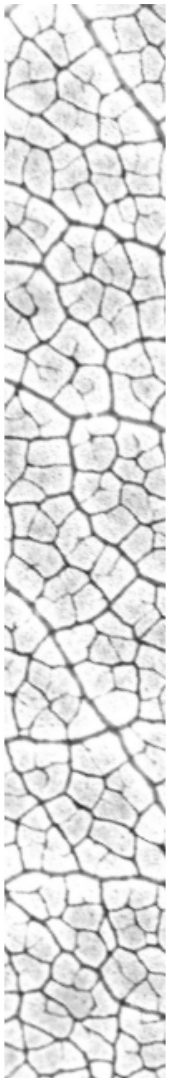

EurAsian Journal of BioSciences
Eurasia J Biosci 12, 129-137 (2018)

The Effect of Magnetized Water on Some Characteristics of Growth and Chemical Constituent in Rice (*Oryza sativa* L.)Var Hashemi

Fatemeh Babaloo [1*], Ahmad Majd [1], Sedighe Arbabian [1], Fariba Sharifnia [1], Faeze Ghanati [2]

[1] Department of Biology, Faculty of Biological Science, North Branch, Islamic Azad University, Tehran, IRAN
[2] Department of plant Science, Faculty of Science, Tarbiat Modarres University, Tehran, IRAN
*Corresponding author: fatemeh_babaloo@yahoo.com

Abstract
Water is a diamagnetic molecule which can be affected by magnetic fields. Since water is the most important constitutive element of living cells, so all cellular biochemical reactions take place in water. Due to molecular characteristic of water, it is assumed that a part of these effects happened under magnetic field treatment. This study aimed to investigate the effects of magnetic water on some characteristics of growth and chemical constituent in rice (*Oryza sativa* L.). To this end rice seeds-paddy- were grown in rice fields as two experimental groups. A group of seeds were irrigated with normal water and in parallel the other group with magnetic water. Results revealed that in comparison to control plants, irrigating with magnetic water increases the growth parameters, photosynthetic pigments, Total carbohydrate and Total protein. Finally the magnetic water with intensity 110 mT-and the time taken to work on development and operation of the plants had positive effects.

Keywords: growth, magnetic water, Oryza sativa L., photosynthetic pigments, total carbohydrate, Total protein

Babaloo F, Majd A, Arbabian S, Sharifnia F, Ghanati F (2018) The Effect of Magnetized Water on Some Characteristics of Growth and Chemical Constituent in Rice (*Oryza sativa* L.)Var Hashemi. Eurasia J Biosci 12: 129-137.

INTRODUCTION

Water is the most important factor for plant growth. Attempts to increase food and energy production for satisfying growing needs, led the intensive development of plant production through the use of chemical additives, which in its turn caused more and more pollution of soil, water and air (Abdolmaleki et al. 2007). Irrigation with magnetic water (MW) increases seed germination (Constantin et al. 2003). The water treated by the magnetic field or pass through a magnetic device called magnetic water, when water is magnetic, some physical and chemical properties changed that may be causing changes in plant characteristics, growth and production. Grewal and Maheshwari (2000) showed magnetic treatment of seeds and irrigation had a potential to improve the early seedling growth and nutrient contents of seedlings. Utilization of magnetic water improved quantity and quality of common bean crop. It was detected that the magnetic field stimulated the shoot development and led to the increase of the germination energy and fresh weight, and shoot length of maize (Aladjadjiyan 2002). Some beneficial effects of the magnetic treatment of irrigating water for the plant yield and water productivity possibly suggested by Maheshwari and Grewal (2009). The understanding of the stimulating effect requires availability of rich experimental materials (Aladjadjiyan 2010). Recently, due to the less harmful influence on the environment; the use of physical methods for plant growth stimulation is getting more popular. Moreover, magnetic water for irrigation is recommended to save irrigating water (Mostafazadeh-Fard et al. 2011) According to Hozayn et al. (2011), experiments on wheat, they have suggested that comparing to unmagnified water, MW irrigation has increased some of the growth parameters, quantity, quality and chemical components of the plants.

Researchers have reported that 125 and 250 mT magnetic treatment produced a biostimulation on the initial growth stages and increased the germination rate of several seeds such as rice (Carbonell et al. 2000, Flórez et al. 2004), wheat (Martínez et al. 2002), and barley (Martínez et al. 2000). Yinan et al. (2005) published that the magnetic field pretreatment had a positive effect on cucumber seedlings, such as stimulating seedling growth and development. Hilal and Hilal (2000) reported that full wheat germination of 100%

Received: November 2017
Accepted: April 2018
Printed: July 2018

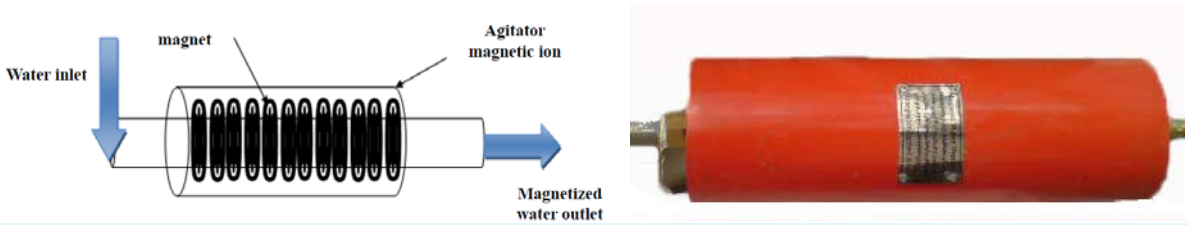

Fig. 1. Magnetic water generating device produced by Iranians technology & research Co

was obtained after 6 days for magnetic treatment compared to a rate of 83% after 9 days for normal practice. Hilal and Hilal (2000), working on tomatoes, pepper, cucumber and wheat seeds, and reported that there are an improvements in germination and seedling emergence when magnetically treated water and seeds were used. In particular, they observed that the germination of pepper seeds was higher with magnetically treated seeds compared to seeds with magnetically treated irrigation water. Cucumber seeds had the highest germination percentage when both irrigation water and seeds were magnetically treated. They also reported that tomato seeds responded more favorably to magnetically treated irrigation water than the magnetically treated seeds. Magnetized water treatment increases plant metabolism in terms of photosynthesis and water uptake (Yano et al. 2004). Chlorophyll is the most important pigment involved directly in the conversion of solar energy into chemical energy at the molecular level, thus chlorophyll content is an indicator of plant health and productivity. Chloroplast has paramagnetic properties which means that magnetic field of magnetic moments of atoms in them are affected by magnetic field and oriented downwards the field direction (Abdolmaleki et al. 2007). Magnetic fields have been reported to exert a positive effect on the germination of seeds (Alexander and Doijode 1995, Carbonell et al. 2000), plant growth and development (De Souza et al. 1999, Martínez et al. 2000), tree growth (Ruzic et al. 1998), the ripening of fruits and vegetables and crop yield (Pietruszewski 1993).

Therefore, the aim of the present article is to study the effects of magnetic water on some characteristics of growth and chemical constituent in rice (*Oryza sativa* L. Var. Hashemi).

MATERIALS AND METHODS

Magnetic water

To provide magnetic water, magnetic water generating device produced by Iranians technology & research Co. and the power of 110 mT field strength was supplied.

Rice seed samples were supplied by Gilan Agriculture Jihad Organization. Seed divided into two groups of samples from the control and treated samples were divided. All conditions of cultivation and harvesting, the samples were similar and only watered with tap water samples and control samples were treated with magnetic water.

Germination tests were performed under laboratory conditions with natural light and the average temperature of 24±2 ºC to study the effect of magnetized water on rice seed germination. After germination the rice seedlings were moved to the field. Random samples of rice harvested in late July 2015 were collected and transferred to the laboratory of Gilan Biotechnology Research Center for further analysis.

Growth parameters

The experiments conducted five times in complete randomization replicated design. Ten days after sowing, the length of roots and stems were measured by a ruler at the accuracy of 0.1 cm. 75 days after planting, leaf area index was measured by Graph paper (last leaf before the formation of clusters was selected to measure leaf area). 40 days after sowing, the biochemical analysis of rice plants were determined.

Photosynthetic pigments

Photosynthetic Pigments (chlorophyll a, chlorophyll b and carotenoids) of leaves were determined as the method described by Amon (1949).

An 80% acetone extract of a known F.W. of leaf was assayed Spectrometrically at 663, 645, 480 nm. The following equations were used to determine the concentration of the pigment fractions as mg/g $^{-1}$ FW.

Chlorophyll a = $(0.0127)(A_{663})- (0.00269)(A_{645})$

Chlorophyll b = $(0.0229)(A_{645})-(0.00468)(A_{663})$

Chlorophyll (a+b) = $(0.0202)(A_{645})+(0.00802)(A_{663})$

Carotenoids= $A_{480}+((0.114)(A_{663})-(0.638)(A_{645}))$

The pigment fractions were calculated as mg/g $^{-1}$ FW.

Organic components

Carbohydrate

Total carpohydrate was determined by the Dubois (1956) method. 0.1 gr of the treatments were corraded along with Na-Pi Buffer (pH:6.8); and 0.5 ml of the samples were pures inside a calorimetrice tube by the dimensions of 16-20 mm diameter. We added 0.5 ml phenol 5% *w/w* and 2.5 ml sulfuric acid 95.5%. The samples were kept lab for 10 min and after shaking in warm water bath by the temperature of 25-30˚C for 10-20 min. After taking out the tubes and cooling, the samples were read at 485 wave length. The standard drawings were calculated and done by using different

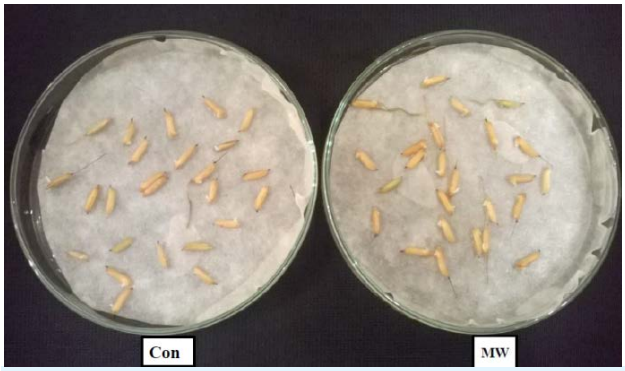

Fig. 2. Compare the percentage of germination of rice seeds, three days after culture treated with magnetized water (mT 110) (MW) and the control seeds (Con)

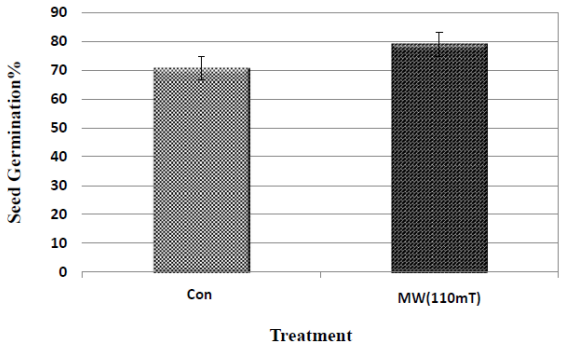

Fig. 3. Compared Seed germination of rice seedlings in control (Con) and treated with magnetized water (mT 110) (MW)

Golucose density of 0-30 µg/ml. The sugar rate of the sample was calculated base on µg/wet weight (Dubois et al. 1956).

Total protein content

Total protein content was determined by the Bradford (1976) method. The standard curve was developed using a solution of 0.5 mg ml bovine serum albumin (BSA) and a solution of 0.15 mM NaCl with spectrophotometry at 595 nm. The concentration of protein in the plant extract was calculated as per mg protein per g of fresh tissue (Bradford 1976).

Statistical analysis

Statistical analyses of data were performed with four independent replicates using Excel and SPSS and significant differences were determined via analysis of variance (ANOVA) and comparisons were tested with T test, $P \leq 0.05$.

RESULTS AND DISCUSSION

In this study, the results showed the positive effects of magnetic water on growth, photosynthetic pigments, total proteins and total carbohydrates of rice plants compared to control treatment.

Germination

Started sprouting in the treatment group (MW) and control (Con) was similar at the same time. But by continuing germination, germination percentage increased in the treatment group (MW) compared to the control. Results shows the comparison of the increase of 8.34% germination in plants treated with magnetized water.

Results are in agreement with the germination data of maize seeds obtained by Aladjadjiyan (2002) as well as Podleoeny et al. (2004) that marked the positive effect of magnetic treatment on the germination and emergence of two broad bean cultivars. These beneficial effects of magnetic treatment of several water types illustrated in the present study may be due to some alterations within plant systematic biochemical level and their possible effects at cell level and mainly due to increased water content. External electric and magnetic fields have been reported to influence both the activation of ions and polarization of dipoles in living cells (Moon and Chung 2000).

Growth criteria

The changes of growth characters (plant height) of rice plants irrigated with magnetic water are shown in **Figure 4**. Rice plants irrigated with magnetic water exhibited highly significant increases in plant height.

Measuring the length of root and stem of rice was made 10 days after planting. Results **Figure 4 (A,B)** indicates that the average length of roots and stems of the plants treated with magnetized water has increased compared to the control. (On average 1 cm root length and 2.4 cm stem length).

The level of rice leaf was done 75 days after planting. **Figure 4 (C)** Means comparison showed that the leaf area of rice plants treated with magnetized water an average of 102.67 mm^2 compared to control plants grown leaf.

In this study, the results showed the positive effects of magnetic water on growth, rice plants compared to control treatment. Magnetic water is considered one of several physical factors affects plant growth and its development. Results obtained in figure 4 showed that rice plants which irrigated with magnetic water grew taller than those irrigated with tap water. Our results are in agreement with those obtained by other researchers; Hilal and Hilal (2000) they reported that magnetized water has more tripled seedling emergence of wheat than tap water. Reina et al. (2002) found significance increase in the rate of water absorption accompanied with an increase in total mass of lettuce with the increase of magnetic force. Moreover, Nasher (2008) found that chick pea plants irrigated with magnetized water were taller than plants irrigated with tap water. Fomicheva et al. (1992) and Belyavskaya (2001) reported that magnetic water significantly induces cell metabolism and mitosis meristematic cells of pea, lentil and flax.

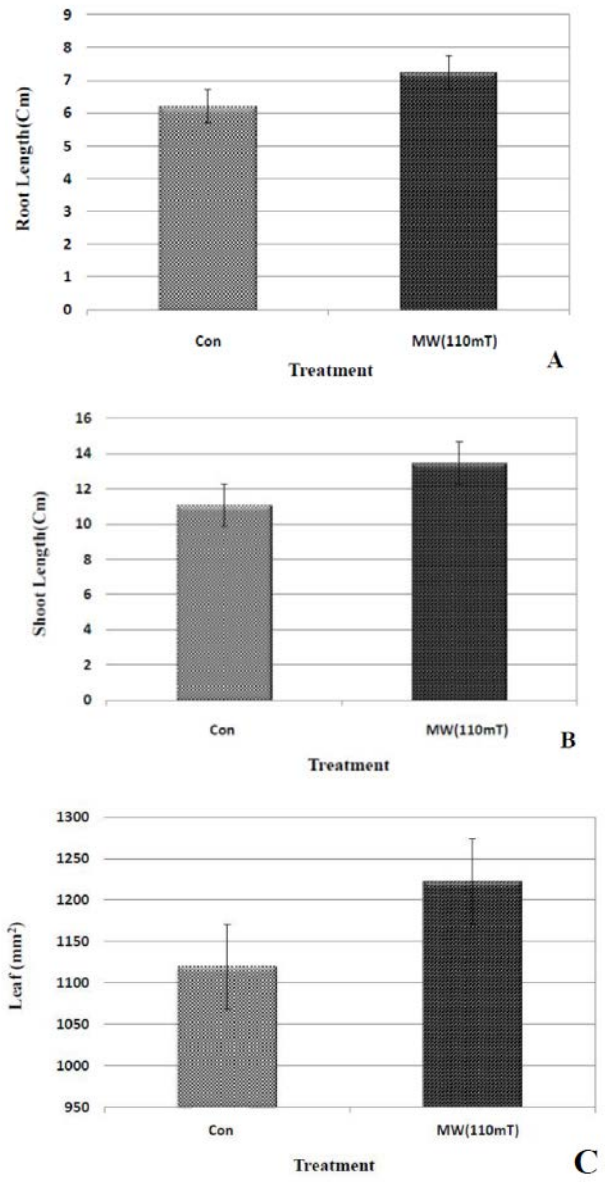

Fig. 4. Compare the roots (A) , shoot (B) and leaf area (C) of rice in the case of the control plants (Con) and treated with magnetized water (mT 110) (MW)

Also, Aladjadjiyan (2002) showed that exposure of *zea mays* seeds to magnetic water has a favorable effect on the development of shoots in the early stage. Atak et al. (2003) and Aycih and Alikamanoglu (2005) concluded that magnetic field increased the shoot and root regeneration rate and their fresh weight in soybean and paulownia organ cultures. Moreover, Celik et al. (2008) and Nasher (2008) concluded that, magnetized water increased growth and consider an important factor for inducing plant growth.

Photosynthetic pigments contents

The results in **Figure 5** show that magnetic water significantly increased all photosynthetic pigments (Chl a, Chl b, Chl a+b and Carotenoids) over the control. The increments reached to Chl a 0.008 (A), Chl b 0.002 (B), Chl a+b 0.012 (C) and Carotenoids 1.07 (D) (mgg^{-1} FW) in the above parameters, respectively.

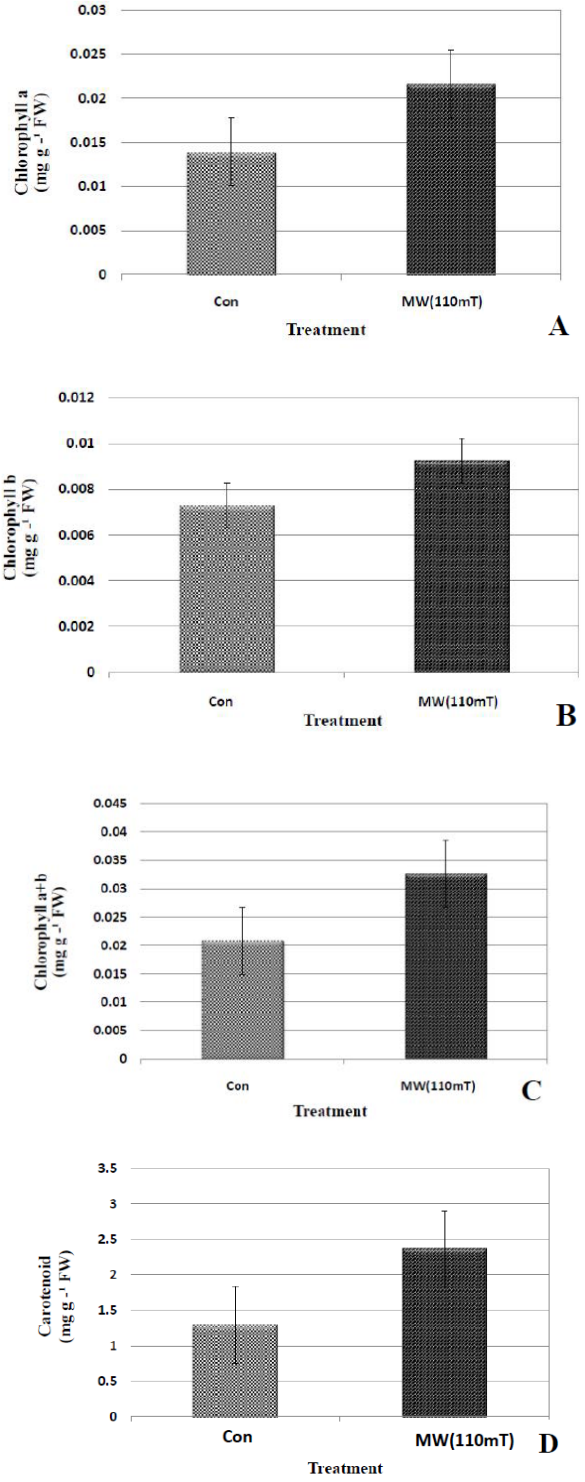

Fig. 5. Compare the amount of chlorophyll a (A), chlorophyll b (B), chlorophyll a+b (C) and carotenoids (D) in leaves of the control plants (Con) And treated with magnetized water (mT 110) (MW) in rice

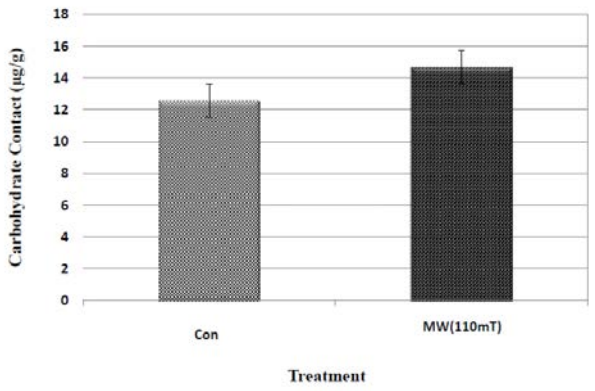

Fig. 6. Compare the total sugar in leaves of control (Con) and treated with magnetized water (mT 110) (MW)

Photosynthetic pigments content in fresh rice have shown an increase in response to irrigation with magnetic water. This increment may be attributed to increasing ions mobility and ions uptake improved under magnetic field (MF) which leads to a better photo stimulation in wheat plants (Pietruszewski 1999). Moreover, magnetic field has the ability to change water properties, thus magnetized water increased rice chlorophyll content (Tian et al. 1989) Several studies reported Similar results for different plants; (Rochalska 2005) found that magnetized field treatment increased the chlorophyll content in sugar beet (*Beta vulgaris* L.) leaves and content of chlorophyll a, b and carotenoids in potato (*Solanum tuberosum* L.) (Rakosy-Tican et al. 2005). Additionally, studies by Atak et al. (2003, 2007) involving MF impact on soybean (*Glycine max* L.) confirmed that MF significantly increased chlorophyll a, chlorophyll b and total chlorophyll contents .These results agreement with that of Atak et al. (2003), Constantin et al. (2003), Mihaela et al. (2007), Mihaela et al. (2009). They showed an increase in chlorophyll content and carotenoids content specifically appeared after treatment with magnetic water. Sadeghipour and Aghaei (2013) found that irrigation with magnetized water increased leaf area and specific leaf area in cowpea than that control, the enhancement in leaf area and specific leaf area in the plants irrigated with magnetic water must have increased photosynthetic rates due to the greater interception of light and the greater amount of assimilates available for vegetative growth. Similar results were found by De souza et al. (2006), Hoff (1981) and Davies (1996) also revealed an increase in photosynthetic rate and influx of water as a result of magnetic treatments.

Organic component

Total available carbohydrate

Results showed that the average total sugar content of the leaves of plants treated with magnetized water on average than the control sample increased 2.06 (µg/g).

In these investigation, irrigated rice plant with magnetic water increased significantly total available carbohydrates contents compared to irrigated with tap water as shown in figure 6. The increasing significantly in carbohydrates because of the close relationship between stomatal conductance and photosynthesis, thus lead to an increase in photosynthesis. The effects of magnetic exposure on plant growth still require proper explanation. They may be the result of bioenergetics structural excitement causing cell pumping and enzymatic stimulation (De Souza et al. 2006).

Total protein contents

Total protein

The analyses indicate a significant difference in total protein level ($p<0.05$). Comparing the means show that the higher protein level belonged to MW (0.9315) and the lower mean refers to Con (0.8025).

Results presented in **Figure 7** indicated that the magnetic water irrigation exhibited marked significant increase in total protein at plant of rice compared with control plants. Moreover, the protein contents increasing in rice plants irrigated with magnetic water more than irrigated with tap water may be responsible for the stimulation of growth. The increasing of protein contents in plants irrigated with magnetic water was accompanied with increasing growth promoters (IAA). In this respect, Kuba and Kakimoto (2000) found that IAA effect on DNA replication. Moreover, Celik et al. (2008) and Shabrangi and Majd (2009) reported that magnetic field is known as an environmental factor which affects on gene expression. Therefore, by augmentation of biological reactions like protein synthesis of rice and its components were increased significantly under magnetic irrigation. These results are logical to improvement growth parameters and growth promoters (IAA) and photosynthetic pigments. The remarkable improvement induced by the magnetic treatment was consistent with the results of other studies on other crops like cereal, sunflower, flax, pea, wheat, pepper, tomato, soybean, potato and sugar beet, in these studies the crop yield were increased (Atak et al. 1997, Crnobarac et al. 2002, Gubbels 1982, Marinkovic et al. 2002, Namba et al. 1995, Oldaçay and Erdem 2002, Özalpan et al. 1999, Pietruszowski 1993, Pittman 1972, Pietruszewski 1999, Reina et al. 2001, Takac et al. 2002, Vakharia et al. 1991, Yurttas et al. 1999). It could be concluded from this study that, broad bean irrigation with magnetic water could effectively increase growth parameters, yield and some chemical constituents. Magnetic water is considered one of several physical factors affects plant growth and its development. Results obtained showed that broad bean plants which irrigated with magnetic water grew taller and heavier than those irrigated with tap water. This results are in line with Hozayn and Abdul Qados (2010). In this respect, Celik et al. (2008) found that the increase in the percentage of

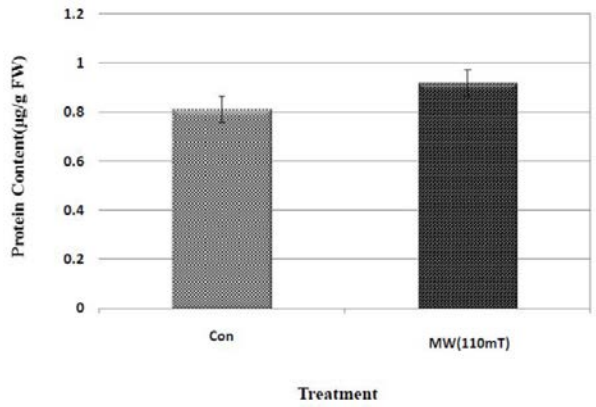

Fig. 7. The effect of Magnetic water on total protein content in leaves of the control plants (Con) And treated with magnetized water (mT 110) (MW) in rice

plant regeneration is due to the effect of magnetic field on cell division and protein synthesis in paulownia node cultures. Shabrangi and Majd (2009) concluded that, biomass increasing needs metabolic changes particularly increasing protein biosynthesis. It was found out that chloroplasts have paramagnetic properties (Campbell 1977). The stimulatory effect of the application of magnetic water on the growth parameters reported in this study may be attributed to the increase in photosynthetic pigments, endogenous promoters (IAA); increase protein biosynthesis. Abdul Qados and Hozayn (2010) findings the stimulatory impact of magnetic water may be also ascribed to the increasing of stomatal conductance and root growth which increase absorption and assimilation of nutrients. In this connection, Formicheva et al. (1992) and Belyavskaya (2001) reported that magnetic water significantly induces cell metabolism and mitosis meristematic cells of pea, lentil and flax. Moreover, the formation of new protein bands in plants treated with magnetic water may be responsible for the stimulation of all growth, and promoters in treated plants. In this respect, Celik et al. (2008) found that the increase in the percentage of plant regeneration is due to the effect of magnetic field on cell division and protein synthesis in paulownia node cultures. Shabrangi and Majd (2009) concluded that, biomass increasing needs metabolic changes particularly increasing protein biosynthesis. The stimulatory effect of magnetized water on growth parameters may be attributed to the induction of cell metabolism and mitosis (Abdul Qados and Hozayn 2010). Also, these results agreement with those obtained by Renia et al. (2001) who found significance increase in rate of water absorption accompanied with an increase in total mass of lettuce with increase of magnetic force.

In summary, growth parameter and yield components of rice plants is concomitantly increased when rice plants irrigated with magnetic water increasing photosynthetic pigments; total protein and carbohydrate.

CONCLUSION

Results of the current study showed the positive impacts of magnetic water on root, stem and leaves growth of rice as well as water relations than that the control. The stimulatory effect of magnetic water on the growth in this research may be due to the increase in root growth and stomatal conductance. So as a simple and safe method, irrigation with magnetic water can be used to improvement plant growth and water used efficiency. It appears that utilization of magnetic water can led to improve quantity and quality of rice (*Oryza sativa* L.). It suggests that magnetic water could stimulate defense system, photosynthetic activity, and translocation efficiency of photo-assimilates in rice plants. Generally, using magnetic water treatment could be a promising technique for agricultural improvements but extensive research is required on different crops.

REFERENCES

Abdolmaleki P, Ghanati F, Sahebjamei H, SabetSarvestani A (2007) Peroxidase activity, lignification and promotion of cell death in tobacco cells exposed to static magnetic field. The Environmentalist 27:435–440. https://doi.org/10.1007/s10669-007-9080-1

Aladjadjiyan A (2002) Study of the Influence of Magnetic Field on Some Biological Characteristics of Zea mais. J. of Central Europ. Agric. 3(2):89-94.

Aladjadjiyan A (2010) Influence of stationary magnetic field on lentil seeds. International Agrophysics 24:321-324.

Aladjadjiyan A (2012) Physical factors for plant growth stimulation improve food quality, food production-approaches, challenges and tasks, Anna Aladjadjiyan (Ed.), ISBN: 978-953- 307-887-8, In Tech Publisher, Rijeka, Croatia, 270 p.

Alexande MP, Doijode SD (1995) Electromagnetic field, a novel tool to increase germination and seedling vigour of conserved onion (Allium cepa L.) and rice (Oryza sativa L.) seeds with low viability. Plant Genetic Resources Newsletter 104:1-5.

Amon OJ (1949) Copper enzyme in isolated chloroplast, polyphenol oxidase in Beta Vulgaris. Plant physiology 24:1-15. https://doi.org/10.1104/pp.24.1.1

Atak C, Celik O, Olgun A, Alikamanolu S, Rzakoulieva A (2007) Effect of magnetic field on peroxidase activities of soybean tissue culture. Biotechnology 21:166-71. https://doi.org/10.1080/13102818.2007.10817438

Atak C, Danilov V, Yurttas B, Yalç›n S, Mutlu D, Rzakoulieva A (1997) Effects of magnetic field on soybean (Glycine max L.Merrill) seeds. Com JINR. Dubna:1-13.

Atak C, Emiroglu O, Aklimanoglu S, Rzakoulieva A (2003) Stimulation of regeneration by magnetic field in soybean (Glycine max L. Merrill) tissue cultures. J Cell Mol. Biol. 2:113–119.

Aycih O, Alikamanoğlu S (2005) The effect of magnetic field on Paulownia tissue cultures Plant Cell. Tissue and Organ Culture 83(1):1109-1114.

Belyavskaya NA (2001) Ultrastructure and calcium balance in meristem cells of pea roots exposed to extremely low magnetic field. Adv Space Res. 28(4):645-650. https://doi.org/10.1016/S0273-1177(01)00373-8

Bradford MM (1976) Arapid sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein – dye binding. Analytical Biochemistry 72:248–254. https://doi.org/10.1016/0003-2697(76)90527-3

Campbell GS (1977) An introduction to environmental biophysics. Springer-Verlag, N.Y., USA. https://doi.org/10.1007/978-1-4684-9917-9

Carbonell MV, Martínez E, Amaya JM (2000) Stimulation of Germination in Rice (Oryza sativa L.) by a Static Magnetic Field. J. Electro. Magnetic Biology 19(1):121-128.

Çelik Ö, Atak Ç, Rzakulieva A (2008) Stimulation of rapid regeneration by a magnetic field in paulownia node cultures. J. of Central Europ. Agric. 9(2):297–303.

Constantin V, Lucia P, Daniela AL (2003) The influence of the magnetic fluids on some physiological processes in Phaseolus vulgaris. Rev. Roum. Biol. Veget. 48(1–2):9–15.

Crnobarc J, Marinkovic B, Tatic M, Malesevic M (2002) The effect of REIS on startup growth and seed yield of sunflower and soybean. Biophysics in agriculture production, University of Novi Sad, Tampograf.

Davies MS (1996) Effects of 60 Hz electromagnetic fields on early growth in three plant species and a replication of previous results. Bioelectromagnetics 17:154-161. https://doi.org/10.1002/(SICI)1521-186X(1996)17:2<154::AID-BEM10>3.0.CO;2-S

De Souza A, Casate R, Porras E (1999) Effect of magnetic treatment of tomato seeds (Lycopersicon esculentum Mill.) On germination and seedling growth [in Spanish]. Invest Agr: Prod. Prot. Veg. 14(3):67-74.

De Souza A, Garcia D, Sueiro L, Gilart F, Porras E, Licea L (2006) Pre-sowing magnetic treatments of tomato seeds increase the growth and yield of plants. Bioelectromagnetics 27:247-257. https://doi.org/10.1002/bem.20206

Dubois M, Mirick DK, Stevens RG (1956) Residential magnetic fields and the risk of breast cancer. Am J Epidemiol. 155:446-54.

Flórez M, Carbonell M V, Martínez E (2004) Early Sprouting and First Stages of Growth of Rice Seeds Exposed to a Magnetic Field. J. Electro. Magnetobiol. 19:271-277. https://doi.org/10.1081/LEBM-200042316

Formicheva VM, Govorun RD, Danilov VT (1992) Proliferative activity and cell reproduction in the root meristem of pea, lentil and flax in the conditions of screening the geomagnetic field. Int. Biophysics. 37:645-648.

Grewal HS, Maheshwari BL (2011) Magnetic treatment of irrigation water and snow pea and chickpea seeds enhances early growth and nutrient contents of seedlings. Bioelectromagnetics 32:58-65. https://doi.org/10.1002/bem.20615

Gubbels GH (1982) Seedling growth and yield response of flax, buckwheat, sunflower and field pea after preseeding magnetic treatment. Can. J. Plant Sci. 62:61-64. https://doi.org/10.4141/cjps82-009

Hilal MH, Hillal MM (2000) Application of magnetic technologies in desert agriculture .1- Seed germination and seedling emergence of some crop in a saline calcareous soil. Egypt J. Soil Sci. 40(3):413-421.

Hoff AJ (1981) Magnetic field effects on photosynthetic reactions. Quarterly Reviews of Biophysics 14(4):599-665. https://doi.org/10.1017/S0033583500002481

Hozayn M, Abdel-Monem AA, Abdul Qados AMS, Abd El-Hameed HM (2011) Response of some food crops for irrigation with magnetized water under green house condition. Australian journal of Basic and Applied Science 5(12):29-36.

Hozayn M, Abdul Qados AMS (2010) Magnetic water technology, a novel tool to increase growth, yield and chemical constituents of lentil under greenhouse condition. American-Eurasian Journal of Agriculture and Environmental Sciences 7(4):457-462.

Hozayn M, Abdul Qados AMS (2010) Response of growth, yield, yield components and some chemical constituents of flax for irrigation with magnetized and tap water. World Applied Science Journal 8(5):630-634.

Ijaz B, Jatoi SA, Ahmad D, Masood MS, Siddiqui S (2012) Changes in germination behavior of wheat seeds exposed to magnetic field and magnetically structured water. African Journal of Biotechnology 11(15):3575-3582.

Kuba M, Kakimoto T (2000) The cytokinin hyposensitive genes of Arabidopsis negatively regulate the cytokinin signalling pathway for cell division and chloroplast development. The Plant J. 23(1):385-394. https://doi.org/10.1046/j.1365-313x.2000.00796.x

Maheshwari BL, Grewal HS (2009) Magnetic treatment of irrigation water: Its effects on vegetable crop yield and water productivity. Agricultural Water Management 96, 1229-1236. https://doi.org/10.1016/j.agwat.2009.03.016

Marinkovic B, Ilin Z, Marinkovic J, Culibrk M, Jacimovic G (2002) Potato yield in function variable electromagnetic field. Biophysics in agriculture production. University of Novi Sad, Tomograf.

Martinez E, Carbonell MV, Amaya JM (2000) Stimulation on the Initial Stages on Growth of Barley (Hordeum vulgare L.) by 125 mT Stationary Magnetic Field. J. Electro. Magnetic Biol. 19(3):271-277. https://doi.org/10.1081/JBC-100102118

Martínez E, Carbonell MV, Flórez M (2002) Magnetic Biostimulation of Initial Growth Stages of Wheat (Triticum aestivum L.). J. Electromagnet Biol. Medicine 21(1):43-53. https://doi.org/10.1081/JBC-120003110

Mihaela R, Dorina C, Carmen A (2007) Biochemical changes induced by low frequency magnetic field exposure of vegetal organisms. Rom. J. Phys. 52(5–7):645–651.

Mihaela R, Simona M, Dorina EC (2009) The response of plant tissues to magnetic fluid and electromagnetic exposure. Romanian J. Biophys. 19(1):73–82.

Moon J, Chung H (2000) Acceleration of Germination of Tomato Seeds by Applying AC Electric and Magnetic Fields. J. Electrostat. 48:103-114. https://doi.org/10.1016/S0304-3886(99)00054-6

Mostafazadeh-Fard B, Khoshravesh M, Mousavi S, Kiani A (2011) Effects of magnetized water and irrigation water salinity on soil moisture distribution in trickle irrigation. Journal of Irrigation and Drainage Engineering 137(6):398-402. https://doi.org/10.1061/(ASCE)IR.1943-4774.0000304

Namba K, Sasao A, Shibusawa S (1995) Effect of magnetic field on germination and plant growth. Acta Horticulture 399:143-147. https://doi.org/10.17660/ActaHortic.1995.399.15

Nasher SH (2008) The Effect of magnetic water on growth of chick-pea seeds. Eng. & Tech. 26(9).

Oldacay S, Erdem G (2002) Evaluation of chlorophyll contents and peroxides activities in I (Helianthus annuus L.) genotypes exposed to radiation and magnetic field. Pak. J. of Appl. Sci. 2(10):934-937. https://doi.org/10.3923/jas.2002.934.937

Özalpan A, Atak C, Yurttas B, Alikamanoglu S, Canbolat Y, Borucu H, Danilov V, Rzakoulieva A (1999) Effect of magnetic field on soybean yield (Glycine max L. Merrill). Turkish Association of Biophysics, XI National Biophysics Congress, Abstract Book, pp: 60.

Pietruszewski ST (1999) Effect of alternating magnetic field on germination, growth and yield of plant seeds. Int. Agrophysics 5(11):209-215.

Pietruszewski ST (1999) Influence of presowing magnetic biostimulation on germination and yield of wheat. Int. Agrophysics 13:241-244.

Pietruszweski S (1993) Effects of magnetic seed treatment on yields of wheat," Seed Sci. Techol. 21:621-626.

Pittman UJ (1972) Biomagnetic responses in potatoes. Can J Plant Sci. 52:727-733. https://doi.org/10.4141/cjps72-119

Podlesny J, Pietruszewski S, Podleoena A (2004) Efficiency of the magnetic treatment of broad bean seeds cultivated under experimental plot conditions. Int. Agrophysics 18:65-71.

Rakosy-Tican L, Aurori CM, Morariu VV (2005) Influence of near null magnetic field on in vitro growth of potato and wild Solanum species. Bioelectromagnetics 26: 548–557. https://doi.org/10.1002/bem.20134

Renia FG, Pascual LA, Fundora IA (2001) Influence of a Stationary Magnetic Field on water relations in lettuce Seeds. Part II: Experimental Results. Bioelectromagnetics 22:596-602. https://doi.org/10.1002/bem.89

Rochalska M (2005) Influence of frequent magnetic field on chlorophyll content in leaves of sugar beet plants. Nukleonika 50:25-8.

Ruzic R, Jerman I, Gogala N (1998) Water stress reveals effects of ELF magnetic fields on the growth of seedlings. Electro- and Magnetobiology 17:17-30. https://doi.org/10.3109/15368379809012884

Sadeghipour O, Aghaei P (2013) Improving the growth of cowpea (Vigna unguiculata L. Walp.) by magnetized water. Journal of Bio. & Env. Sci. 3(1):37-43.

Shabrangi A, Majd A (2009) Effect of magnetic fields on growth and antioxidant systems in agricultural plants. PIERS Proceedings, Beijing, China, March 23-27.

Takac A, Gvozdenovic G, Marinkovic B (2002) Effect of resonant impulse electromagnetic stimulation on yield of tomato and pepper. Biophysics in agriculture production, University of Novi Sad, Tampograf.

Tian WX, Kuang YL, Mei ZP (1989) Effect of magnetic water on seed germination, seedling growth and grain yield of rice. J Jilin Agric Univ. 11:11-6.

Vakharia DN, Davariya RL, Parameswaran M (1991) Influence of magnetic treatment on groundnut yield and attributes. Indian J. Plant Physiol. XXXIV:131-136.

Yano A, Ohashi Y, Hirasaki T, Fujiwara K (2004) Effects of 60 Hz magnetic field on photosynthetic uptake and early growth of radish seedlings. Bioelectromagnetics 25(8):572-581. https://doi.org/10.1002/bem.20036

Yinan L, Yuan L, Yongquing Y, Chunyang L (2005) Effect of Seed Pretreatment by Magnetic Field on the Sensitivity of Cucumber (Cucumis sativus) Seedlings to Ultraviolet-B Radiation. J. Environ. Experim. Botany. 54:286-294. https://doi.org/10.1016/j.envexpbot.2004.09.006

Yurttas B, Atak C, Gökdoan G, Canbolat Y, Danilov V, Rzakoulieva A (1999) Detection of the positive effect of magnetic field on sunflower plants (Helianthus annuus L.). Turkish Association of Biophysics, XI National Biophysics Congress, Abstract Book, pp: 59.