https://doi.org/10.17221/1/2020-RAE

# Influence of magnetised irrigation water on the fertigation process and potato productivity

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**Citation:** Mostafa H. (2020): Influence of magnetised irrigation water on the fertigation process and potato productivity. Res. Agr. Eng., 66: 43–51.

**Abstract:** An experiment was conducted for two seasons on a farm in the Mit Kenana village, Qalyobia, Egypt. The aim was to study the influence of a magnetised water technology on the fertilisers during irrigation (fertigation) and its impact on the water, soil as well as the yield and yield components for potatoes. The experiment included: Normal water (NM), magnetic water (MW), adding fertiliser before (FMW) and after magnetism (MWF). The results indicated that irrigation with magnetised water and then adding fertiliser (MWF) had a positive significant effect on the water and soil properties, the tuber engineering parameters improved and the potato productivity increased by 40.5% higher than the NM method.

The fertigation unit has to be installed after the magnetic device because the direct magnetisation of the water with the fertilisers contributes to the cracking and increases the solubility of the fertilisers that may lead to the possibility of leaching some of them away from the roots, which implies losing some of them and, therefore, decreasing the effectiveness of the fertilisers.

**Keywords:** magnetisation technology; fertilisers; soil properties; plant production

Efficient water use allows for the use of more arable land and to produce agricultural crops. Therefore, the adoption of modern methods and means of irrigation with high efficiencies is very important and necessary to increase the production and provide adequate food. Fertilisation with irrigation is an important means to rationalise the fertilisers usage because they are characterised by a high overall efficiency and a lack of fertiliser and water losses (Mostafa, Derbala 2013; Mostafa 2014).

The agrarian water input per unit area should be diminished in light of water shortage at the moment, expanding rivalry from different sectors of water use and other ecological concerns (Mostafa, Thormann 2013; Surendran et al. 2016a).

Magnetised water is understood as water flowing through magnets and, hence, the degree of the water treatment magnetically depends on three factors (Ahmed 2009): the quantity of the fluid within the magnetic tool, the strength of the magnet used for this purpose and the duration of the treatment. A magnetic water treatment works by positively controlling the negative-negative charges to strengthen the water properties which is useful in improving the industrial cooling and the performance of power generation (Wang et al. 2018). When water molecules are positioned during a magnetic flux, the hydrogen bonds between the molecules either change or disintegrate and reduce the adhesion angle to only 105 ° (Hilal et al. 2002; Ghernaout 2018), which decreases the union range between the molecules and, thus, absorbs the energy. Among them, the electrolysis increases the susceptibility and affects the crystal decomposition. Magnetised water results in large crystals being broken down into small crystals, easily passing through the roots of the pores of plants and soils (Chibowski 2018; Hachicha et al. 2018). Therefore,

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the quantity of salts within the water is the same as the amount is not less, but not harmful, as the plant must take everything that it needs to grow, and, therefore, the rest of the salt crystals and other useless components are also easily leached from the soil (Bogatin 1999; Hassani et al. 2015).

Irrigation with magnetic water (MW) improved the growth characteristics of peppers and tomatoes (number of leaves, plant height, and leaf area) as reported by Selim et al. (2009) and Ahmed et al. (2013). Snap bean vegetative growth characteristics were improved after irrigation with MW (Midan, Tantawy 2013; Fatahallah et al. 2014).

Irrigation with MW increased the kinetin content, which plays an important role in root and shoot formation, and the induced genes involved in the chloroplast development (Hozayn, Abdul Qados 2010) on chick peas and (Fatahallah et al. 2014) beans may be attributed to its positive role on the nutrients' assimilation and absorption, and consequently increasing the plant growth characteristics. Irrigation with MW has led to the improved surface tension, hydrogen bonding, conductivity, pH and solubility of salts in the soil. The chlorophyll contents (photosynthetic pigments) of the lentil (Amir et al. 2010) and the common bean (Moussa 2011) induced a significant increase compared to the control treatment.

The MW treatment increased the yield (10–15%), the root formation, the transfer of phosphorus fertilisers into a more soluble form and reduced the soil salinification (Bogatin et al. 1999). They also reported that the magnetic treatment improved the conditions of the root layers due to the leaching of the salts, the better permeability of the irrigated water and, the better dissociation of the fertilisers.

The magnetic field has a significant effect on the concentrations of magnesium and calcium which occurred more in the magnetic treatment compared to non-magnetic treatment (Ashrafi et al. 2012). A decrease in the physical analyses of the irrigation water values was indicated while, the values of the chemical analyses increased with the increasing magnetic field levels (Abdel-Aziz et al. 2017; Chibowski 2018). Meanwhile, non-significant cation values were observed at different magnetic field levels (Hachicha et al. 2018; Wang et al. 2018).

As magnetic water moves through the soil, it leads to positive charges in the chemical and physical properties, i.e., reduces the soil electrical conductivity (EC) and pH; improves the soil permeability, quickens the water movement to dissolve the soil salts, entails the better assimilation of the nutrients which become available for the plant uptake (Grewal, Maheshwari 2011; Mohamed, Baseem 2013).

Because of the impact of the magnetic field on the water and soil salts, it may cause a serious problem with using fertilisers with irrigation water (fertigation). Therefore, the main aim is to study the effect of the magnetisation process of the water on the fertilisation, whether the addition before or after the magnetisation process has a higher or lower effect on the water and soil properties as well as the potato productivity.

## MATERIAL AND METHODS

An experiment was conducted on farm in the Mit Kenana village, Qalyobia, Egypt during the 2017–2018 and 2018–2019 seasons to measure influence of magnetised irrigation on the fertigation process and potato productivity. The region is characterised by being arid with a total of 22 mm rainfall and a medium temperature (19 ± 5 °C), humidity and evaporation per year. The physical and chemical properties of the water and soil are shown in Tables 1–3.

A permanent magnet with a magnetic strength of 0.16 T (Tesla) was used in this study to magnetise the

Table 1. Chemical analysis of the water at the experimental site

| pH | EC ($dS \cdot m^{-1}$)* | Soluble cations ($mmol \cdot L^{-1}$) | | | | Soluble anions ($mmol \cdot L^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $Cl^{-}$ | $CO_3^{=}$ | $HCO^{3-}$ | $SO_4^{=}$ |
| 7.51 | 1.51 | 4.8 | 3.7 | 6.1 | 0.34 | 4.6 | 0.00 | 5.0 | 6.0 |

*$dS \cdot m^{-1}$= 640 ppm; EC – electrical conductivity

Table 2. Chemical analysis of the soil

| Depth (cm) | pH | EC ($dS \cdot m^{-1}$) | Soluble cations ($mmol \cdot L^{-1}$) | | | Soluble anions ($mmol \cdot 3L^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $Cl^{-}$ | $CO_3^{=}$ | $HCO^{3-}$ | $SO_4^{=}$ |
| 0–60 | 7.81 | 0.99 | 2.10 | 2.40 | 4.22 | 0.40 | 4 | 0.00 | 1.9 | 5.6 |

*$dS \cdot m^{-1}$= 640 ppm; EC – electrical conductivity

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Table 3. Physical analysis of the soil

| Depth (cm) | Sand (%) | Silt (%) | Clay (%) | Textural Class |
|---|---|---|---|---|
| 0–60 | 81.5 % | 13.5 % | 5 % | Sand |

irrigation water. The magnetic tool (Figure 1) (40 cm long) consists of an inner metal tube (25 mm diameter) and an outer stainless-steel tube (52 mm in diameter). The magnets are distributed between the two tubes and placed in two rows (upper and lower) where the south pole of the magnet is directed into the inner tube in the upper row, and vice versa in the lower row where the north poles are directed to the inner tube. This arrangement makes the direction of the current vertical with the passage level of the water (Ahmed 2009). The tool could be easily installed through the pipe network (Figure 2).

The irrigation system was constructed according to standard procedures (Figure 2). Laterals of 16 mm in diameter with built-in drippers (4 $L \cdot h^{-1} \cdot 30\ cm^{-1}$ spacing) and 75 cm between the lines were used. The control valves were installed at the inlet of each treatment to control the flow of the water. One bar pressure was maintained using a 0.75 kW pump. All the network pipes were made of polyethylene and there were thirteen irrigations with an irrigation interval of 8 days. The quantity of the applied water was based on the soil moisture deficit up to the field capacity to a depth of 60 cm shortly before each irrigation event. The soil water content was measured before the irrigations by gravimetric moisture, which was determined by calculating the proportion of the water loss relative to the dry soil weight after oven-drying the soil samples.

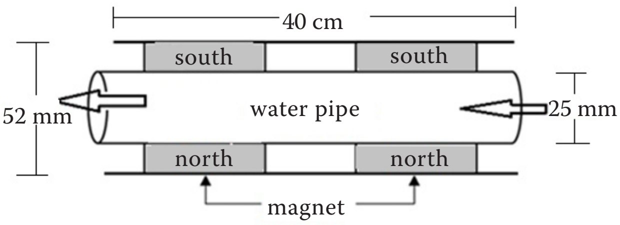


Figure 1. The magnetisation tool

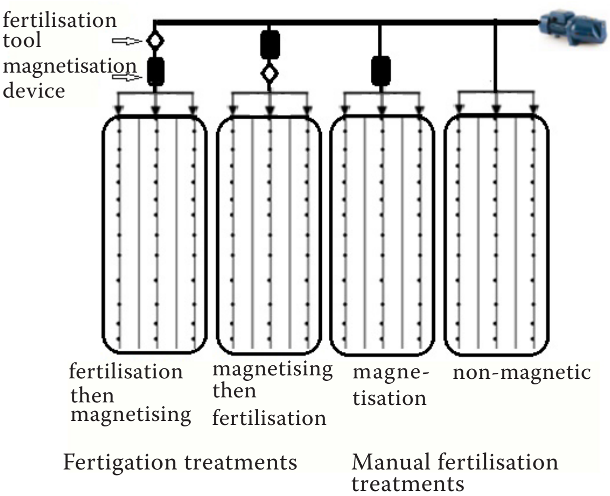


Figure 2. Experimental layout

The experiment was designed as four treatments (Figure 2): (*i*) The first treatment (NM): used normal water (non-magnetic) and the fertilisers were added manually to the plants on the soil. (*ii*) The second treatment (MW): used magnetised water and the fertilisers was manually added to the plants on the soil. (*iii*) The third treatment (Adding the fertiliser to the water after the magnetisation – MWF): the water first passes through the magnetisation tool and then the fertiliser is added (the fertigation system is set up after the magnetisation tool). (*iv*) The fourth treatment (Adding the fertiliser to the water before the magnetisation – FMW): the fertilisers are mixed with the irrigation and then they are passed through the magnetisation system (the fertigation system is set up before the magnetisation tool).

Potato tubers (*Solanum tuberosum* Linnaeus) of the cultivar "Spunta" were hand planted in two seasons (beginning of October 2017 and 2018) at 30 cm apart on one side of the ridges (10 m long and 0.75 m wide). The plot consisted of 3 ridges. All the other agricultural practices for a potato crop were used as recommended by the Agriculture Ministry (MALR 2017).

The soil and water characteristics were measured in the Soil Fertility Lab – Plant Nutrition Research Department – Soil, Water and Environment Research Institute, the Ministry of Agriculture, Egypt. The soil pH (pH meter with 0.1 accuracy: JENCO 167, USA) and EC (EC Meter: ORION 105, USA, 0 to 199.99 $dS \cdot m^{-1}$, and 0.5% accuracy) were measured in 1 : 2.5 soil to water suspensions in the soil paste extract. Some soluble cations and anions were measured by titration methods and a flame-photometer (Jenway PFP7, USA) according to Jackson (1967). The chlorophyll ratio in the plants was measured with a chlorophyll meter (SPAD 502 Plus, Germany).

Fifteen plants were randomly selected from each treatment at 80 and 120 days after planting to measure the plant height (cm), the number of leaves per plant and the chlorophyll ratio.

At harvest (120 days from planting), the plants were harvested and the data were recorded for the following traits: the number of tubers/plant, the tuber

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fresh weight (g), the tuber dimensions (length, width and thickness) and the total tuber yield ($Mg \cdot ha^{-1}$) was recorded as the total weight of the harvested tuber per treatment.

All the data collected were statistically analysed as described by Snedcor and Cochran (1982). The means among the treatments were compared using the Least Significant Difference (LSD) at a $P < 0.05$ probability.

## RESULTS AND DISCUSSION

**Water properties.** The data in Table (4) shows that the pH changed when exposed to the magnetic field and adding the fertilisers method, whether before or after the magnetisation process. The value of the pH was slightly increased after being exposed to the magnetic field from 7.51 for the NM treatment to 7.57 and 7.59 for both the MW and MWF treatments, respectively, but the value of the pH significantly increased to 7.83 by adding fertiliser before the magnetic process. This increase in the pH may be due to the formation of more bicarbonate, calcium, and hydroxide ions as well as alkaline substances during the addition of the magnetic fertilisers, which reduced the acidity as decided by Hassani et al. (2015).

The EC of the water slightly increased by 7% when it passed through the magnetic device, but it significantly increased by 42 and 39% for both the MWF and FMW treatments, respectively. This EC increase was due to the addition of the fertilisers, either before or after the magnetisation process. For the MW treatment, the value of all the cations and anions decreased. Ca, Mg, K and Na decreased by 8, 5, 6, and 7%, respectively, and by 7, 32 and 18% for Cl, $HCO_3$ and $SO_4$, respectively. For the MWF treatment, the cation and anion values showed a higher decrease except for K and Na, which increased by 10 and 28%, due to the fertiliser components that were added after the magnetisation. In the addition of the fertiliser and the subsequent the magnetic water case, the cation as well as the anion values increased with the same trend as the magnetic water without the fertilisers case.

The decrease in the value of anions is due to their union with the fertiliser cations and the formation of calcium carbonate molecules. Similar data were also obtained by Hilal et al. (2002) and Abd-Elrahman et al. (2019). The magnetisation process changes the metal ions and, therefore, they do not act as salt ions, thus reducing the ability of the water molecules to bind to the ions. It has been found that magnetism leads to use of natural levels of salts in the water without causing any harmful effects on the plant and, thus, causing the sodium and chlorine to not accumulate in the plant's tissues and the soil as reported by Surendran et al. (2016b) and Chibowski (2018).

**Soil properties.** The results showed a decrease in the soil pH after harvesting by using the magnetised water treatments as shown in Table 5 whether it was in the magnetisation and the addition of fertilisers by hand only or the addition of the fertiliser before and after the process of magnetisation.

The average value of the soil pH through the 60 cm depth was 7.81 for the NM treatment and decreased to 7.75, 7.53 and 7.60 in the case of the MW, MWF and FMW treatments, respectively. This is because the volume of the molecules in the magnetised water is half that of the non-magnetised water, which makes it possible to achieve high permeability between the cellular membranes and to reduce the concentration of the hydrogen ions per the volume unit as reported by Raiteri and Gale (2010) and Ghernaout (2018).

There was an increase in the EC of the soil solution where the average value increased from 0.99 $dS \cdot m^{-1}$ before planting (Table 2 and 3) to 1.2 $dS \cdot m^{-1}$ after harvesting by using the NM water treatment for

Table 4. Effect of the magnetic and fertiliser treatment in the water properties

| Treatment | pH | EC | Soluble cations ($mmol \cdot L^{-1}$) | | | | Soluble anions ($mmol \cdot L^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $Cl^{-}$ | $HCO_3^{-}$ | $SO_4^{=}$ |
| NM | 7.51 | 1.51 | 4.8 | 3.7 | 6.1 | 0.34 | 4.6 | 5.0 | 6.0 |
| MW | 7.57 | 1.62 | 4.4 | 3.5 | 5.7 | 0.32 | 4.3 | 3.4 | 5.3 |
| MWF | 7.59 | 2.15* | 3.2* | 3.3 | 7.85* | 3.78* | 3.9 | 1.1* | 3.8* |
| FMW | 7.83* | 2.10* | 4.1 | 3.3 | 7.74* | 2.57* | 4.11 | 2.9 | 4.68 |
| $LSD_{0.05}$ | 0.12 | 0.33 | 0.73 | ns | 1.31 | 1.05 | ns | 2.3 | 2.42 |

*Significant changes (–/+) comparable to the values in Table 1; EC – electrical conductivity; ns – not significant; NW – normal water (non-magnetic); MW – magnetised water; MWF – adding the fertiliser to the water after the magnetisation; FMW – adding the fertiliser to the water before the magnetisation

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Table 5. Effect of the magnetic and fertigation treatment on the pH, EC, cations and anions of the soil

| Treatment | pH | EC | Soluble cations (mmol·L$^{-1}$) | | | | Soluble anions (mmol·L$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $Cl^{-}$ | $HCO_3^{-}$ | $SO_4^{=}$ |
| NM | 7.81 | 1.20* | 2.0 | 2.05 | 4.80 | 0.35 | 3.61 | 2.30 | 5.90 |
| MW | 7.75 | 0.91 | 1.80 | 1.50* | 2.44* | 0.30 | 3.5 | 1.70 | 3.70* |
| MWF | 7.53* | 0.77* | 1.67 | 1.45* | 2.10* | 0.28 | 2.42* | 1.50* | 3.40* |
| FMW | 7.60* | 0.80 | 1.75 | 1.47* | 2.28* | 0.31 | 2.70* | 1.73 | 3.60* |
| $LSD_{0.05}$ | 0.17 | 0.2 | ns | 0.44 | 1.34 | ns | 0.91 | 0.7 | 1.44 |

*Significant changes (–/+) comparable to values in table 2 and 3; for more explanation see Table 4

the 0–60 cm depth, respectively (Table 5). However, there was a decrease in the EC of the soil solution after harvesting by an average of 8, 22 and 19% in the case of the MW, MWF and FMW treatments, respectively. The findings demonstrate the positive role of the irrigation water magnetisation process in decreasing the soil's EC by preventing the salts from accumulating. These findings are in line with those of Ahmed and Abd El-Kader (2016) who said the soil EC mean values for the magnetic water were lower than those for the non-magnetic water.

During the magnetisation and the addition of the fertiliser before and after the magnetisation process, the values of the soil elements such as Ca, Mg, K and Na changed, due to the effect of the magnetic water on the solubility of these elements in the soil.

The results in Table 5 show the average values of the soluble contents of the cations after harvesting are reduced by 5, 14 and 12.5% for Ca, Mg and K respectively, while Na increased by 13.7% than before the cultivation for the NM treatment. The values of the anions also changed, where $HCO_3$ and $SO_4$ are increased by 21 and 5.3% respectively, but Cl reduced by 9.7% than before the cultivation for the NM treatment. Such results were confirmed with those of Hachicha et al. (2018).

The magnetisation process reduced the value of all the cations and anions after harvesting. In respect to Ca, Mg, K, Na, Cl, $HCO_3$ and $SO_4$, the results revealed these magnetic treatments effected the solubility of these cations and anions in the soil. All the mean values of the soluble contents of these elements after harvesting were less than those before cultivation, especially for the MWF treatment that recorded the highest reduction. The solubility of Ca, Mg, K, Na, Cl, $HCO_3$ and $SO_4$ tends to decrease by 21, 39.6, 30, 50.3, 39.5, 21 and 39%, respectively (Table 5). The MWF treatment leads to the intensive reduction of the soluble Na salts (> 50%), meanwhile, the decrease in the other elements (Ca, Mg and K) is less than 40%.

This is because Na is a paramagnetic element that has a small positive susceptibility to magnetic fields, while the other elements are diamagnetic which are slightly repelled by a magnetic field (Hilal et al. 2002; Grewal, Maheshwari 2011). Also, some of the carbonates and sulfates are also deposited in the soil pores in the non-magnetic water, but by using the magnetic process, the carbonate and sulfate salts cannot be deposited as reported by Samir (2008) and Fanous et al. (2017).

**Yield and yield component of the potato.** The effect of the magnetic water and fertigation process before and after the magnetisation on the vegetative growth (plant height, number of leaves and chlorophyll ratio) of the potato was measured for two seasons. The plant height increases with all the magnetised water during both seasons, with the largest increase in the length of 24.66% for the MWF followed by 14.81 and 16.83% for the FMW and MW treatments respectively, compared to the case of the non-magnetic water (Figure 3).

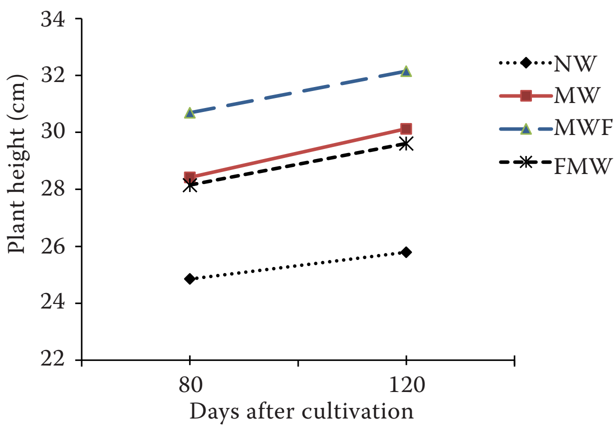


Figure 3. Effect of the magnetic water and fertigation treatments on the plant height

NW – normal water (non-magnetic); MW – magnetised water; MWF – adding the fertiliser to the water after the magnetisation; FMW – adding the fertiliser to the water before the magnetisation

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During both seasons, the magnetised water and fertigation processes positively affected the average number of plant leaves, especially in the case of the MWF treatment, which increased by 21.7% (Figure 4). The increase in the plant height and the number of leaves is due to the stimulating impact of the magnetic process, which may be attributed to their role in increasing the absorption and assimilation of the nutrients as a consequence of increasing the plant growth as discussed by Hozayn (2014), particularly in the case of the MWF treatment not affected by the magnetisation process, which reduced its leaching away from the root zone.

Also, the chlorophyll ratio increased with all the magnetised water treatments during both seasons, with an average of a 9.43, 7 and 4.5% increase in the MWF, FMW and MW treatments, respectively, than the normal water treatment on the 80$^{th}$ day of planting. The promoting influence of the magnetic water may be due to the increase in the pigments, photosynthetic rate, and protein biosynthesis (Hozayn, Abdul Qados 2010). Before harvesting, the non-magnetic treatment gave a higher chlorophyll ratio (46.4) than the magnetic treatments and the MWF treatment recorded the lowest chlorophyll ratio (43.34) due to the late growth rate of the non-magnetic water treatment, where the leaves were greener than the MWF treatment (Figure 5).

The effect of the different magnetic and fertigation treatments on the engineering dimensions of the potato tuber such as the length, width and thickness were investigated. The results indicated a significant impact caused by the different magnetic and fertigation treatments on the tested parameters. A significantly higher length, width and thickness were recorded in the MWF treatment (28, 29.9 and 19.8%, respectively) compared to the non-magnetic water treatment. There were non-significant differences between the MW and FMW treatments. The comparison among the different magnetic and fertigation treatments indicated an improvement in the studied engineering parameters (Table 6).

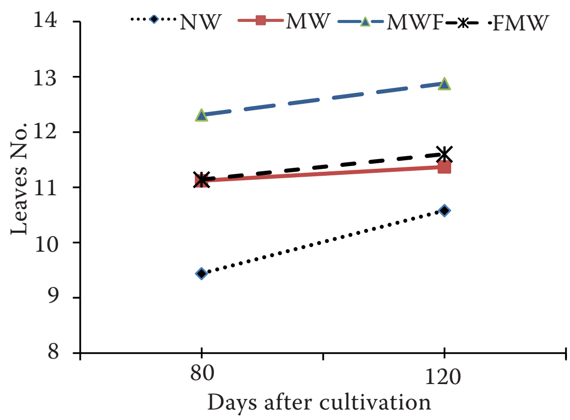


Figure 4. Effect of the magnetic water and fertigation treatments on the number of leaves

NW – normal water (non-magnetic); MW – magnetised water; MWF – adding the fertiliser to the water after the magnetisation; FMW – adding the fertiliser to the water before the magnetisation

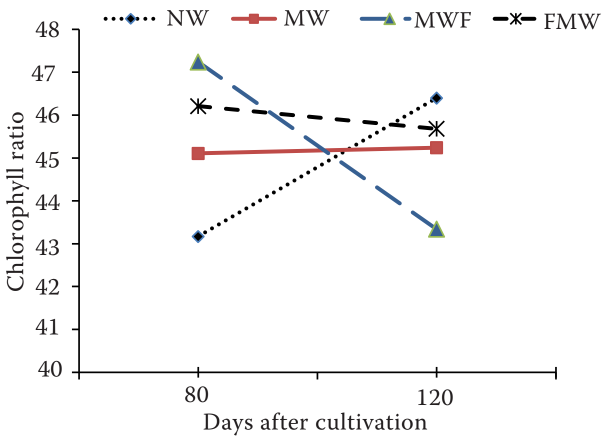


Figure 5. Effect of the magnetic water and fertigation treatments on the chlorophyll ratio

For explanation see Figure 4

With the use of all the magnetised water process, the number of tubers per plant and the weight increased compared to the non-magnetic water treatment (Table 7). The average number of tubers per plant and the weight that was irrigated with the MWF treatment reached to 12.67 and 21.67% higher values than the non-magnetic water treatment, respectively. For the FMW and MW treatments, the average number of tubers per plant and the weight increased with the same rate, but with a smaller ratio than the MWF treatment.

Regarding the positive results, there was a significant increase in the yield. The highest yield was 44.17 Mg·ha$^{-1}$ for the MWF treatment, 40.5% higher than the NM treatment. The data show non-significant differences of the yield under both the MW and FMW treatments throughout the two seasons.

The decrease in the potato yield by the NW and MW treatments matches to the decrease in the average number of tubers per plant and the average tuber weight. However, the impact of the average weight of the tuber on the potato yield was more evident than the impact of the average number of tubers per plant

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Table 6. The mean length, width and thickness for the potato tubers

| Treatments | Length (mm) | | Width (mm) | | Thickness (mm) | |
|---|---|---|---|---|---|---|
| | mean* | CV (%) | mean | CV (%) | mean | CV (%) |
| NM | 93.2[a] ± 5.6 | 6.0 | 45.26[a] ± 7.7 | 19.0 | 37.09[a] ± 3.7 | 10.0 |
| MW | 101.89[b] ± 7.7 | 7.6 | 53.41[b] ± 4.3 | 9.8 | 42.34[b] ± 3.9 | 9.1 |
| MWF | 119.3[c] ± 8.1 | 6.7 | 58.79[c] ± 5.5 | 11.2 | 44.45[b] ± 5.6 | 12.6 |
| FMW | 107.73[b] ± 7.3 | 6.8 | 53.53[b] ± 4.1 | 9.4 | 43.05[b] ± 3.2 | 7.5 |
| $LSD_{0.05}$ | 6.12 | | 3.01 | | 4.11 | |

*mean ± standard deviation (SD); CV – the coefficient of variation (%); for more explanation see Table 4

Table 7. The mean No. of tubers, tuber mass and yield for the potatoes

| Treatments | No. of tubers | Tuber weight (g) | Yield ($Mg·ha^{-1}$) |
|---|---|---|---|
| NW | 7.1[a] | 97.92[a] | 31.44[a] |
| MW | 7.6[b] | 112.83[b] | 39.55[b] |
| MWF | 8.2[c] | 119.13[c] | 44.17[c] |
| FMW | 8.0[bc] | 113.03[bc] | 40.82[b] |
| $LSD_{0.05}$ | 0.4 | 6.12 | 3.19 |

Means followed by the same letter (a–c) are not significantly different from one another based on LSD at $P \leq 0.05$; for more explanation see Table 4

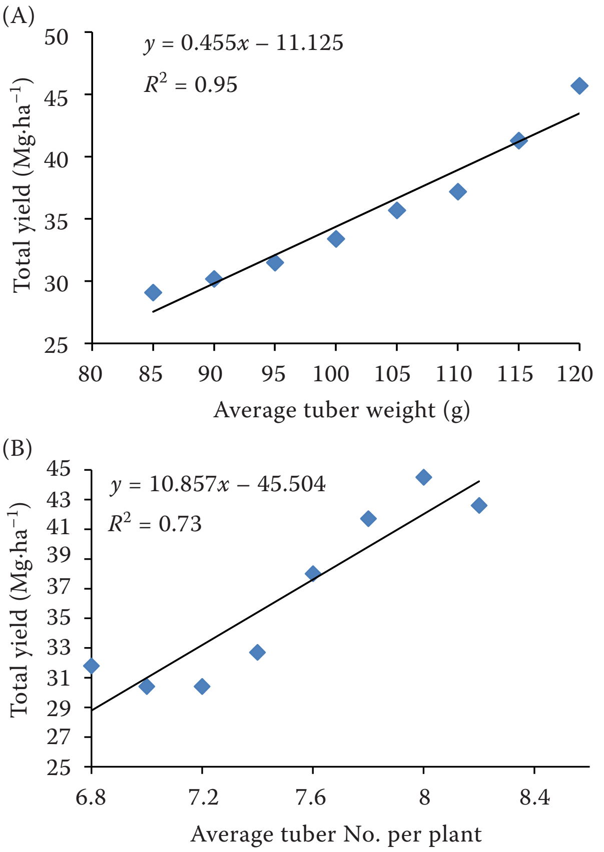


Figure 6. The relationship between the total yield and (A) the average number of tubers and (B) the average tuber weight as affected by the magnetisation process and fertigation

(Figure 6). These findings are in close perspective to those stated by Doklega (2017) and Zayton et al. (2015).

The yield for the magnetised water treatment was less than the magnetic water then the fertigation case because the fertilisers were spread by hand on the soil surface before the irrigation and these fertilisers are either soluble or have low solubility meaning that some of them were lost and it consequently decreased the effectiveness of the fertilisers. However, the increase in the yield more than that in the non-magnetic water treatment was due to the role of the magnetised water by the irrigation, leading to an increase in the growth of the tubers and, thus, the increase in the yield (Mohamed 2013; Yousif 2017).

## CONCLUSION

The results proved that the magnetisation process for the irrigation water then adding the fertilisers (fertigation) positively affected the vegetative measurements (plant height, number of plant leaves and chlorophyll ratio) and the engineering dimensions of the potato tubers, such as the length, width and thickness that lead to an increase in productivity by 40.5%.

From here it would be recommend that the magnetic devices have to be installed before the fertigation units in the irrigation network due to the role of the magnetisation in the cracking and increasing the

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solubility of the fertilisers that may lead to leaching some of the fertilisers away from the roots, which means losing some of the roots and, consequently, decreasing the effectiveness of the fertilisers.

**Acknowledgement:** The author would like to acknowledge the support of "Delta Water company for the magnetic water treatment – http://www.delta-water.net/" for providing the technical support and I would like to give special thanks to the "Elkholy farm - Mit Kenana village, Qalyobia, Egypt" for giving us the opportunity to proceed with the experimental work.

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Received: January 7, 2020
Accepted: June 4, 2020
Published online: June 27, 2020