J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol. 13 (5):157 - 164, 2022

Journal of Soil Sciences and Agricultural Engineering

Journal homepage & Available online at: www.jssae.journals.ekb.eg

Response of Squash Productivity to Deficit Irrigation Treatments and Magnetic Iron Rates in Clay Soil

Farrag, D. Kh.[1]; A. KH. Abdelhalim[2*]; Manal A. Abd Alla[1] and R. Kh. Drewesh[2]

[1]Cross-pollinated Vegetables Dept., Sakha Sta. Hort. Inst., Agric. Res. Center, Egypt.
[2]Water Req. And Field Irrigation. Dept., Soil water and Environment Research Institute, ARC, Egypt.

Cross Mark

ABSTRACT

A field experiment was conducted during the two successive summer seasons of 2019 and 2020 in a clay soil. This work was done to study the effect of three irrigation water depletion treatments (50, 65 and 80% of available soil moisture, SPE) and two levels of magnetic iron application and their interactions on squash yield and its components, water application requirements, water consumption, water use efficiency, water productivity, NPK and chlorophyll contents. Results indicated that the total depth of water application requirements were 389.2, 427.0 and 490.5 mm in 2019 season, and were 400.9, 436.2 and 510.7 mm in 2020 under I_{80}, I_{65} and I_{50}, respectively. The best WUE values of 13.34 and 12.9 kg/m^3 were recorded with I_{65} and Fe_2 treatment in 2019 and 2020 growing seasons, respectively. The highest yields of 23.9 and 23.65 t/fed were obtained with low depletion rate (I_{50}) and Fe_2 treatment, in 2019 and 2020 seasons, respectively. All of the evaluated yield components and vegetative growth traits exhibited higher values with I_{50}, and the values tended to decrease, gradually, with increasing water depletion. Furthermore, higher values of all the above-mentioned fruit quality and attributes were attained from the application of magnetic iron at 150 kg/fed (Fe_2). On conclusion, it is advisable to irrigate squash crop under I_{50} (50% of available soil moisture) combined with applying magnetic iron at rate of 150 kg/fed in order to obtain higher and reasonable fruit yield and quality and water productivity as well under the experimental conditions.

Keywords: squash, water applied, MI, consumptive use, water productivity.

INTRODUCTION

Agriculture is the largest consumer of freshwater supplies with abou 70% in average and nearly 95% in some of developing countries (Steduto *et al*., 2012). Deficit irrigation will play an important role in farm-level water management strategies, with consequent increases in the output generated per unit of water used in agriculture. It is also successful in increasing water productivity for different crops without causing severe yield reduction. This strategy allows sustaining under water deficit conditions in order to reduce costs and increase the net income (Kirda *et al*., 2002). For water productivity (WP) offers a quantifiable benchmark to assess crop production in relation to available water resources (Bouman *et al*., 2005). WP can be defined in several ways depending on the temporal and spatial scales of concern and study objectives.

Squash (*Cucurbite Pe*po, L.,) belongs to Cucurbitaceae family and rich in carbohydrates and amino acids. Also, important commercial crop that planting in open and greenhouse fields (El-Mageed, Taia and Semida, 2015). They conducted an experiment and found that reduced water to 85% from ETc is recommended to squash crop and the high WUE come from same treatment. Summer squash is sensitive to water stress, and may be damaged by, excessive soil water from seed sowing to emergence. Since summer squash rooting depth is relatively shallow, soil water has to be maintained above 65% of the available soil water capacity in order to avoid detrimental water deficit (Mario *et al*., 1997). Squash roots, most of which are in the top of 40–50 cm of soil, develop rapidly. Irrigation squash crop should be scheduled to avoid excessive moisture or water stress. Lack of adequate soil water at harvest can result in misshapen fruits, but too much soil water can aggravate root and stem rot diseases (Richard *et al*., 2002). Under Egyptian conditions, El-Gindy *et al*., 2009 conducted a field experiment to test the effect of two methods of applying nitrogen fertilizer (fertigation and broadcasting), two irrigation levels and two irrigation systems surface and subsurface drip on summer squash production in the sandy soils. Finally, they concluded that subsurface has good water distribution in the soil and the maximum value was 4.51 kg/m^3 with (subsurface irrigation - 60 % ETc – Fertigation), but the minimum values 3.03 kg/m^3 with (surface drip – 80% ETc – Trinational broadcast fertilization). Another work, in clay loam soil at private farm, Dakahlia Governorate, Egypt a field experiment was done to study the effect of irrigation intervals and rates of nitrogen N on Squash crop. The results indicated that irrigation every 12 days with added 75 kg N/fed to squash crop increasing water and N uses efficiencies (Ibrahim and Salim, 2007). Finally, they concluded that squash crop is one of the most important in Egypt and it responds well to application of water application (AW) and N fertilizer. For saving water, Refai and Hassan, 2019 studied the effect of irrigation regimes, N fertilizer and planting date in squash plant. They found that planting squash in autumn season saved 32% of AW compared with planting in spring season. In addition,

*** Corresponding author.**
E-mail address: hady.khamis@outlook.com
DOI: 10.21608/jssae.2022.137711.1076

irrigate with 0.8 AW plus 100% N and biofertilizer (Bio-gem) saved 20% AW and improved squash productivity. Also, in sandy loam soil in Egypt (Elnemr and Elmetwalli, 2021) found that decreasing water level to 80% ETc for squash increasing WP under good irrigation uniformity. Also, they draw attention to deficit irrigation me be required sometimes specially in arid regions. The using modern system to irrigate squash crop, Okasha *et al*., 2020 recommended that interaction between drip irrigation system and irrigation intervals every 7 days showed significant positive effects on the studied traits, especially, crop yield, water productivity, and squash quality attributes under clay soil condition.

In other crops, the using magnetic irrigation water increased tomato yield by 39.9 to 66.7% and improved the yield a quality (Yusuf and Ogunlela, 2015). Farah *et al*., 2021, indicated that the irrigation by partial root drying PRD irrigation method and using soil mulch under deficit irrigation conditions could be used as a water-saving strategy without reducing yield squash crop in arid and semi-arid regions. Rout and Sahoo, 2015 reported some roles of iron in plant growth and its metabolism. These roles of iron according to its ability to gain and lose electrons. Also, iron works as cofactor enzymes involved in a wide variety of oxidations-reductions reactions. This function makes iron an essential nutrient and its deficiency causes iron chlorosis. On the other hand, iron toxicity in plants indicated by bronzing characteristics which have been observed in plants grown than 100 mM solution, that higher iron uptake by plants reduce protein synthesis in leaves. Esmailnegad *et al*., 2020, summarized that using magnetized water improved growth and biochemical of squash under toxicity of herbicides by increasing proline and cytokine concentrations in plant. Abd El-Mageed, Taia *et al*., 2016, studied the effect many types of mulching on squash under water stress they found that interaction between these treatments saving 15% AW without detrimental effect on plant growth or yield. Fandika *et al*., 2011 concluded that controlling irrigation water modify yield and WUE of some varieties of squash crop. Doklega, Samar M.A, 2018 summarized that the interactions among irrigation intervals, organic fertilizer and foliar application with some antioxidant's treatments showed that irrigated every 10 days and fertilized with compost (15 m^3/fed) as well as foliar spraying with yeast extract (2g/L) can be recommended to increase the quantity of the yield and improve the squash fruits quality and reduce the amount of irrigation water used. Abdd El-Maged Taia *et al*., 2016 studied that combined effect of salicylic acid and deficit irrigation on squash and they resulted that these treatments allowing water savings 20-40% without any detrimental effect on plant growth or yield.

The ultimate target for the present investigation is to supply the right amounts of water needed for the plants. The specific objectives are to test the effect of three irrigation water deficit treatments (50, 65 and 80 % of available soil moisture) and two levels of magnetic iron (Fe: 0, and 150 kg/fed) and their interactions on squash yield and its components, yield quality, applied irrigation water, water consumption, water use efficiency, water productivity, and leaf NPK and chlorophyll contents under field conditions in clay soils.

MATERIALS AND METHODS

Experimental site description:

This study was carried out in clay soil at the Horticultural Research field, Sakha Agricultural Research Station, Kafr El-Sheikh Governorate (Middle North Nile Delta) Egypt during the growing seasons of 2019 and 2020 to study the effect of irrigation amounts, and soil application of magnetic iron (MI, the spherical-shaped magnetic Fe2O3 NPs with an average particle size of below 10 nm selected for this study was. The oxide was brown, red in color probably due to partial oxidation to α-Fe2O3, red oxide, Shankramma *et al*., 2016) on squash productivity and some water relations. The experimental design was a split plot involving two factors; main treatment (irrigation amounts) and sub main treatment (magnetic iron application).

Meteorological data as comparison to Pan Evaporation:

Data presented in Table 1 show the meteorological parameters during the studied period, recorded from Sakha Agrometeorological Station. The meteorological parameters included: air temperature (T, ºC), relative humidity (RH.,%), wind speed (WS, m sec^{-1} at 2 m height) and evaporation pan (Ep, mm day^{-1}).

Table 1. Mean monthly meteorological data at Kafr El-Sheikh area during 2019 and 2020 growing seasons.

Months	T (ºC)			RH (%)			WS	Pan Evap.
	Max.	Min.	Mean	Max.	Min.	Mean	m Sec^{-1}	(mm day^{-1})
May	31.9	25.4	28.7	76.4	37.9	57.2	0.79	6.83
June	33.0	28.0	30.5	81.5	50.0	65.8	1.19	8.46
July	33.5	28.4	31.1	85.3	54.4	69.9	0.97	8.08
August	34.2	25.9	30.1	89.7	55.6	72.7	0.80	6.82
May	31.9	23.5	27.7	85.9	35.4	60.6	1.32	7.70
June	31.10	25.8	28.5	78.0	42.6	60.3	1.29	8.44
July	33.7	27.3	30.5	84.2	51.4	67.8	1.17	8.77
August	34.6	28.8	31.7	85.3	49.6	67.5	1.07	8.03

*** Source: meteorological station at Sakha 31^0-07' N Latitude, 30^0-57'E Longitude, N. elevation 6 m.**

Soil data:

Disturbed and undisturbed samples from the top 60 cm soil surface at the experimental site were collected for main physical, hydro-physical and chemical soil properties determination. Soil particle size distribution and bulk density were determined as described by Klute (1986). Field capacity, permanent wilting point and available water characters were determined according to James (1988). Chemical characteristics of soil were determined as described by Jackson (1973). The obtained data are presented in Table 2.

Table 2. Main physical, hydro-physical and chemical soil properties of the experimental site (mean of 2019 and 2020 seasons)

Soil layer depth (cm)	Particle size distribution			Textural class	Bulk density ($g\ cm^{-3}$)	Soil- water constants		
	Sand%	Silt%	Clay%			F.C*(%,wt/wt)	P.W.P**(%,wt/wt)	A.W***(%,wt/wt)
0-15	13.80	25.30	60.90			42.12	21.38	20.74
15-30	18.30	30.10	52.70	Clay	1.18	40.38	20.95	19.43
30-45	21.12	28.02	50.86	Clay	1.20	39.78	20.78	19.00
45-60	19.78	31.56	48.66	Clay	1.21	38.12	20.65	17.47
Mean	18.25	28.52	53.23	Clay	1.18	40.10	20.94	19.16

Soil chemical characteristics

Soil layer depth(cm)	pH	EC $dS\ m^{-1}$	Soluble cations, $meqL^{-1}$				Soluble anions, $meqL^{-1}$			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
0-15	8.09	2.32	4.35	4.70	13.62	0.53	N.D.	8.95	3.22	11.03
15-30	8.06	2.43	3.22	5.65	15.19	0.24	N.D.	9.08	8.98	6.07
30-45	8.01	3.20	4.90	5.92	20.94	0.24	N.D.	11.64	12.95	7.41
45-60	7.94	3.27	6.50	11.95	13.98	0.27	N.D.	10.53	14.90	7.27
Mean	8.02	2.80	4.74	7.06	15.94	0.33	N.D.	10.05	10.01	7.94

FC* (Field capacity), PWP(Permanent wilting point) , AW***(Available soil water) and N.D. (not detected)**

Experimental design and tested treatments:

A split plot experimental design with three replicates was used to implement the field experiment. The tested treatments were as follows:

The main plots were allocated to three irrigation depletion treatments:

I_1 Irrigation with amount of water equals to 50% of available soil moisture,

I_2 Irrigation with amount of water equals to 65% of available soil moisture, and

I_3 Irrigation with amount of water equals to 80% of available soil moisture.

The sub-main plots were allocated to two magnetic iron application treatments:

- Fe_1: Without magnetic iron application, and
- Fe_2: With magnetic iron application

For the Fe soil application technique, magnetite iron (MI) was distributed and incorporated into the soil surface before transplanting at 150 kg MI/fed rate.

Agricultural practices:

Squash seedlings (Mabrouka, hybrid), 18 days age, were transplanted on one side of the ridge in hills spaced 0.40 m apart giving a plant density of about three plants m^{-2}. Transplanting dates were on May 28, 2019, and May 30, 2020. The experimental plot area was equals 52.5 m^2 (1/80 feddan) and contain 8 ridges.

All agricultural practices for squash crop were implemented according to the technical recommendations of A.R.C.

Irrigation water (I.W.):

Applied irrigation water (AIW):

Irrigation event occurs when cumulative pan evaporation is equal to the experimental fraction multiplied by available soil moisture in the soil profile at the experimental site. The depths of applied irrigation water were calculated as a fraction of the available soil moisture in the top 60 cm layer (=135.6 mm at the experimental site).

$$Irrigation\ depth\ (mm) = \frac{fraction\ X\ available\ soil\ moisture\ (mm)}{Ea}$$

where:

ID = depth of applied irrigation water (mm),

***fraction* = 50, 65, and 80% in this experiment, and Ea = application efficiency of the surface irrigation system (=60% at the site).**

A submerged flow spile with fixed dimension was used to measure the applied irrigation water. Water discharged to the experimental plots was calculated according to the following equation (Michael, 1978).

$$q = CA\sqrt{2gh}$$

where:

q = Discharge of irrigation water (cm^3/s),
C = Coefficient of discharge = 0.62 (determined by experiment),
A = Inner cross section area of the irrigation spile (cm^2),
g = Gravity acceleration (cm/s^2) and
h = Average effective head (cm).

The volume of water delivered to each plot (7m×7.5m = 52.5 m^2) was calculated by substituting Q in the following equation:

$$Q = q \times T \times n$$

where:

Q = volume of water (m^3),
q = discharge (m^3/min),
T = total irrigation time (min) and
n = number of spiles per each plot.

Water consumptive use (CU):

Water consumptive use was calculated as soil moisture depletion (SMD) according to Hansen *et al.* (1979).

$$CU = SMD = \sum_{i=1}^{i=N} \frac{\theta_2 - \theta_1}{100} * Dbi * Di$$

where:

CU = Water consumptive use in the effective root zone (60 cm), cm,
Θ_2 = Gravimetric soil moisture percentage 48 hours after irrigation (% on mass basis),
Θ_1= Gravimetric soil moisture percentage before irrigation (% on mass basis),
Dbi = soil bulk density ($g\ cm^{-3}$) for the given depth,
D_i = soil layer depth (20 cm), and
i = number of soil layers (i = 1 to i = 4) each 15 cm depth.

Crop- water relations:

Consumptive use efficiency (Ecu%):

The consumptive use efficiency (Ecu) was calculated as described by Doornbos and Pruitt (1977) as follows:

$$Ecu = \frac{ETc}{AW}\ X\ 100$$

where:

Ecu = Consumptive use efficiency (%)
ETc = Total crop evapotranspiration ≅ consumptive use ($m^3\ fed^{-1}$).
AW = Water applied to the field ($m^3\ fed^{-1}$).

Water use efficiency (WUE):

Water use efficiency is generally outlined as crop yield per cubic meter of water consumed by growing crop. It was calculated according to (Ali *et al*., 2007)

$$WUE = \frac{Squash\ yield, Y\ (\frac{kg}{feddan})}{Consumed\ Water, WCU\ (\frac{m^3}{feddan})}$$

where:

WUE = water use efficiency (kg m^{-3} of consumed water),
Y = Squash yield (kg fed^{-1}), and
WCU = Total water consumption of the crop during growing season (m^3 fed^{-1}.).

Productivity of irrigation water (PIW):

Productivity of irrigation water (PIW) was estimated according to (Ali *et al.*, 2007).

$$PIW = \frac{GY}{AW}$$

where:

PIW= productivity of irrigation water (kg m^{-3} of applied water),
GY= yield kg/fed and
AW = applied water (m^3/fed.). (Irrigation water + effective rainfall)
Note: effect rainfall = rainfall*0.7 (Novica, 1979) No rain during summer at the site

Crop measurements and calculations:

Vegetative growth measurements:

The following squash vegetative parameters were measured:

- Plant height (cm)
- Number of leaves per plant
- Leaf area per plant (dm^2)
- Chlorophyll content ($mgdm^{-2}$): determined spectrobolometrically 60 days after transplanting as described by Moran and Porath (1982).

Fruit yield, yield components, and quality:

- Early fruit yield (yield of first three picking) and total fruit yield (t fed^{-1})
- Mean fruit weight (g)
- Vitamin C (mg/100 g fresh weight), and
- Total Soluble Solids (TSS, %)

Mineral contents

Samples were collected 60 days after transplanting from leaves of squash plants to determine NPK contents. Nitrogen (%) was determined in the digestion product using the micro-kjeldahl method (AOAC, 1980). Phosphorus (%) was determined calorimetrically according to King (1951). Potassium (%) was determined using a flame photometer (Jackson, 1973).

Statistical analysis:

All data were statistically explored analyzed according to the technique of analysis of variance (ANOVA) as published by Gomez and Gomez (1984). Means of the treatments were compared by the least significant difference (LSD) at 5% level and 1 % level of significance according to Waller and Duncan (1969).

RESULTS AND DISCUSSION

Effect of tested treatments on water relations:

Seasonal water applied in the two growing seasons:

The results in Table (3) represent the total seasonal water applied for squash crop in the 2019 and 2020 growing seasons. These amounts were 1635, 1795 and 2060 m^3/fed (389٢, 427٠ and 490٥ m^3/ha) in the first season and 1684, 1832 and 2145 m^3/fed (400٩, 436٢ and 510٧ m^3/ha) in the second season for I_3, I_2 and I_1 treatments, respectively. For the 50% CPE treatment the depth of AW were 49.05 and 51.07 cm for 2019 and 2020 season, respectively. The same results were nearly obtained by Abd El-Mageed, *et al.* (2016), they stated that the depth of applied water was 47.9 cm..

Table 3. Seasonal water applied as affected by irrigation treatments in the two growing seasons.

Applied water	Seasonal applied water: AW ($m^3 fed^{-1}$) 2019	AW ($m^3 fed^{-1}$) 2020	AW ($m^3 fed^{-1}$) mean	AW (cm) 2019	AW (cm) 2020	AW (cm) mean
I_1	2060.0	2145.0	2102.5	49.05	51.07	50.06
I_2	1795.0	1832.0	1813.5	42.70	43.62	43.16
I_3	1635.0	1684.0	1659.5	38.92	40.09	39.51

I_1: irrigation at 50% CPE, I_2: irrigation at 65% CPE, I_3: irrigation at 80% CPE, Fe_1: without magnetic iron application and Fe_2: with magnetic iron application.

Crop water consumptive use (CU)

Results in Table (4) showed that irrigation and magnetic iron treatments affected the consumed water by squash crop. The I_1 irrigation treatment recorded the highest water consumptive use values. The means of obtained values increased by 10.5 and 15.96% compared to I_2 and I_3 treatments, respectively. The values of water consumptive use were affected by the application of magnetic iron and taken same line under different irrigation treatments. The Fe_2 treatment recorded CU values compared with Fe_1 ~~of~~ in the two seasons. The highest values of water consumptive use (42.60 and 41.52 cm) were obtained from the I_1 x Fe_2 interaction in the first and second seasons, respectively. Similar results were obtained by El-Mageed *et al*., (2016). They showed that the water consumptive use decreased with increasing water stress from I1 to I3 treatment. On the other hand the highest water use efficiency (WUE) was obtained at water stress conditions $1_{70\%}$ treatments.

The effect of irrigation treatments and magnetic iron rates on consumptive use efficiency (Ecu%).

The mean values of consumptive use efficiency (Ecu%) of squash crop as affected by irrigation treatments and magnetic iron rates are presented in Table (4). Results showed that increasing depletion (i.e. water stress) and adding magnetic iron increased Ecu% values. The Ecu% values were 85.7, 86.7 and 87.8% in the 2019 season and 80.7, 85.9 and 87.4% in 2020 season for I_1, I_2 and I_3 treatments, respectively. Also, the values of Ecu% under magnetic iron treatments were 85.2 and 87.9% in the 2019 season and 83.2 and 86.1% in the 2020 season under Fe_1 and Fe_2, respectively.

Table 4. Consumptive use (CU) and consumptive use efficiency (Ecu) as influenced by irrigation and magnetic iron application treatments during the two growing seasons.

Treatments: Irrigation	Foliar application	CU (cm) 2019	CU (cm) 2020	CU (cm) mean	Ecu (%) 2019	Ecu (%) 2020	Ecu (%) mean
I_1	Fe_1	41.50	40.90	41.20	84.60	80.09	82.34
	Fe_2	42.60	41.52	42.06	86.85	81.30	84.07
	Mean I_1	42.05	41.21	41.63	85.72	80.69	83.20
I_2	Fe_1	36.18	36.80	36.49	84.73	84.37	84.55
	Fe_2	37.88	38.10	37.99	88.71	87.34	88.02
	Mean I_2	37.03	37.45	37.24	86.72	85.88	86.30
I_3	Fe_1	33.52	34.10	33.81	86.13	85.05	85.59
	Fe_2	34.33	35.95	35.14	88.20	89.67	88.93
	Mean I_3	33.93	35.03	34.48	87.78	87.37	87.58
	Mean I	37.67	37.90	37.79	86.74	84.65	85.70

I_1: irrigation at 50% CPE, I_2: irrigation at 65% CPE, I_3: irrigation at 80% CPE, Fe_1: without magnetic iron application and Fe_2: with magnetic iron application.

Effect of irrigation and magnetic iron treatments on productivity of irrigation water (kg m^{-3}) of squash crop.

The mean values of productivity of irrigation water (PIW) of squash crop as affected by irrigation treatments and magnetic iron rates are presented in Table (5).

Table 5. Effect of irrigation treatments and magnetic iron application rates on productivity of irrigation water (PIW) and water use efficiency (WUE) in both growing seasons.

Treatments		Productivity of irrigation water (kg m^{-3})		Water Use Efficiency (kg m^{-3})	
		2019	2020	2019	2020
(I_1)	Fe 1	10.89 bc	10.36 b	12.87 ab	12.93 ab
	Fe 2	11.60 ab	11.03 a	13.36 a	13.56 a
	Mean I_1	11.25	10.69	13.11	13.25
(I_2)	Fe 1	11.27 abc	10.69 ab	13.32 a	12.67 b
	Fe 2	11.83 a	11.27 a	13.34 a	12.90 ab
	Mean I_2	11.55	10.97	13.33	12.78
(I_3)	Fe 1	9.55 d	9.14 c	11.09 c	10.75 c
	Fe 2	10.83 c	10.12 b	12.28 b	11.29 c
	Mean I_3	10.19	9.63	11.69	11.02

I_1: irrigation at 50% CPE, I_2: irrigation at 65% CPE, I_3: irrigation at 80% CPE, Fe_1: without magnetic iron application and Fe_2: with magnetic iron application

Results showed that the highest PIW values were recorded for I_1 and I_2 treatments under application of magnetic iron (Fe_2). These values were significantly higher than I_3 irrigation treatment. The obtained PIW values were 11.25, 11.25 and 10.19 kg/m^3 in the 2019 season and 10.29, 10.79 and 9.63 in 2020 kg/m^3 season, for I_1, I_2 and I_3 treatments, respectively. Also, magnetic iron application increased the productivity of irrigation water as iron works as cofactor enzymes in oxidation-reduction reactions (Rout and Sahoo, 2015). Average PIW values were 10.57 and 11.3 kg/m^3 in 2019 season and 10.1 and 10.8 kg/m^3 in 2020 season for Fe_1 and Fe_2 magnetic iron treatments, respectively. Results also indicated that, the highest PIW values of 11.83 and 11.27 kg m-3 were recorded from the interaction between I_2 and Fe_2 treatment in the 1st and 2nd seasons, respectively. Productivity of irrigation water (PIW) significantly affected by irrigation treatments and application of MI. As with less water, the production is close to the squash crop, also, the addition of iron also increases the plant's ability to benefit from water. These results are in line with those Abd El-Mageed *et al*, 2016.

Water Use Efficiency, (kg m^{-3})

The mean values of water use efficiency (WUE) of squash crop as affected by irrigation treatments and magnetic iron rates are presented in Table (5). Results indicated that, there were significant effects of the tested treatments on WUE values. Results showed that WUE had the same trend as PIW but with higher values than PIW. The average WUE values were 13.11, 13.33 and 11.69 kg/m^3 in the 2019 season and 13.25, 12.78 and 11.02 kg/m^3 in 2020 season for the I_1, I_2 and I_3 irrigation treatments, respectively. The average WUE values as affected by magnetic iron rates were 12.4 and 13.0 kg/m^3 in 2019 season and 12.11 and 12.58 kg/m^3 in 2020 season for Fe_1 and Fe_2 treatments, respectively.

Effect of irrigation and magnetic iron treatments on plant characteristics:

The mean values of plant characteristics (shoots fresh, shoot dry weights, no of leaves/plant, and leaf area/plant) of squash crop as affected by irrigation treatments and magnetic iron rates are presented in Table (6). Results indicated that decreasing the period of depletion (I_1 = 50%) significantly increased plant characters (shoot fresh and dry weights, No of leaves/plant and leaf area/plant). But no deference between I_1 and I_2, the shoot fresh weight increased 13.4, 12.6 and 11.59 gm in 2019 season and 13.22, 12.09 and 11.15 gm in 2020 season under I_1, I_2 and I_3 treatments, respectively. The shoots dry weights were 10.47, 9.82 and 8.83 gm in 2019 season and 10.43, 9.19 and 8.49 g in 2020 season for I_1, I_2 and I_3 treatments, respectively. The results demonstrate that increasing period of depletion decreased the No of leaves/ plant as well as magnetic iron, 24.17, 22.83 and 20.0 in 2019 season and 23.83, 21.83 and 19.42 in 2020 season for 50, 65 and 80% depletion, respectively. With regard to leaf area/plant, it takes the same trend in the first season it was 3.14, 2.62 and 1.97 cm^2 and in second season it was 3.05, 2.52 and 1.82 cm^2 for 50, 65 and 80% depletion, respectively.

Table 6. Effect of irrigation water applied and magnetic iron application rates on shoots fresh and dry weights (g), no of leaves/plant and Leaf area/plant (cm^2) in the two growing seasons.

Plant Charact.		Shoots fresh weight (g)		Shoots dry weight (g)		No of leaves/plant		Leaf area /plant (cm^2)	
Treatments		2019	2020	2019	2020	2019	2020	2019	2020
(I_1)	Fe_1	13.07 ab	12.93 ab	10.14 b	10.12 b	23.67 ab	23.33 a	3.08 a	3.02 a
	Fe_2	13.73 a	13.52 a	10.80 a	10.73 a	24.67 a	24.33 a	3.18 a	3.06 a
	Mean	13.40	13.22	10.47	10.43	24.17	23.83	3.14	3.05
(I_2)	Fe_1	12.26 bc	11.81 cd	9.73 b	9.02 c	22.33 bc	21.00bc	2.26 b	2.12 b
	Fe_2	12.93 ab	12.37 bc	9.91 b	9.36 c	23.33 ab	22.67ab	2.97 a	2.91 a
	Mean	12.60	12.09	9.82	9.19	22.83	21.83	2.62	2.52
(I_3)	Fe_1	11.34 d	10.80 e	8.49 d	8.03 d	18.67 d	18.17 d	1.87 b	1.69 b
	Fe_2	11.83 cd	11.50 de	9.16 c	8.95 c	21.33 c	20.67 c	2.07 b	1.95 b
	Mean	11.59	11.15	8.83	8.49	20.00	19.42	1.97	1.82

I_1: irrigation at 50% CPE, I_2: irrigation at 65% CPE, I_3: irrigation at 80% CPE, Fe_1: without magnetic iron application and Fe_2: with magnetic iron application

Effect of irrigation and magnetic iron application on yield and yield components of squash:

Irrigation water depletion caused an observed adverse action on yield and yield components. Fruit weight, fruit length and fruit diameter were significantly reduced with increasing period depletion (Table 7). The highest values of the previous parameters were recorded with low depletion (50%) irrigation followed by moderate depletion (65 %) treatment followed by high depletion 80% in both seasons. Using irrigation depletion rates affected the parameters Table (7), for fruit weight it was 157.3, 147.8 and 110 g in the 2019 season, 157.0, 150.4 and 107.5 g in 2020 season under I_1, I_2 and I_3 treatments, respectively. Fruit length it was 13.10, 11.65 and 10.83 cm in the 2019 season, 21.87, 11.05 and 10.20 cm in 2020 season under I_1, I_2 and I_3 treatments, respectively. Fruit diameter it was 3.84, 2.75 and 2.48 cm in the 2019 season, 3.87, 2.72 and 2.37 cm in 2020 season under I_1, I_2 and I_3 treatments, respectively.

Table 7. Effect of irrigation water applied and magnetic iron application on and fruit weight, g, fruit length, cm and fruit diameter, cm.

Yield Components		Fruit Weight (g.)		Fruit length, cm		Fruit diameter, cm	
Treatments		2019	2020	2019	2020	2019	2020
(I_1)	Fe 1	154.7 b	153.8 b	13.00 a	12.90 a	3.83 a	3.80 a
	Fe 2	159.9 a	160.3 a	13.20 a	12.83 a	3.85 a	3.93 a
	Mean	157.3	157.0	13.10	12.87	3.84	3.87
(I_2)	Fe 1	142.6 c	148.6 b	11.60 bc	10.93 bc	2.73 b	2.63 bc
	Fe 2	153.0 b	152.1 b	11.70 b	11.17 b	2.77 b	2.80 b
	Mean	147.8	150.4	11.65	11.05	2.75	2.72
(I_3)	Fe 1	99.0 e	97.0 d	10.73 d	10.00 d	2.47 b	2.30 d
	Fe 2	121.0 d	118.0 c	10.93 cd	10.40 cd	2.50 b	2.43 cd
	Mean	110.0	107.5	10.83	10.20	2.48	2.37

I_1: irrigation at 50% CPE, I_2: irrigation at 65% CPE, I_3: irrigation at 80% CPE, Fe_1: without magnetic iron application and Fe_2: with magnetic iron application

Results in Table (8) demonstrate that increaseing the period of water depletion period significantly have effects early and total yield of squash crop. The results in Table (8) showed the effect of the percentage of depletion and adding magnetic iron on the early yield and total yield ton/fed) of squash. From Table 6 the irrigation by 50% from depletion showed positive significant effects on total yield and early yield of squash in the two growing seasons as compared with another two treatments. The data showed that early yield record that in 2019 season 6.54, 5.51 and 4.32 ton/fed, 6.28, 4.22 and 4.12 ton/fed in the 2020 season under I_1, I_2 and I_3 treatments, respectively. The highest total yield of fruit occurred when low depletion by significant defiance's. The production was 23.16, 20.74 and 16.66 ton/fed in the first season 2019, and it was 22.93, 20.11 and 16.22 ton/fed in the second season 2020. The interaction recorded in total yield amounted by 23.9 and 23.65 ton/fed under 50% CPE and application of magnetic iron (150 kg MI/fed) for 2019 and 2020 seasons, respectively, compared with using 80% CPE depletion in the first and second seasons, respectively. In this regard, the increase in yield might be due to several reasons that iron works as a cofactor for enzymes involved in a wide variety of oxidation-reduction reactions Also, helps in many operations in plant such as, respiration, hormone synthesis and DNA synthesis. This function makes iron an essential nutrient, and its deficiency causes iron chlorosis (Rout and Sahoo, 2015). In contrast, the values of TSS% occurred with increasing water stress by extension the depletion percentage up to 80% (I_3) treatment. The data in table (8) presented that TSS values were 9.22, 9.35 and 9.45 % in the 2019 and 9.0, 9.25 and 9.46% in the 2020 under I_1, I_2 and I_3 treatments, respectively. But the interaction between depletion irrigation at 80% and application of magnetic iron isn't significant ($p>0.05$).

Table 8. Effect of irrigation water applied and magnetic iron application on, early and total yield (ton fed^{-1}) and TSS%.

Treatments		Early yield (tonfed^{-1})		Total Yield (tonfed^{-1})		TSS %	
		2019	2020	2019	2020	2019	2020
(I_1)	Fe 1	6.27 b	6.10 a	22.43 b	22.22 b	9.20 a	9.00 b
	Fe 2	6.80 a	6.46 a	23.90 a	23.65 a	9.24 a	9.00 b
	Mean	6.54	6.28	23.16	22.93	9.22	9.00
(I_2)	Fe 1	5.22 d	5.00 c	20.24 c	19.58 d	9.30 a	9.20 ab
	Fe 2	5.80 c	5.45 b	21.23 bc	20.64 c	9.40 a	9.30 ab
	Mean	5.51	5.22	20.74	20.11	9.35	9.25
(I_3)	Fe 1	3.94 f	3.73 e	15.62 e	15.40 f	9.40 a	9.48 a
	Fe 2	4.70 e	4.52 d	17.71 d	17.05 e	9.50 a	9.45 a
	Mean	4.32	4.12	16.66	16.22	9.45	9.46

I_1: irrigation at 50% CPE, I_2: irrigation at 65% CPE, I_3: irrigation at 80% CPE, Fe_1: without magnetic iron application and Fe_2: with magnetic iron application

N, P, K and chlorophyll contents in squash leaves: -

Data listed in Table (9) show that the irrigation by depletion levels had significant effects on N, P and K % in leaves of squash plant in two growing seasons. That low depletion help plant to increase of three elements N, P and K in leaves, it was 5.15, 4.45 and 4.0% N in the 2019 and 5.08, 4.2 and 3.85% N in 2020 season under I_1, I_2 and I_3 treatments, respectively. The same trend was observed with P and K elements. Across all treatments the added magnetic iron cusses increasing in concentrations in N, P and K concentrations in squash leaves. As iron works as a cofactor for enzymes involved in a wide variety of oxidation-reduction reactions in plant (Rout and Sahoo, 2015).

Table 9. Effect of irrigation water applied and magnetic iron application on N, P, K % in leaves of squash in the two seasons.

Treatments		N, (%)		P, (%)		K, (%)	
		2019	2020	2019	2020	2019	2020
(I_1)	Fe 1	5.00 ab	4.96 a	0.54 a	0.50 a	4.80 a	4.79 a
	Fe 2	5.30 a	5.20 a	0.56 a	0.52 a	5.04 a	4.58 a
	Mean	5.15	5.08	0.55	0.51	4.92	4.82
(I_2)	Fe 1	4.30 cd	4.10 b	0.40 c	0.39 bc	4.00 bc	3.94 b
	Fe 2	4.60 bc	4.30 b	0.44 b	0.42 b	4.25 b	4.05 b
	Mean	4.45	4.20	0.42	0.41	4.12	4.00
(I_3)	Fe 1	3.90 d	3.70 b	0.35 d	0.34 c	3.52 d	3.46 d
	Fe 2	4.10 cd	4.00 b	0.39 c	0.38 bc	3.90 c	3.70 c
	Mean	4.00	3.85	0.37	0.36	3.71	3.58

I_1: irrigation at 50% CPE, I_2: irrigation at 65% CPE, I_3: irrigation at 80% CPE, Fe_1: without magnetic iron application and Fe_2: with magnetic iron application

Table (10) shows the values of chlorophyll concentration, CAT (M mol $min^{-1}g^{-1}$ protein) and DHAR (M mol $min^{-1}g^{-1}$ protein) at depletion levels with magnetic application. Results show that the chlorophyll concentration, generally decreased with increasing water stress for two seasons , the highest chlorophyll concentration of 46.73 and 46.0 $mgdm^{-2}$ were recorded with the treatments 50% depletion and 150 kg/fed MI in 2019 and 2020 respectively , while the minimum values of chlorophyll concentration of 37.63 and 36.93 $mgdm^{-2}$ were recorded with the treatment 80% depletion and no MI application in 2019 and 2020 respectively. The same results obtained with those (Amer, *et al.*, 2009) with cucumber crop the family of squash, that chlorophyll a and b were significantly decreased with increasing water deficit. Water stress resulted in increment production of reactive oxygen radicals in plants leading to a decrease amount of chlorophyll contents, pointing out the degree of the oxidative damages. This reduction may be also caused by chlorophyll biosynthesis route prevention (Lalinia *et al*., 2012). Also, these increases would be ascribed to the functional role of Fe and Zn in activation of enzymes that complicated in chlorophyll biosynthesis route and some antioxidant enzymes as glutathione reductase and ascorbate peroxidase in the pathway protection of chlorophyll reduction by the free active oxygen radicals (Ibrahim, *et al*., 2017).

Table 10. Effect of irrigation water applied and magnetic iron application on chlorophyll, mgdm^{-2}, CAT (M mol min^{-1} g^{-1} protein) and DHAR (M mol min^{-1} g^{-1} protein).

Treatments		Chlorophyll, (mgdm^{-2})		CAT (M mol min^{-1} g^{-1} protein)		DHAR (M mol min^{-1} g^{-1} protein)	
		2019	2020	2019	2020	2019	2020
(I_1)	Fe_1	44.66 ab	44.21 ab	107.5 d	129.0 d	0.299 d	0.215 e
	Fe_2	46.73 a	46.00 a	68.45 e	126.9 d	0.259 e	0.270 d
	Mean	45.70	45.10	78.97	127.9	0.279	0.242
(I_2)	Fe_1	40.56 c	40.30 c	365.5 c	483.7 b	0.631 b	0.687 b
	Fe_2	43.80 b	43.60 b	335.4 c	428.6 c	0.575 c	0.631 c
	Mean	42.18	41.95	350.4	456.1	0.603	0.659
(I_3)	Fe_1	37.63 d	36.93 d	505.3 a	543.9 a	0.697 a	0.753 a
	Fe_2	39.90 cd	39.43 c	423.5 b	483.7 b	0.676 a	0.702 b
	Mean	38.77	38.18	464.4	513.8	0.686	0.727

I_1: irrigation at 50% CPE, I_2: irrigation at 65% CPE, I_3: irrigation at 80% CPE, Fe_1: without magnetic iron application and Fe_2: with magnetic iron application

CONCLUSION

Squash crop is one of the most important vegetables crop in Egypt and it affected to application of water rates. Also, summer squash is sensitive to water stress and excessive soil water. It rooting depth is relatively shallow, soil water has to be maintained above 50% of the available soil water capacity in order to avoid detrimental water. From this study it is recommended to irrigate squash crop under I_{50} (50% of APE) combined with applying magnetic Iron 150 kg/fed MI in order to obtain higher and fruit yield, quality and water productivity as well under the experimental conditions.

REFERENCES

Abd El-Mageed Taia,.A., W.M. Semida, G.F. Mohamed, M.M. Rady, 2016. Combined effect of foliar-applied salicylic acid and deficit irrigation on physiological–anatomical responses, and yield of squash plants under saline soil. South African J. of Botany, 106: 8–16.

Abd El-Mageed, Taia A., W. M. Semida and M.H. Abd El-Wahed, 2016. Effect of mulching on plant water status, soil salinity and yield of squash under summer-fall deficit irrigation in salt affected soil. Agricultural Water Management, 173: 1–12.

Ali, M.H.; M.R. Hoque; A.A. Hassan and A. khair, 2007. Effects of deficit irrigation on yield, water productivity and economic returns of wheat. Agricultural water management, 92 (3): 151-161.

Amer K. H., Midan Sally A., and J. L. Hatfield, 2009. Effect of Deficit Irrigation and Fertilization on Cucumber. Agronomy J. Vol. 101, 6: 1556 – 1564.

AOAC, 1980. Association of Official Agricultural Chemists. Official Methods of Analysis. 13th Ed., Washington D.C.

Bouman, B.A.M., Peng, S., Casta neda, A.R., and R.M. Visperas, 2005. Yield and water use of irrigated tropical aerobic rice systems. Agric. Water Manage., 74: 87–105.

Doklega, Samar M. A., 2018. Impact of Irrigation Intervals, Organic Fertilizer and Foliar Application with Some Antioxidants on Summer Squash. J. Plant Production, Mansoura Univ., Vol. 9 (1): 143 –151.

Doornbos, J. and Pruit W.O., 1977. Crop water requirements. Irrigation and Drainage Paper, No. 24, FAO Rome.

El-Gindy A. M., E. El-Banna, M. A. El-Adl and M. F. Metwally, 2009. Effect of fertilization and irrigation Water levels on summer squash yield Under drip irrigation. Misr J. Ag. Eng., 26(1): 94-106.

El-Mageed, Taia A. Abd and W. M. Semida, 2015. Effect of deficit irrigation and growing seasons on plant water status, fruit yield and water use efficiency of squash under saline soil. Scientia Horticulture 186: 89–100.

Elnemr M. K. and A. H. Elmetwalli, 2021. Production of drip irrigated squash (Cucurbita Pepo, L.) under different levels of irrigation and uniformity. AgricEngInt, Vol. 23, No.1: 65-74.

Esmailnegad N, J. Khara, M. Akhgari, 2020. The effect of magnetized water on the growth and some biochemical parameters of squash (Cucurbita pepo) plants under toxicity of herbicide trifluralin . NBR. 6 (4) :478-486.

Fandika, I.R., P.D. Kemp, J.P. Millner and D. J. Horne, 2011. Yield and water use efficiency in buttercup squash (Cucurbita maxima Duchesne) and heritage pumpkin (Cucurbita pepo Linn). AJCS 5(6):742-747.

Farah A.H., H. M. Al-Ghobari, T. K. Zin El-Abedin, M. S. Alrasasimah and A. A. El-Shafei, 2021. Impact of Partial Root Drying and Soil Mulching on Squash Yield and Water Use Efficiency in Arid. Agronomy, 11, 706: 1-20.

Gomez, K.A. and A. Gomez, 1984. Statistical procedures for agricultural research. 1st ed. John Willey & Sons, New York.

Hansen, V.W., Israelsen and Stringharm Q.E., 1979. Irrigation principles and practices, 4th ed., John Willey and Sons, New York.

Ibrahim, E.A. and E.M. Selim, 20٠٧. Effect of irrigation intervals and nitrogen fertilizer rates on summer squash (Cucurbita pepo L.) growth, yield, nutritional status and water use efficiency. J. Agric. Sci. Mansoura Univ., 32 (12): 10333-10345.

Ibrahim, Seham A., E. M. Desoky and A. S. Elrys, 2017. Influencing of Water Stress and Micronutrients on Physio-Chemical Attributes, Yield and Anatomical Features of Common Bean Plants (Phaseolus vulgaris L.). Egypt. J. Agron. Vol. 39, No. 3,: 251-265.

Jackson, M.L., 1973. Soil chemical analysis. Prentice Hall of India, Private Ltd. New Delhi.

James, L.G., 1988. Principles of farm irrigation system design. John Willey and Sons Inc., New York, 543.

King, E. J., 1951. Micro-analysis in medical biochemistry. 2nd Ed. Churchill, London

Kirda C., Moutonnet P., Hera C. and Nielsen D.R., 2002. Crop yield response to deficit irrigation. Dordrecht, The Netherlands, Kluwer Academic Publishers.

Klute, A., 1986. Water retention: laboratory methods: In: A. Koute (ed). Methods of soil analysis, Part 1, 2nd ed. Agron. Monogr. 9, ASA, Madison, W1, USA, 635-660.

Lalinia, A., H., M.A., Galostian, N. Bahabadi, E.M. and M.M. Khameneh, 2012. Echophysiological impact of water stress on growth and development of Mungbean. International J. of Agronomy and Plant Pro., 3 (12): 599-607.

Mario, H., Bill, M., Jason, S., and S., John, 1997. Oregon State University Western Oregon Sguash Irrigation Guide, vol. 541. Department of Bioresource Engineering, 116 Gilmore Hall, Corvallis, : 737–6304 (OR: 97331-3906).

Michael, A. M. 1978. Irrigation – Theory and practices. Vikas Publishing House, New Delhi.

Moran, R. and D. Porath, 1982. Chlorophyll determination in intact tissue using N, N dimethyl formamide. Plant Physio. 65: 478-479.

Novica, V., 1979. Irrigation of agriculture crops. Fac. Agric. Press, Novia sad, Yugoslavia.

Okasha E.M., Fadl A. Hashem and El-Metwally I.M., 2020. Effect of irrigation system and irrigation intervals on the water application efficiency, growth, yield, water productivity and quality of squash under clay soil conditions. Plant Archives Vol., 20: 3266-3275.

Refai, E.S. and A.A. Hassan, 2019. Management of Irrigation and Nitrogen Fertilization for Squash Grown at Different Plantation Seasons under Assiut Governorate Conditions. Middle East J. Agric. Res., 8(1): 356-370.

Richard, M., Jose, A., Mark, G., Keith, M., 2002. Spring Squash Production in California. Vegetable Research and Information Center, Vegetable Reproduction Series, California, Publication 7245.

Rout G.R. and S. Sahoo, 2015. Role of iron in plant growth and metabolism. Reviews in Agricultural Science, 3:1-24.

Shankramma, K. S. Yallappa, M. B. Shivanna and J. Manjanna, 2016. Fe2O3 magnetic nanoparticles to enhance S. lycopersicum (tomato) plant growth and their biomineralization. Appl Nanosci, 6:983–990

Steduto, P., J. M. Faurès, J. Hoogeveen, J. Winpenny, and J. Burke, 2012. Coping with water scarcity: an action framework for agriculture and food security. Rome: Food and Agriculture Organization of the United Nations.

Waller, R.A. and D.B. Duncan, 1969. Symmetric multiple comparison problem. Amer. Stat. Assoc. December, : 1485-1503.

Yusuf K.O. and A.O. Ogunlela, 2015. Impact of Magnetic Treatment of Irrigation Water on the Growth and Yield of Tomato. Not Sci Biol, 7(3): 345-348.

استجابة انتاجية محصول الكوسة لمعدلات استنفاذ ماء الري وإضافة الحديد المغناطيسي في التربة الطينية

ضياء الدين خلف فراج [١] ،عبدالهادى خميس عبدالحليم[٢] ، منال عبدالرحمن عبدالله[١] ورضا خالد درويش[٢]

[١]قسم بحوث الخضر خلطية التلقيح محطة بحوث البساتين بسخا- معهد بحوث البساتين- مركز البحوث الزراعية- مصر

[٢]قسم المقننات المائية والري الحقلي - معهد بحوث الأراضي والمياه والبيئة - مركز البحوث الزراعية - مصر

اقيمت تجربة حقلية بمحطة بحوث البساتين بسخا - كفر الشيخ لمنطقة شمال الدلتا خلال موسمي ٢٠١٩ ، ٢٠٢٠م وذلك بهدف دراسة التأثير المشترك لنقص المياه واضافه الحديد المغناطيسي علي المحصول الكلي والمبكر للكوسة الصيفي وكذلك بعض العلاقات المائية للمحصول. وكانت معاملات الري (٥٠ ، ٦٥ و ٨٠٪ من الماء الميسر) وكذلك استخدام مستويان من الحديد المغناطيسي (٠ ، و ١٥٠ كجم / فدان MI) وتفاعلاتهما على إنتاجية وحده المياه (IWP) ، النمو الخضري ومكونات المحصول. بلغ إجمالي كمية مياه الري المضافة ٣٨٩,٢ و ٤٢٧,٠ و ٤٩٠,٥ مم في موسم ٢٠١٩ و ٤٠٠,٩ و ٤٣٦,٢ و ٥١٠,٧ ملم في ٢٠٢٠ تحت I_{80} (استنفاذ ٨٠%) و I_{65} (استنفاذ ٦٥%) و I_{50} (استنفاذ ٥٠%) من الماء المتاح على التوالي. سجلت انتاجيه وحده المياه أعلي القيم ١٣,٣٤ و ١٢,٩ كجم / م٣ مع I_{65} وMI F_2) لموسمي ٢٠١٩ و ٢٠٢٠ على التوالي. وأشارت النتائج ان كمية الماء المضاف واضافه الحديد المغناطيسي لها تأثير معنوي علي المحصول ومكوناته وكانت افضل التداخلات بين الماء المضاف واضافه الحديد المغناطيسي هي I_{50} وF_2. وتميل القيمة إلى الانخفاض تدريجيًا ، مع زيادة استنفاد المياه تحت I_{65} و I_{80} من CPE. اوضحت النتائج ايضا القياسات الخضرية تاثيرا معنويا بالري واضافه الحديد المغناطيسي كما كان تأثير التفاعل بين الري واضافه الحديد المغناطيسي تأثيرا معنويا لكل الصفات الخضرية.وعليه فتوصي الدراسة بانه يتم ري محصول الكوسة الصيفي عند ٥٠% من من الماء الميسر باستخدام البخر تجميعي من وعاء البخر مع أضافه ١٥٠ كجم/ فدان من الحديد المغناطيسي من أجل الحصول على محصول واعلى استفادة من وحدة المياه.