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Effect of Mineral and Organic Fertilization Rates under Magnetized Water Irrigation on Growth, Yield, and Quality of Crisphead Lettuce

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TO SOLVE rising fertilizer costs and preserve environment from pollution in addition decrease mineral fertilization with using organic fertilizers on leafy vegetables that used in salad, a field experiment was done to investigate the impact of irrigation treatments (magnetized water and normal water) and different rates of N and vermicompost fertilizers (100% N, 75% N + 25% vermicompost, 50% N + 50% vermicompost, 25% N + 75% vermicompost and 100% vermicompost) on crisphead lettuce growth and quality. The results cleared that irrigation with magnetized water gave the highest values of vegetative growth, ion concentrations, yield and quality. Furthermore, crisphead lettuce fertilized with 50% N + 50% vermicompost exhibited the highest vegetative growth, yield, chlorophyll contents and Mg percentage, while plants fertilized with 75% N + 25% vermicompost gave the highest quality of crisphead plants. Thus, it is recommended that irrigate crisphead lettuce with magnetized water and fertilized plants with 50% N + 50% vermicompost. This treatment can help decrease production costs by 50% with high yield.

Keywords: Criphead lettuce, magnetized water, N recommended doses, vermicompost.

1. Introduction

Crisphead lettuce (*Lactuca sativa* L.) one of family Asteraceae members, that affluent source of vitamins, folate (Kim *et al.,* 2016), antioxidants and anti- carcinogenic. It supplies fat in small amount, several dietary fibre, It contains high amount of water, that makes it a hydrating food, and it is commonly utilized in salad.

Irrigation with magnetized water enhanced plant growth (Abd El-Hady and Doklega, 2018), productivity and quality. Therefore, magnetized water could be one of the most promising methods for increasing agricultural production as an eco-friendly strategy (Silva and Dobranzki, 2014), save irrigation water (Mostafazadeh-Fard *et al.,* 2011), and decrease mineral fertilization (Dawa et al., 2019 and Abd El-Hady et al., 2023).

In traditional practise, chemical fertilizer is used in cropping systems with high-value crops because it provides nutrients. The continual and indiscriminate application of chemical fertilizers results in yield instability and endangers the health of the soil, especially when it comes to environmental pollution caused by fertilizers and micronutrient deficiencies. The increased use of chemical fertilizers and intensified cropping are making organic fertilizers important for maintaining soil productivity. Consequently, there has been trend towards of using organic vegetables without dangerous artificial chemicals (Doklega and Abd El-Hady, 2017).

Decreasing nitrogen fertilizer can be a potential process to agriculture which benefits environment and plant production. However, it is substantial to balance decreases of N fertilizer and sufficient plant nutrition and yield (Seadh et al., 2021 and Farouk *et al.,* 2023). There are more researches are needed to decrease nitrogen fertilizer, that is used in high amounts and caused reduction in quality. N fertilizer has effect on plant growth and productivity and plays substantial functions in several biochemical and physiological operations in plants (Baddour and Sakara, 2021). It is a component of numerous enzymes, and chlorophyll that is crucial to the photosynthetic processes in plants. It plays major function in various metabolic reactions and a

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structural constituent of cell walls (Marschner, 2012). El- Bassyouni (2016) cleared that lettuce plant growth, yield, vitamin C percentage were increasing in addition decreasing nitrate content with enhancing levels of N fertilizer. Nowadays, various studies have been done to resolve this problem by using organic fertilization like vermicompost.

Vermicompost ameliorates plant growth and it is efficient used in agriculture. It improves healthy and productivity of plants, also regulate plants development through supplying with humic acid and hormones. As well as, it participates in soil fertility with raise microbial activity (Arancon and Edwards, 2005). Durak *et al.* (2017) showed that vermicompost increased lettuce plant growth and yield compared to control. It has positive effect on soil physical, chemical and biological attributes (Tejada *et al.*, 2006). Using organic and inorganic fertilizers enhance growth and productivity; moreover, it can enhance the competence of the usage of these fertilizers to reduce production costs (Chatterjee, 2008). Application of Vermicompost combined with Nfertilization gave significant influence on head lettuce yield and quality (Doklega and Imryed, 2020).

Therefore, this study aims to investigate the impact of irrigation with magnetized water, different doses of N and vermicompost fertilizers on crisphead lettuce growth, yield, and quality. The objective is to speed up plant growth while at the same time decreasing costs and environmental pollution.

2. Materials and Methods

A field experiment was done at an experimental farm of Agriculture, Mansoura university, El-Dakahlia governorate, in two winter seasons: 2020/2021 and 2021/2022. The study aimed to investigate the impact of irrigation treatments (magnetized water and normal water), different doses of N and vermicompost fertilizers (100% N, 75% N + 25% vermicompost, 50% N + 50% vermicompost, 25% N + 75% vermicompost and 100% vermicompost) on crisphead lettuce growth, yield, and quality. The experimental design was a strip-plot design with three replicates, where irrigation water treatments was assigned in the vertical plots and fertilization rates to the horizontal plots.

Crisphead lettuce seedlings were transplanted on 12 and 15 December in 2020/2021 and 2021/2022 seasons, respectively. Seedlings were transplanted on ridges (at intervals of 40 cm) 0.7m width and 9m length, thus plot area was 12.6 m^2, consist of 2 ridges.

A random sample of the soil experiment was taken to evaluate its physical and chemical properties (Table 1).

Irrigation with magnetized water was done bypassing it through an electromagnetic field generator (1 inch in diameter) that was provided by Delta Water Company. The magnetic induction used for this process ranged from 100 to 150 mT.

Table 1. Physical and chemical properties of experimental soil.

Seasons	Particle size distribution (%)				Texture class	OM (%)	SP, %	EC dS m^{-1} 1:5	pH (1:2.5)	Available nutrient (mg kg^{-1} soil)		
	Coarse Sand	Fine Sand	Silt	Clay						N	P	K
1st	2.4	22.5	39.4	35.7	Loamy	1.23	2.24	1.12	7.77	44.1	5.87	308
2nd	3.4	24.3	42.7	29.6	Loamy	1.33	2.41	1.23	7.63	45.5	6.77	311

SP: Saturation percentage OM: Organic matter

Recommended dose of N fertilizer was added at dose 155 kg N ha^{-1} as ammonium sulphate (20.5 % N) in two equal doses, first one after 3 weeks from transplanting, while the second addition was added after 3 weeks from the first one. The Egyptian Ministry of Agriculture's recommendations were all followed.

During soil preparation calcium super phosphate 6.8 P was added at 715 kg ha^{-1}, while potassium sulphate (48% K) at 240 kg ha^{-1} was added with N fertilizer.

Vermicompost was added during soil preparation and calculated the percentage of amount based on N%, the chemical analysis of vermicompost was 1.21, 2.01, and 1.24% of N, P and K, respectively, organic matter 29.94, organic carbon 19.83 and C/N ratio 1:15.

The following data were recorded:

1. After 100 days from transplanting, ten plants were randomly taken (5 from each ridge) to measure vegetative growth and yield: leaf area (m^2), number of outer leaves, plant fresh weight (kg/plant), head weight (kg), and total yield (ton ha^{-1}).
2. Pigments content: Chlorophyll a, b, and a+b (mg/g Fw) were determined according to Lichtenthaler and Wellburn (1985).
3. Chemical contents: N, P and K % were determined in dry samples as described by A.O.A.C. (2012).
4. Head quality:

a) Total sugars % was estimated according to Malik and Srivastava (1979).
b) Total dissolved solids (TDS) %: was determined by using a refractometer based on A.O.A.C. (2012).
c) Vitamin C (mg/100 g Fw): was determined with the 2, 6-dichlorophenol indophenol method according to A.O.A.C. (2012).
d) Magnesium (Mg) percentage: was estimated according to Jackson (1967).

Statistical analysis:

The analysis of variance (ANOVA) was performed on the data using the Gomez and Gomez (1984) approach. To compare the means of various treatments, the Duncan Multiple Range Test was used (Duncan, 1955).

3. Results

1. Vegetative growth and yield were improved with irrigation treatments and fertilization rate

The results in Table 2 demonstrate the effect of irrigation treatments and fertilization rate on vegetative growth and yield (leaf area, number of outer leaves, fresh weight, head weight and total yield). The results cleared that irrigation with magnetized water gave the highest vegetative characters and increased total yield by 17.23 and 18 % in the first and second seasons, respectively compared to irrigation with normal water.

Concerning the impact of fertilization rates, the data in the same table clear that fertilized crisphead lettuce with 50% N +50% vermicompost gave the highest values of vegetative growth and yield, except for leaf area in the first season. However, the fertilization with 100 % N gave the maximum values of leaf area in the first season only. There were no significant variations noticed between 100% N and 50% N +50% vermicompost in number of outer leaves.

Table 2. Vegetative growth and yield in crisphead lettuce as affected by irrigation treatments and fertilization rate.

Treatments	Leaf area (m^2)		No. of outer leaves/plant		Fresh weight (g)		Head weight (kg)		Total yield (t ha^{-1})	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Irrigation treatments										
Magnetized water	2.06 a	2.07 a	9.4 a	9.7 a	1.06 a	1.08 a	1.20 a	1.22 a	42.87 a	43.72 a
Normal water	2.00 b	1.96 b	8.1 b	8.5 b	0.81 b	0.88 b	1.02 b	1.04 b	36.57 b	37.05 b
B- Fertilization rate										
100 % N	2.09 a	2.06 b	10.0 a	10.0 ab	1.04 b	1.04 b	1.17 c	1.18 c	41.83 c	42.04 c
75% N + 25% vermicompost	2.04 c	2.05 c	9.2 b	9. 5 b	1.04 b	1.06 b	1.22 b	1.26 b	43.73 b	44.94 b
50% N +50% vermicompost	2.08 b	2.08 a	9.8 a	10.2 a	1.08 a	1.13 a	1.26 a	1.28 a	45.07 a	45.79 a
25% N +75% vermicompost	2.00 d	1.95 d	7.8 c	8.3 c	0.80 c	0.87 c	1.06 d	1.08 d	37.87 d	38.43 d
100% vermicompost	1.90 e	1.92 e	6.8 d	7.3 d	0.73 d	0.80 d	0.84 e	0.86 e	30.11 e	30.72 e

Concerning the interaction influence between irrigation treatments and fertilization rates, figure 1 and 2 show that irrigation with magnetized water and fertilized with 50% N +50% vermicompost gave the maximum vegetative growth and yield followed by 75% N +25% vermicompost in the first and second season.

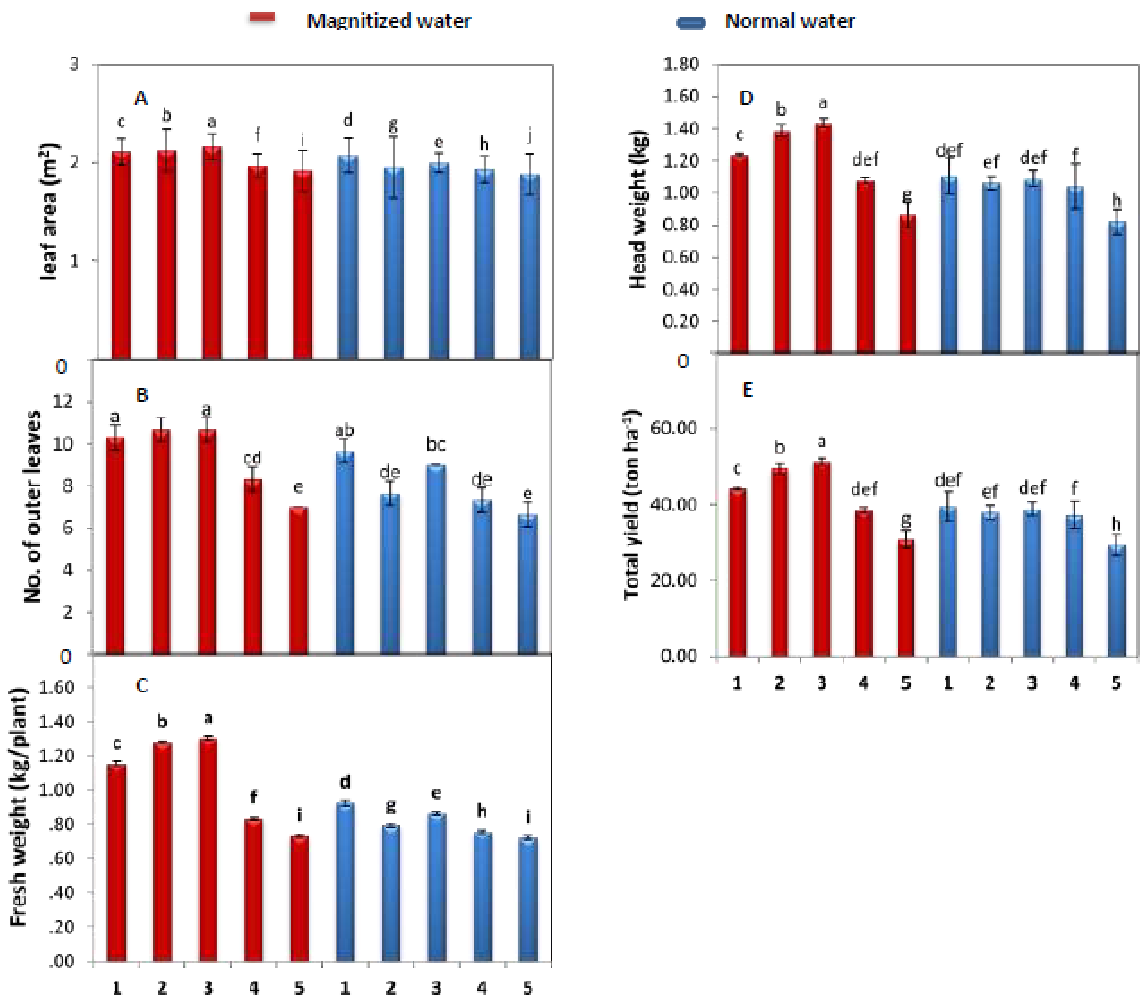

Fig. 1. Effect of irrigation treatments and fertilization rate on vegetative growth and yield of crisphead lettuce in the first season. 1:100%N, 2: 75% N + 25% vermicompost, 3: 50% N + 50% vermicompost, 4: 25% N + 75% vermicompost, 5: 100% vermicompost. Different letters clear significant variation between treatments according to Duncan test ($p \leq 0.05$).

2. Pigments content were improved with irrigation treatments and fertilization rate

The results displayed in Table 3 show the effect irrigation treatments and fertilization rate on chlorophyll contents, and cleared that irrigate crisphead lettuce with magnetized water significantly increased chlorophyll a, chlorophyll b, and chlorophyll a+b contents compared to irrigation with normal water. Regarding the effect of fertilization rate, results in the same table clear that fertilized crisphead lettuce with 50% N +50% vermicompost gave the maximum chlorophyll contents in the first and second seasons, followed by 100% N fertilization.

The results in Figure 3 and 4 demonstrate that irrigation with magnetized water and fertilized with 50% N +50% vermicompost gave the highest chlorophyll contents, further, there were no significant differences observed between fertilized with 50% N +50% vermicompost and fertilized fertilized with 75% N +25% vermicompost under irrigation with magnetized water in the first season.

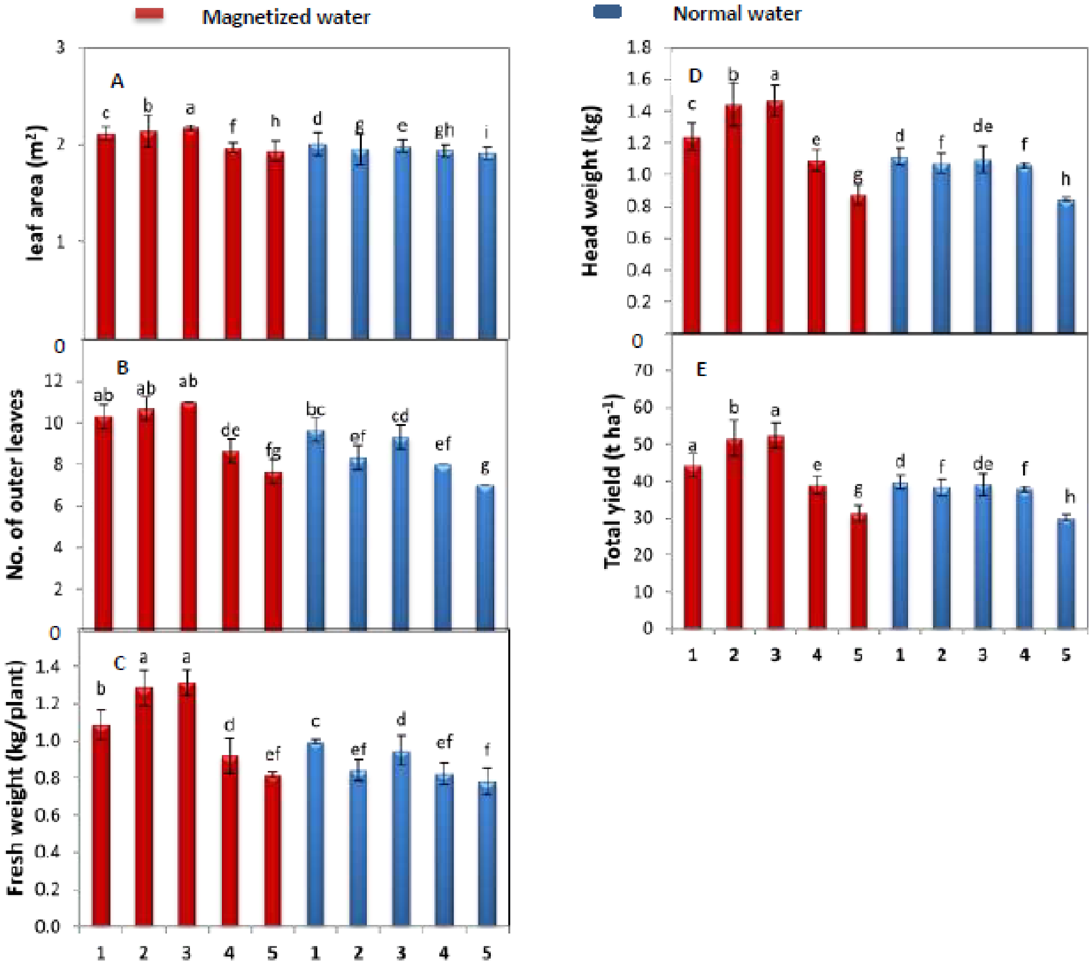

Fig. 2. Effect of irrigation treatments and fertilization rate on vegetative growth and yield of crisphead lettuce in the second season. 1:100%N, 2: 75% N + 25% vermicompost, 3: 50% N + 50% vermicompost, 4: 25% N + 75% vermicompost, 5: 100% vermicompost. Different letters clear significant variation between treatments according to Duncan test ($p \leq 0.05$).

Table 3. Chlorophyll contents in crisphead lettuce as affected by irrigation treatments and fertilization rate.

Treatments	Chlorophyll a ($mg\ g^{-1}FW$)		Chlorophyll b ($mg\ g^{-1}\ FW$)		Total Chlorophyll ($mg\ g^{-1}\ FW$)	
	1st	2nd	1st	2nd	1st	2nd
A- Irrigation treatments:						
Magnetized water	0.622 a	0.645 a	0.397 a	0.409 a	1.019 a	1.053 a
Normal water	0.582 b	0.603 b	0.352 b	0.366 b	0.935 b	0.969 b
B- Fertilization rate:						
100 % N	0.627 b	0.654 b	0.397 b	0.416 b	1.024 b	1.070 b
75% N + 25% vermicompost	0.614 c	0.640 c	0.401 ab	0.404 c	1.014 c	1.044 c
50% N +50% vermicompost	0.638 a	0.661 a	0.404 a	0.426 a	1.042 a	1.087 a
25% N +75% vermicompost	0.579 d	0.598 d	0.347 c	0.358 d	0.926 d	0.957 d
100% vermicompost	0.553 e	0.565 e	0.325 d	0.333 e	0.878 e	0.899 e

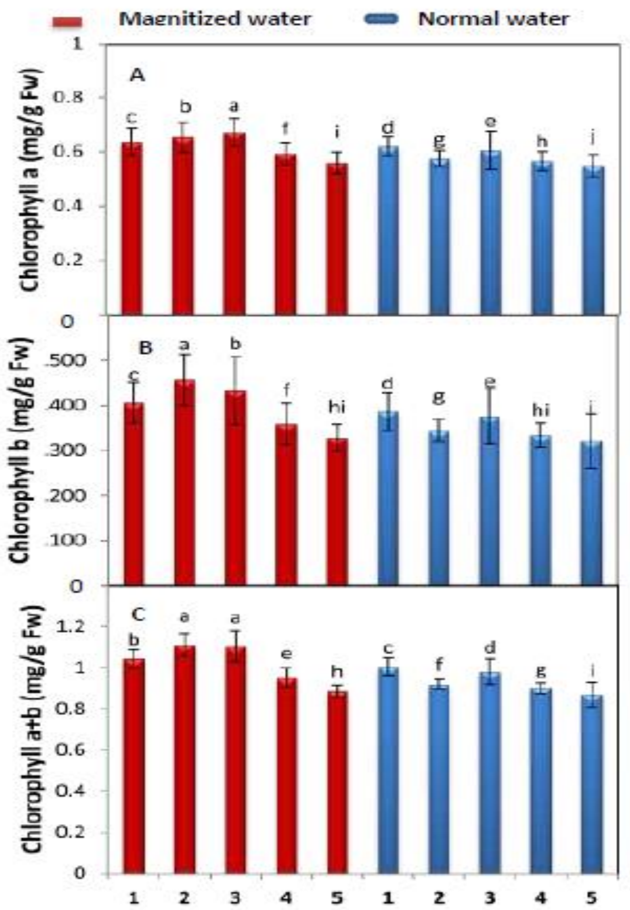

Fig. 3. Effect of irrigation treatments and fertilization rate on chlorophyll contents of crisphead lettuce in the first season. 1:100%N, 2: 75% N + 25% vermicompost, 3: 50% N + 50% vermicompost, 4: 25% N + 75% vermicompost, 5: 100% vermicompost. Different letters clear significant variation between treatments according to Duncan test (p ≤ 0.05).

Table 4. Ion percentage in crisphead lettuce as affected by irrigation treatments and fertilization rate.

Treatments	N (%)		P (%)		K (%)		Mg (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Irrigation treatments								
Magnetized water	2.43 a	2.54 a	0.218 a	0.232 a	2.59 a	2.68 a	1.30 a	1.33 a
Normal water	2.11 b	2.21 b	0.200 b	0.208 b	2.38 b	2.43 b	1.13 b	1.17 b
B- Fertilization rate								
100 % N	2.47 a	2.65 a	0.221 a	0.240 a	2.68 a	2.79 a	1.31 b	1.36 b
75% N + 25% vermicompost	2.51 a	2.67 a	0.223 a	0.239 a	2.66 b	2.76 b	1.27 c	1.30 c
50% N +50% vermicompost	2.41 b	2.48 b	0.222 a	0.233 b	2.60 c	2.67 c	1.38 a	1.41 a
25% N +75% vermicompost	2.07 c	2.17 c	0.201 b	0.205 c	2.34 d	2.38 d	1.12 d	1.16 d
100% vermicompost	1.89 d	1.92 d	0.179 c	0.184 d	2.14 e	2.18 e	0.99 e	1.00 e

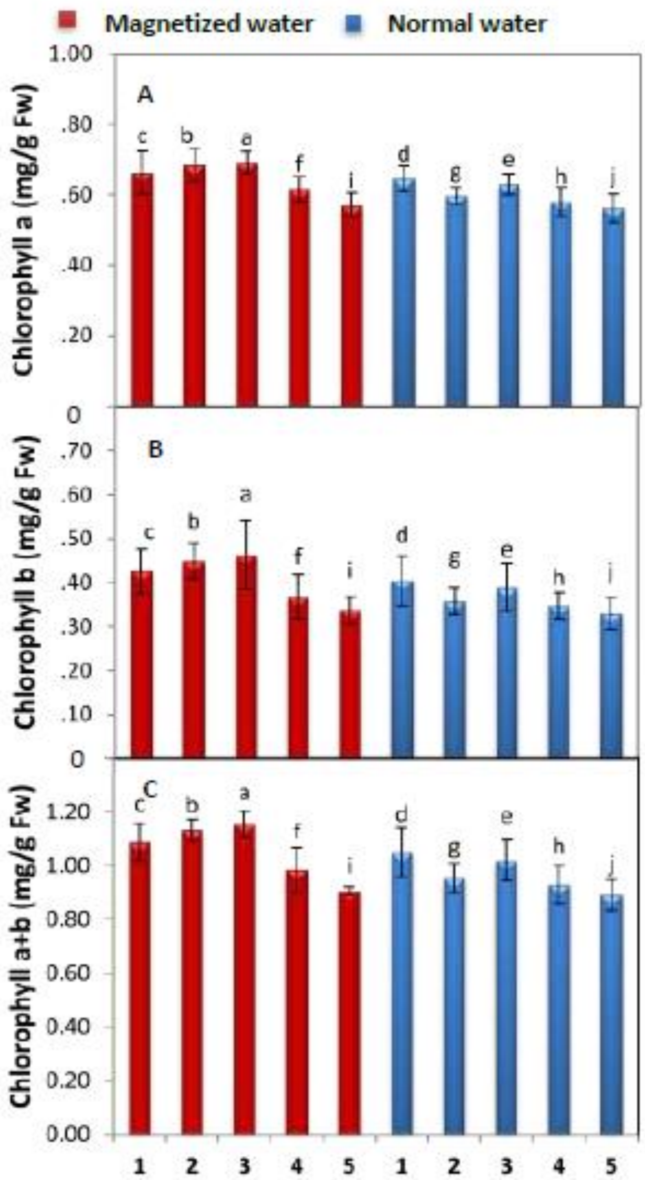

Fig. 4. Effect of irrigation treatments and fertilization rate on chlorophyll contents of crisphead lettuce in the second season. 1:100%N, 2: 75% N + 25% vermicompost, 3: 50% N + 50% vermicompost, 4: 25% N + 75% vermicompost, 5: 100% vermicompost. Different letters clear significant variation between treatments according to Duncan test ($p \leq 0.05$).

3. Chemical contents were improved with irrigation treatments and fertilization rate

Data presented in Table 4 clear that irrigation crisphead lettuce with magnetized water had a significant positive effect on the chemical percentage of N, P, K and Mg compared to irrigation with normal water. Furthermore, there were no significant variations noticed between 100 % N and 75% N + 25% vermicompost and the two treatments gave the maximum percentage of N and P, meanwhile, fertilization with 100 % N gave the highest percentage of K followed by fertilization with 75% N + 25% vermicompost. On the other side, fertilized with 50% N +50% vermicompost gave the maximum values of Mg percentage, followed by 100 % N treatments.Concerning the interaction impact between irrigation treatments and fertilization rates results in Figures 5 and 6 irrigation crisphead lettuce with magnetized water and fertilized with 50% N + 50% vermicompost gave the maximum percentage of N, P, K and Mg in both seasons, followed by irrigation with magnetized water and fertilized with 75% N + 25% vermicompost.

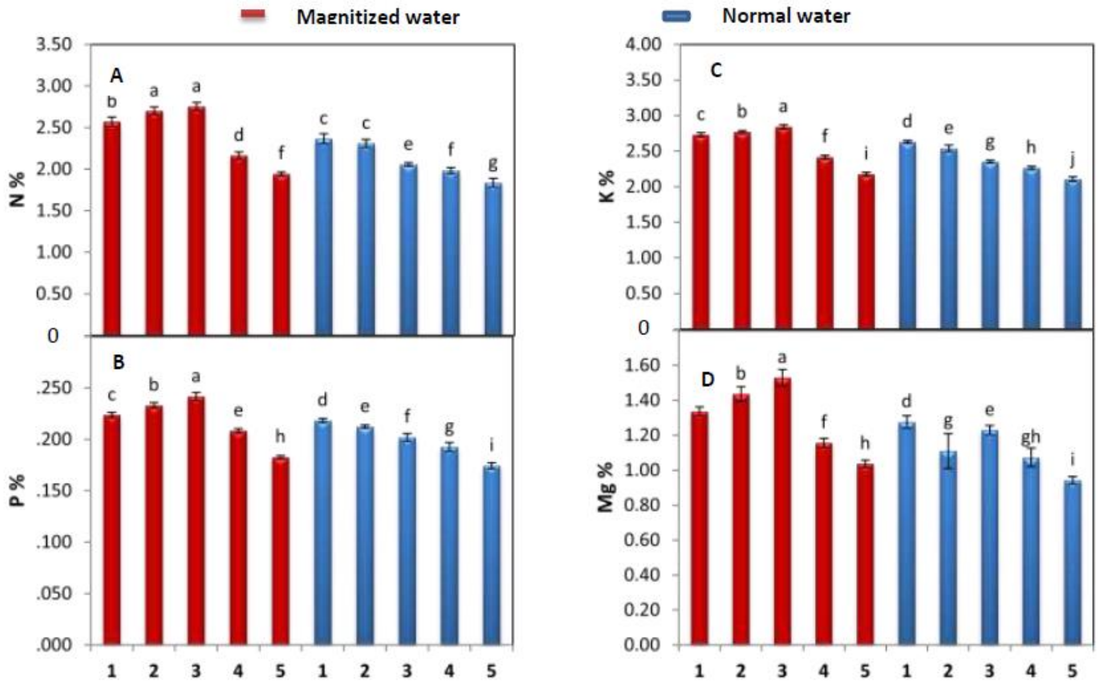

Fig. 5. Effect of irrigation treatments and fertilization rate on chemical contents of crisphead lettuce in the first season. 1:100%N, 2: 75% N + 25% vermicompost, 3: 50% N + 50% vermicompost, 4: 25% N + 75% vermicompost, 5: 100% vermicompost. Different letters clear significant variation between treatments according to Duncan test (p ≤ 0.05).

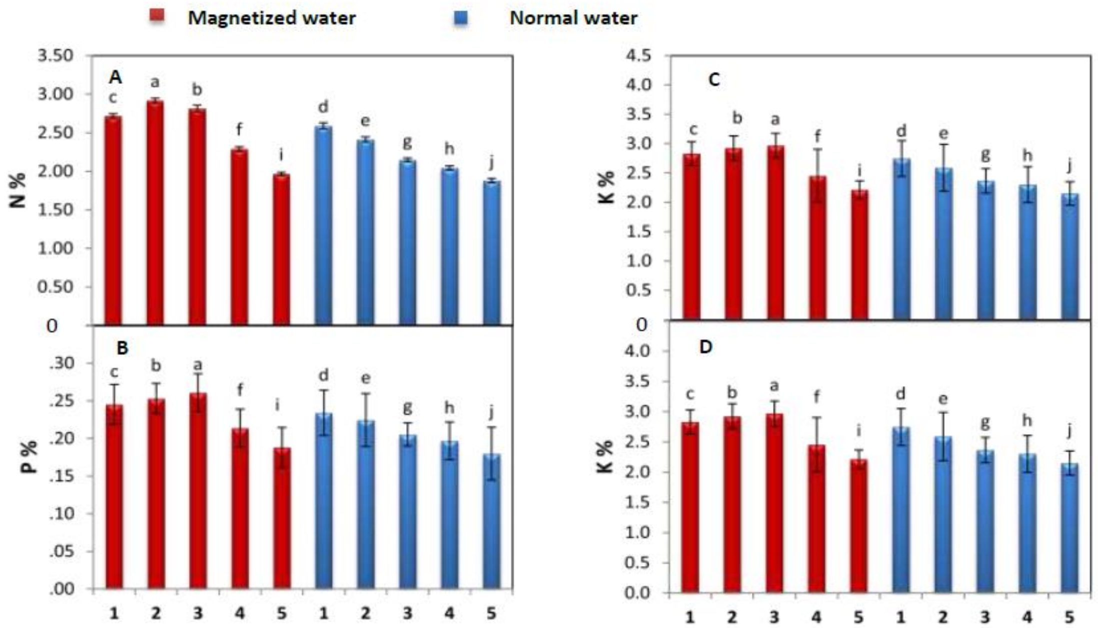

Fig. 6. Effect of irrigation treatments and fertilization rate on chemical contents of crisphead lettuce in the second season. 1:100%N, 2: 75% N + 25% vermicompost, 3: 50% N + 50% vermicompost, 4: 25% N + 75% vermicompost, 5: 100% vermicompost. Different letters clear significant variation between treatments according to Duncan test (p ≤ 0.05).

4. Head quality were improved with irrigation treatments and fertilization rate

Data presented in Table 5 demonstrate that irrigation with magnetized water significantly enhanced the head quality (total sugars, TSS and vitamin C) of crisphead lettuce in both seasons. Moreover, the same table show that fertilization rates had a significant influence on head quality. The maximum quality contents were obtained from crisphead lettuce fertilized with 100 % N and 75% N + 25% vermicompost without any significant differences between the two treatments, except total sugars contents in the second season only, while plants fertilized with 50% N +50% vermicompost came in the third order.

Concerning the interaction effect between irrigation treatments and fertilization rates, the results in Figures 7 and 8 clear that irrigation with magnetized water and fertilizing with 50% N +50% vermicompost gave the maximum values of total sugars, TSS and vitamin C in crisphead lettuce, these results were obtained in both seasons.

Table 5. Quality contents in crisphead lettuce as affected by irrigation treatments and fertilization rate.

Treatments	Total sugars (%)		Total dissolved solids %		Vitamin C (mg 100g-1Fw)	
	1st	2nd	1st	2nd	1st	2nd
A- Irrigation treatments						
Magnetized water	1.59 a	1.65 a	4.82 a	4.82 a	9.39 a	10.20 a
Normal water	1.30 b	1.38 b	4.39 b	4.36 b	8.84 b	9.76 b
B- Fertilization rate						
100 % N	1.65 a	1.74 a	4.96 a	4.89 a	9.51 a	10.37 a
75% N + 25% vermicompost	1.64 a	1.71 b	4.97 a	4.88 a	9.53 a	10.33 a
50% N +50% vermicompost	1.60 b	1.66 c	4.83 b	4.85 a	9.45 b	10.22 b
25% N +75% vermicompost	1.29 c	1.34 d	4.33 c	4.28 b	8.78 c	9.68 c
100% vermicompost	1.07 d	1.13 e	3.93 d	4.05 c	8.31 d	9.29 d

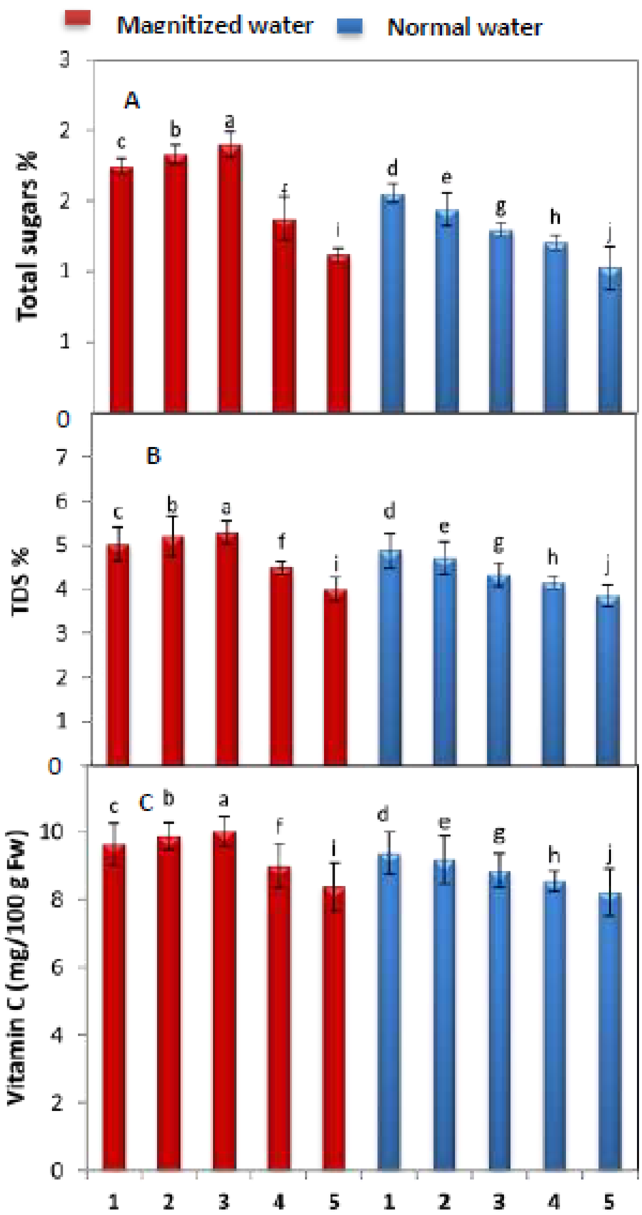

Fig. 7. Effect of irrigation treatments and fertilization rate on head quality of crisphead lettuce in the first season. . 1:100%N, 2: 75% N + 25% vermicompost, 3: 50% N + 50% vermicompost, 4: 25% N + 75% vermicompost, 5: 100% vermicompost. Different letters clear significant variation between treatments according to Duncan test ($p \leq 0.05$).

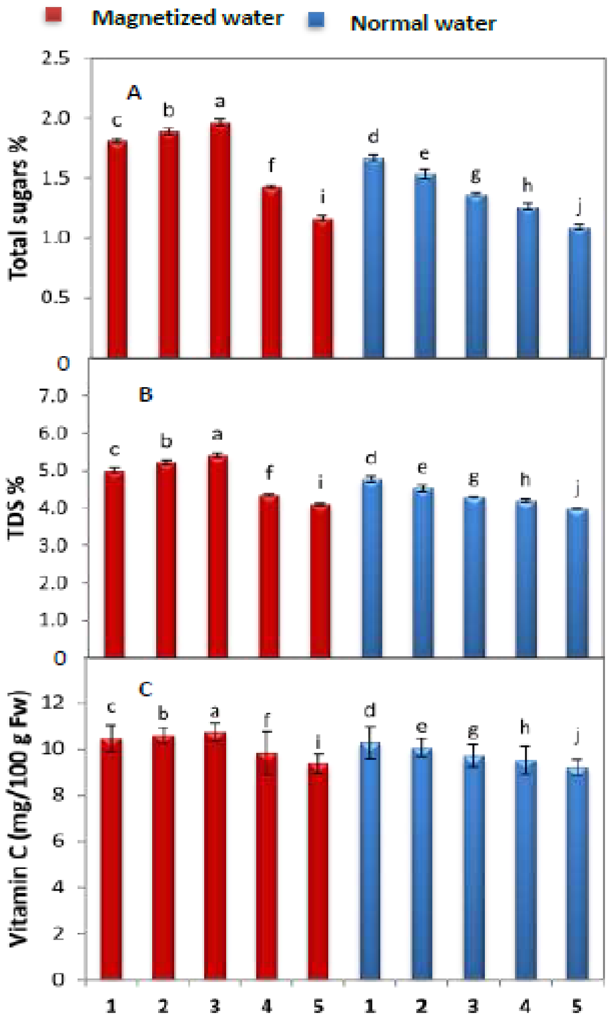

Fig. 8. Effect of irrigation treatments and fertilization rate on head quality of crisphead lettuce in the second season. . 1:100%N, 2: 75% N + 25% vermicompost, 3: 50% N + 50% vermicompost, 4: 25% N + 75% vermicompost, 5: 100% vermicompost. Different letters clear significant variation between treatments according to Duncan test ($p \leq 0.05$).

Discussion

Results of this study declared that irrigation with magnetized water significantly affected on vegetative growth of crisphead lettuce (*Lactuca sativa* L.) plants such as No. of outer leaves/plant, and fresh weight. The previous results may be due the effect of magnetized water on biochemical chances or altered enzyme activity such a heading stage (Dhawi, and Khayri (2009), increasing plant growth regulator leading to induce Phenylalanine Ammonia-Lyrase during cell differentiation (Abobatta, 2015) or induction of mitosis and cell metabolism (Amera and Hozayn, 2010) and magnetized water properties (Cai *et al.*, 2009). The stimulatory impact of magnetized water on vegetative growth may be due to enhance total count of bacteria which enhance soil fertility, improving soil characters, motivate root growth in early stage which lead to better root system that reflect on plant growth (Dawa *et al.*, 2019).

Results also show that magnetized water significantly impacted in plant chlorophyll content of crisphead lettuce which significantly increased compared to irrigation with normal water. These results may be regarded to the effect of magnetized water on plant light harvest from chloroplasts and magnetized water chemical composition (Abobatta, 2019). The favourable impact of magnetized water on chlorophyll contents may be due to enhance Mg percentage as shown in (Table 4) that plays important role in enhancing chlorophyll contents, that Mg is the central atom in the chlorophyll molecular and has important role in the promotion of various plant enzymes needed for growth and contributes to protein synthesis (Dawa et al., 2019). These results are agree with Atak *et al.* (2007), they found that chlorophyll a, chlorophyll b and total chlorophyll contents increased 21%, 13% and 18%, respectively in all magnetic treatment relative to control treatment.

On the other side magnetized water significantly increased total yield and head weight, these results may regarded to improvement of magnetized water on the plant growth parameter and chlorophyll content (Radhakrishnan and Kumari, 2013), increasing ions availability and uptake which reflected on enzymes activity and photosynthesis stimulation (Dhawi and Khayri, 2009). Results are in the same line with Imriad (2017), who found that irrigation head lettuce with magnetized water increased head weight and total yield.

Nitrogen fertilizer is one of the importance nutrients for plant which play a vital role in plant growth, protein synthesis and plant production. Nowadays farmers adding a large amount of nitrogen fertilizers (over dose) lading to nitrogen accumulation in plant and effect on human healthy and losing nitrogen by leaching from the soils leading to environment pollution. Reducing the amount of nitrogen fertilizers by using organic fertilizers such as compost or vermicompost which provide plant with nutrient, hormones, humic acids, improving soil structure (Tejada *et al.,* 2006), soil ph nutrient availability and soil fertility (Arancon and Edwards, 2005) causing increasing production, low costs, preserve environment and good human healthy (Frasetya *et al.,* 2019). So, reducing nitrogen fertilizers by adding vermicompost as shown in the previous results significantly impact lettuce plant growth parameters and the best results were recorded at the treatment of 50% N + 50 % vermcompost in both seasons except leaf area in the first season. This result may be due to vermicompost effects on saving nutrient and increasing nutrients availability and reducing nutrient losses which lead to increase photosynthesis and vegetative plant growth. Similar findings by Merajipoor *et al.* (2020), who found that the combination between vermcompost and nitrogen fertilizers favors more nutrients uptake and nutrient use efficiency. This results are in compatibility with those obtained by Farid et al. (2023), El-Naqma et al. (2023), El-Sherpiny et al. (2023), Awad et al. (2022).

Beside results shows that chlorophyll content also took the same trend where the treatment of 50 % nitrogen + 50% vermicompost gave the better results of chlorophyll a, b and a+b compared with the control treatment. These results may regarded to occur multiple sources of nitrogen in that treatment where there is a mineral and amino acid form, adding to its availability to plant which affected directly on chlorophyll content in lettuce plant.

In the same way total yield and head weight of lettuce plant increased and recorded the better result at the treatment of 50 % nitrogen + 50% virmicompost. The results may due to the balance in nitrogen form and its availability to plant which reflected in growth parameters and chlorophyll content then plant production. These results are in the same line with (Doklega and Imryed, 2020).

The treatment of 50 % nitrogen + 50% vermicompost and irrigation with magnetized water recorded the best results in both seasons. Result may due to the interaction between nitrogen effects and magnetized water effect on plant which reduced the mineral amount of nitrogen and reduce the loses amount so the costs reduce and the environment saved (Abd El-Hady *et al.,* 2023). Moreover, the treatment of 50 % nitrogen + 50% vermicompost irrigated with magnetized water gave the highest nutrients content (N, P, and K %). These results may due to vermicompost effect on increasing nutrient availability by reducing soil ph, improving soil structure, microorganisms activists and its content of nutrients on the other side the role magnetized water on increasing ions mobility and uptake surface tension and improved oxygen content so mineral nutrients more available for plants (Nasher, 2008). Esitken and Turan (2004) found that increasing magnetic field increasing contents of N, Mg, K, and Fe but reduced P content.

Conclusion

Current results clear that irrigation with magnetized water and fertilized with 50% N +50% vermicompost, followed by irrigation with magnetized water and fertilized with 75% N +25% vermicompost, thus using magnetized water could decrease N fertilization and reduce production costs and preserve environment from pollution. However, more researches are needed to show the effect of magnetized water on physiological and anatomical characters of plants.

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