	24.3^{**}	1241.03^{**}	38.3^{**}	100^{**}
Interaction of two factors	4	6.05^{ns}	0.3^{ns}	6872^{ns}	5266711^{ns}	26.38^{**}	89.7^{**}	0.6^{ns}	5.5^{ns}
Experimental error	18	20.35	1.85	8354.9	5694309	2.26	2.6	0.65	0.1
CV	-	1.03	4.01	1.76	17.53	0.7	0.69	0.81	2.19

** and ns show significance at the 1% probability level and insignificance, respectively. FS= Fertile Spike Number, TKW= 1000-grain weight, GY= Grain yield, BY= Biological yield, DSE= Days to spike emergence, DPM= Days to physiological maturity, PH= Plant height, GS= Number of grains in per spike.

Table 4. Means comparison for the studied plant traits as affected by the treatments

Treatments		FS	TKW	GY	BY	DSE	DPM	PH
Organic compounds	Control	422.8 d	31.5 d	4461.5 e	215.6 a	244 a	92.9 c	13.6 d
	Aminolforte	448.6 a	36 a	5758 a	210.3 cd	229.5 c	101.7 a	15.2 a
	Kadostim	437.8 ab	35 ab	5401.5 b	209.5 d	224.8 e	101.1 a	14.8 b
	Cattle manure	432.3 b	33 cd	5086.5 d	212.5 b	233.1 b	98.9 b	14.2 c
	Compost	435.5 bc	34 bc	5219 c	211.5 bc	227.3 d	99.9 b	14.4 bc
Water type	Magnetic water	441.3 a	35 a	5308.2 a	212.8 a	233.8 a	100.1 a	15.04 a
	Tap water	429.5 b	32 b	5062.2 b	211 b	229.7 b	97.7 b	13.8 b

Means were compared on the basis of LSD test. In each column and treatment, means with similar letter(s) were not significant at the 5% probability level. FS= Fertile Spike Number, TKW= 1000-grain weight, GY= Grain yield, BY= Biological yield, DSE= Days to spike emergence, DPM= Days to physiological maturity, PH= Plant height, GS= Number of grains in per spike.

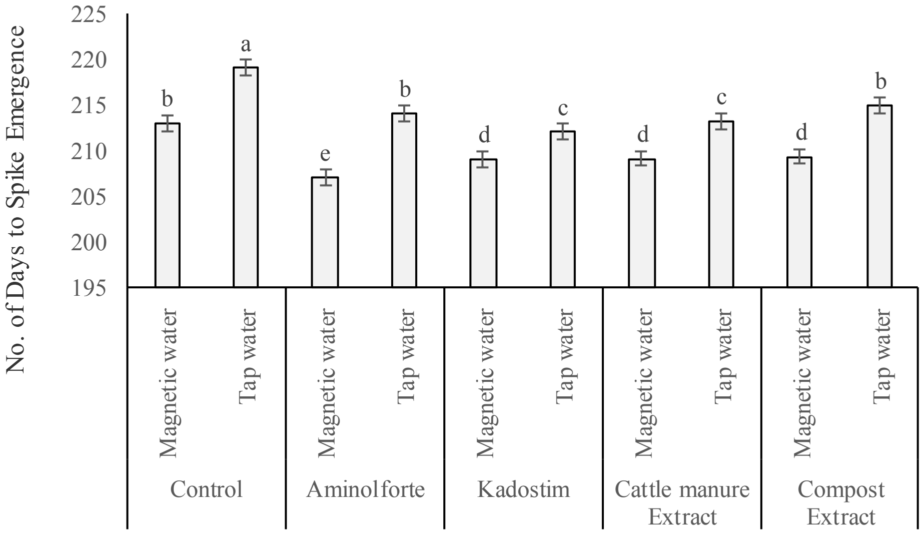

Figure 1. Interaction between organic compounds and water type for the number of days to spike emergence

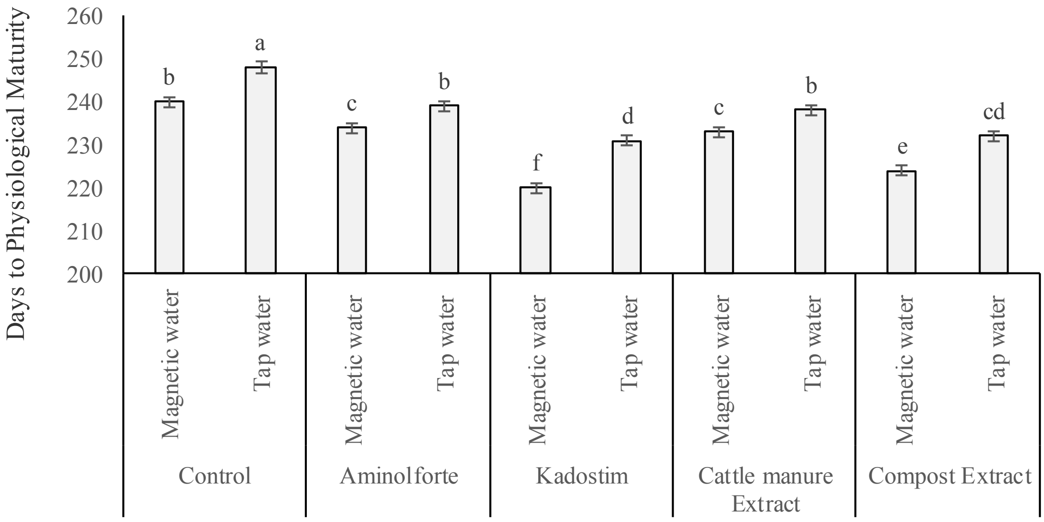

Figure 2. Interaction between organic compounds and water type for the number of days to physiological maturity