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Abstract

Maize is a crop that in Italy has high irrigation needs. In many cultivated areas the water used for irrigation has a high salinity. To limit the damage caused by the salts provided, suitable irrigation strategies can be adopted in relation to the crop and the type of soil and to the rainfall regime. Therefore, in order to evaluate the most appropriate irrigation strategy to be used in the cultivation on sandy clay loam red soil, in southern Italy, a research on a four-year rotation was carried. Two maize cultivars were compared, two levels of water salinity and 5 irrigation regimes were compared. Maize grain yield was reduced by 34% in the 3rd year crop rotation when the soil salinity was doubled. Higher yield occurred restoring 100% of maximum crop evapotranspiration (ETc), instead leaching requirement application didn’t affected yield. The application of lowest irrigation volume improved the irrigation water use efficiency. Salinity improved grain protein content and reduced moisture content. Rainfall was not sufficient to leach all the salts supplied with irrigation. The supply of more water as leaching requirement did not reduce the soil salinity and the harmful effect of salinity on maize crop yield because of the more salts supplied by more irrigation volume.

Keywords	Maize yield; Brackish water; Furrow irrigation; Irrigation WUE
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To the Editorial Board

Dear Editor,

I send you the paper work entitled "Agronomic response of maize (Zea mays L.) to water salinity and irrigation regime in southern Italy." to be submitted to the referees for a possible publication in your journal

The material presented is original and has not been submitted simultaneously for publication elsewhere.
In the hope that our article may be of interest to the scientific community, I would like to send my best regards.

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Sincerely
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Highlights:

Maize is a crop that in Italy has high irrigation needs

Maize grain yield was reduced by 34% when the soil salinity was doubled

Rainfall was not sufficient to leach all the salts supplied with irrigation

The supply of more water as leaching requirement did not reduce the soil salinity

Salinity improved grain protein content and reduced moisture content

Agronomic response of maize (Zea mays L.) to water salinity and irrigation regime in southern Italy.

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ABSTRACT

Maize is a crop that in Italy has high irrigation needs. In many cultivated areas the water used for irrigation has a high salinity. To limit the damage caused by the salts provided, suitable irrigation strategies can be adopted in relation to the crop and the type of soil and to the rainfall regime. Therefore, in order to evaluate the most appropriate irrigation strategy to be used in the cultivation on sandy clay loam red soil, in southern Italy, a research on a four-year rotation was carried. Two maize cultivars were compared, two levels of water salinity and 5 irrigation regimes were compared. Maize grain yield was reduced by 34% in the 3rd year crop rotation when the soil salinity was doubled. Higher yield occurred restoring 100% of maximum crop evapotranspiration (ETc), instead leaching requirement application didn't affected yield. The application of lowest irrigation volume improved the irrigation water use efficiency. Salinity improved grain protein content and reduced moisture content. Rainfall was not sufficient to leach all the salts supplied with irrigation. The supply of more water as leaching requirement did not reduce the soil salinity and the harmful effect of salinity on maize crop yield because of the more salts supplied by more irrigation volume.

Keywords: Maize yield; Brackish water; Furrow irrigation; Irrigation WUE

1. Introduction

Irrigation is a very important agronomic practice in agriculture. Today, the development of urbanization, industry and activities performed during leisure time competing for good water quality and this is leading to the decline of the use of good quality water for irrigation (Bergez and Nolleau, 2003; Qadir and Oster, 2004; Zwart and Bastiaansen, 2004), so an alternative could be the use of large salt water resources in the world (Mantell et al., 1985).

It is feasible to use salt water for irrigation but only for particular crops and soils and with appropriate water management (Oster, 1994; Shalhevet, 1994). Drip irrigation, with its low-release volume and frequent applications, can maintain a high matrix potential of the soil in the root zone and thus offset the decrease in osmotic potential caused by saline water while maintaining high total water potential for plant growth (Kang et al., 2010). Wan et al. (2007)

studied the effects of drip irrigation with saline water on tomato (*Licopersicum esculeuntum* Mill.) and pointed out that the variation of the electrical conductivity of water (EC_w) from 1.1 to 4.9 dS m^{-1} has little effect on yield of tomatoes but the efficiency of water use increases with the increase in water salinity; besides, the salinity of the soil along the 0-0.90 m profile did not increase after 3 years of irrigation. Chen et al. (2009) studied the effect of drip irrigation with saline water (EC_w between 1.6 and 10.9 dS m^{-1}) on high oleic sunflower crop (*Helianhtus annuus* L.). They noted that the emergency rate decreased by 2% for each dS m^{-1} increase when EC_w was above 6.3 dS m^{-1}, while yield declined by 1.8% for every dS m^{-1} increase when the EC_w was greater than 1.6 dS m^{-1}.

The maize (*Zea mays* L.), classified as moderately sensitive to salinity (Maas and Grattan 1999), is one of the world's leading crops, because the excellent starch composition is becoming a major raw material for the food, textiles, paper and feed industry (Fan et al., 2008; Kang et al., 2010; Tian et al., 2009). Most studies on this crop have shown that salinity is one of the main causes of plant stress (Mengal and Kirby, 1987). The intraspecific variability of corn to salinity is high (Schubert et al., 2009). The resistance to salinity can be improved by implementing strategies to avoid sodium toxicity in the second stage of the crop cycle and to overcome osmotic problems in the first stage of saline stress. In general, corn in salinity conditions shows stunted growth during the first phase, with dark green leaves but without symptoms of toxicity.

Several studies have also been carried out on the application of different irrigation systems to maize crops. Schneekloth et al. (2006) found that reducing water supply during vegetative growth has little effect on yield. Significant yield reductions can be attributed to water shortages during the reproduction phases (Bennett et al, 1989; Denmead and Shaw, 1960; Harder et al., 1982; Robins and Domingo, 1953; Schneekloth et al., 1991; Aguilar et al., 2007). It is well known that furrow irrigation is a less efficient method of irrigation respect to a pivot system, but the irregular form of some fields prevent the use of the latter method, so if the soil is clayey an alternative may be furrow irrigation (Nelson and Al-Kaisi, 2011). As a strategy for improving irrigation efficiency, Fischbach and Mulliner (1974), Sepaskhah and Kamgar-Haghighi (1997), Golzardi et al. (2017) and Yarami and Sepaskhah (2018) have used an every-other-furrow irrigation method reducing the amount of water applied. They have found that this method of irrigation decreases the evaporation of water from the surface of the soil and allows the soil to retain more water after a rainy event. Other studies have shown a reduction in both water leakage for deep percolation (Sepaskhah and Parand, 2006) and nitrate leaching (Lehrsch et al., 2000) with an irrigation with every-other-furrow with respect to the single furrow method.

In order to make a further contribution to this problem, the aim of this research was to evaluate the effects of two irrigation water salinity levels and different irrigation regimes on maize grown on a shallow clay soil resting on limestone rock sliced, in southern Italy, irrigated by furrow method.

2. Materials and methods

2.1. Study area and climatic conditions

The research was carried out at the experimental field of DISAAT of Bari University 'Aldo Moro' in the area of Valenzano (BA) (41°46' NL, 16°54' EL, 72 m a.s.l.).

The experiment consisted of a 4 year crop rotation with: grain maize, *Zea mays* L., (maize 1st year), sunflower, *Helianthus annuus* L., grain maize (maize 3rd year) and wheat, *Triticum durum* Desf.. The soil type was sandy clay loam red of good fertility, lying on bedrock characterized by fissured limestone (Ruphtic Lithic, USDA classification, Soil Survey Staff 1999), and 0.30 m deep.

The average monthly temperatures during the maize growing seasons (April-September) were reported in Fig. 1. Total precipitation during the maize cropping cycle (April-September 1st and 3rd year crop rotation) was 120 and 130.2 mm, respectively (Fig. 1). Evaporation from the "class A" evaporimeter on average varied from 5.8 (July) to 8.1 mm d^{-1} (August) in the first year and from 4.0 (May) to 8.4 mm d^{-1} (August) in the third one.

2.2. Experimental design and field management

The first three crops (grain maize, sunflower and grain maize) were irrigated by furrow irrigation. Two salinity levels of irrigation water (fresh and brackish water), with the electrical conductivity of 1.2 and 5 dS m^{-1}, respectively, and five irrigation regimes as follow, were compared (Table 1 and 2):

$IRC_{75\%}$ - Seasonal irrigation volume (SIV) of 75% of the maximum crop evapotranspiration (ETc);

$IRC_{100\%}$ - SIV equal of 100% of ETc;

$IRC_{100\%}LR_{50\%}$ - SIV of 100% of ETc plus 50% of leaching requirement (LR), calculated as:

$$LR = \frac{\mathrm{ECw}}{5\ \mathrm{ECe} - \mathrm{ECw}} \qquad (1)$$

where EC_w = electric conductivity of irrigation water (dS m^{-1}); EC_e = electrical conductivity of the saturated extract of the soil, corresponding to 10% reduction of the maximum yield, considered to be equal to 2.5 dS m^{-1}

$IRC_{100\%}LR_{100\%}$ - SIV of 100% of ETc plus 100% of LR calculated as above;

$IRI_{75\%}$ - SIV of 75% of ETc obtained by skipping one watering at the vegetative stage, supplying watering volumes equal to 100% ETc for three irrigations at the flowering stage and 75% ETc for the rest of the growing season.

The split-plot experimental design with four replicates was utilized: water types (fresh and brackish) were assigned to the plots and the 5 irrigation regimes to the sub-plots of 5 × 4.9 m. In the treatment $IRC_{100\%}$ irrigation was performed whenever the soil water matrix potential of layer explored by the roots reached -0.1 MPa, providing the irrigation volume required to bring the matrix potential to -0.03 MPa.

Based on these limits, the irrigation interval was determined by the evapotranspiration criteria, by the relationship:

$$L = V = \sum_{1}^{n} E_d K_p K_c \qquad (2)$$

where L = irrigation threshold, equal to cumulative maximum evapotranspiration, net of effective rainfall (mm);

V = watering volume corresponding to the irrigation regime of l00% ETc (mm);

E_d = daily evaporation from "class A" pan (mm);

K_p = conversion coefficient of E_d in reference crop evapotranspiration (ETo) (K_p = 0.8); K_c = crop coefficient, which is varied as follows: 0.4 from sowing to the fourth leaf; 0.9 from the fourth leaf at the start of male inflorescence; 1.1 from the issue of male inflorescence to milk maturation; 0.6 from milk to waxy maturation.

Maize seeds of two commercial hybrids F1 class FAO 400 (‘PR35A52’ and ‘DKC5143’ in the 1^{st} and 3^{rd} year of the crop rotation, respectively) were sowed on April on previously fertilized soil with 75 kg ha^{-1} of N and 150 kg ha^{-1} of $P_2 0_5$. A different maize hybrid was used in the second crop cycle (3^{rd} year of the crop rotation) because seeds of PR35A52 were not available. The sowing was performed in rows 70 cm apart and at 25 cm distance along the row. At the beginning of the crop cycle of the second crop cycle of maize, the EC_e was on average 1.2 and 3.1 dS m^{-1}, respectively for the previously watered soils with fresh water and brackish water.

Immediately after sowing, to facilitate the emergence of crops, 3 watering by sprinkler method were carried out using fresh water, giving a total volume of 600 m^3 ha^{-1} of water. Subsequently, until the waxy ripening the expected treatments were applied, adopting the furrow irrigation method. Both years, chemical weeding was carried out, while during the crop cycle pest control was performed against slugs and pyralide.

2.3. Plant materials and measurements

The main morphological and productive parameters were measured at the grain harvest on September. The grain moisture content at threshing was determined in the laboratory after drying for 48 h at 65 °C (yield was expressed at 13.5% of moisture).

Irrigation water use efficiency (IWUE) is calculated as the ratio between marketable yield and seasonal irrigation volume:

$$\mathrm{IWUE} = \frac{\mathrm{Y}}{\mathrm{I}} \quad (3)$$

where Y is the maize grain yield (kg ha^{-1}), I is seasonal irrigation volume (m^{-3} ha^{-1}) (Wang et al. 2015; Ali et al., 2018).

Kernel protein, fat and starch content were determined by near-infrared reflectance spectroscopy (NIRS) using Infratec 1241 Grain analyzer (Foss Tecator, Sweden) and expressed in a percentage dry matter of grain. Data were submitted to the analysis of variance and the differences between means were analyzed following the Duncan test.

3. Results and Discussion

3.1. Irrigation regimes and salinity levels

The seasonal irrigation volumes administered to the crop during the two years the maize cultivation cycle, including the quantities of water distributed immediately after sowing to encourage germination and emergence of the seedlings, amounted to 2275 and 3024 m^3 ha^{-1} in the 1st year and to 3135 and 3976 m^3 ha^{-1} in the 3rd year, respectively in $IRC_{75\%}$ and $IRC_{100\%}$ treatments; the same irrigation volumes were administrated in both salinity treatments. In $IRC_{100\%}LR_{50\%}$ and $IRC_{100\%}LR_{100\%}$ treatments, the seasonal irrigation volume was different between salinity levels. In fact, in the first year the values of this parameter were equal to 3174 and 3330 m^3 ha^{-1} (fresh water) and to 4038 and 5050 m^3 ha^{-1} (brackish water) respectively in $IRC_{100\%}LR_{50\%}$ and $IRC_{100\%}$ $LR_{100\%}$; in the third year, on the other hand, they amounted to 4142 and 4300 m^3 ha^{-1} (fresh water) and 5091 and 6200 m^3 ha^{-1} ((brackish water), respectively for the two irrigation regimes (Table 2).

The yield results were different in the two years both because the cultivars were different and, mainly, due to the negative effect on soil fertility of the solutes accumulated in plots irrigated with brackish water during the previous irrigation seasons. The amount of salt brought to the soil with the irrigation water during the 3 irrigated seasons, related to the three crops in succession of our study (maize, sunflower, maize), has changed in relation to irrigation regimes and salinity levels. In particular, between fresh and brackish water it has gone from 6.54 to 28.42 Mg ha^{-1} with the lowest seasonal irrigation volume ($IRC_{75\%}$ and $IRI_{75\%}$) and from 8.99 to 59.36 Mg ha^{-1} with the highest irrigation volume (Table 3). The salts supplied during irrigation have led to an increase in the electrical conductivity of the saturated extract (EC_e) of the soil up to the highest values at the end of the irrigation season and the lowest values at the end of the rainy season (Fig. 2). Most likely, the addition of saline-sodium leaching water to the shallow clay soil resting on cracked limestone rock favored the formation of transient salinity (Rengasamy, 2002), responsible for soil EC_e increase at the end of the irrigation season, subsequently removed with the rainwater falling during the winter. It is interesting to note that autumn-winter precipitation rates of 394 and 250 mm, occurred respectively in the first and third year of crop rotation, have leached salts supplied by irrigation reducing the EC_e of 68 and 39% when watered with fresh water and 71 and 43% when irrigated with brackish water (Fig. 2).

In both years no significant effects of saline treatments and different irrigation regimes on seed germination and on seed emergence are highlighted. Such results are similar to those observed by Maas et al. (1983) which found a good germination and emergence of maize under saline conditions. The analysis of variance showed significant effects both of the salinity of water and of the irrigation regimes on some morphological and productive parameters of maize (Table 4); there are no significant effects of the interactions between salinity and irrigation systems. The height of the plants in 1st year was not influenced by salinity levels, while in 3rd year it varied on average from 2.59 to 1.97 m, respectively in fresh and brackish treatments (Fig. 3) ; the average length of the ears was higher in 3rd year than in 1st year (20.5 cm vs. 19.3 cm), probably because the two cultivars used had different characteristics (Fig. 4). While the length of the fertile part of the spikes completely developed in 1st year recorded, on average, higher values (16.8 and 16.7 cm) in $IRC_{100\%}LR_{100\%}$ and $IRC_{100\%}LR_{50\%}$ treatments, using brackish water and fresh water respectively; in the 3rd year, on the other hand, using salty water, the lowest values were recorded in $IRC_{75\%}$; when fresh water was used, however, no significant differences were observed due to irrigation regimes (Table 4). As the salinity of the water and the irrigation regime varies, in both years there were no significant differences in the number of rows of kernels per ear. This parameter is most influenced by genetic factors and not by agronomic techniques (Sadeghi and Rahimi, 2015). Also Kang et al. (2010) did not find any significant differences in the number of carioxide rows per ear as the irrigation quality and regime changes. According to other studies reported in the literature, the number of kernels per row varied in line with the length of the fertile part of the ear (Baghdadi et al., 2012; Sarlangue et al., 2007; Turgut et al., 2005) (Table 4). Echarte et al. (2000) argued that increased maize plant density reduced the number of kernels in the rows. The average amount of grain per ear, on average, in the first year was not affected by water quality, whereas in the third year one it was significantly higher when fresh water than brackish water was used (228 versus 166 g ear^{-1}). As a consequence, the use of brackish water in the first year has shown low reduction in grain yield compared with fresh water. This decrease was lower than that foreseen by the Maas and Hoffman (1977) equation for a value of EC_e of 3 dS m^{-1}. In fact, the Mass and Hoffman's equation estimated a 16% reduction in maize yield, while in our research the reduction was only 1.3%. In the second crop cycle of maize, grain yield, on average, varied from 10.2 to 6.8 Mg ha^{-1}, respectively with fresh and brackish water (Fig. 5), most likely due to the accumulation of solutes in the soil during the three irrigation seasons, despite the effect of the rainfall and the supply of leaching water requirements (Cucci et al., 2016).

Although the use of brackish water for irrigation is traditionally based on the application of excess water (leaching requirements) in order to maintain low salinity in the root zone to minimize yield loss caused by salinity (Ayers and Westcot,1985), the increasing amount of water used also increases the salts added to the soil, so the addition of more water does not necessarily correspond to an optimal use of it (Amer, 2010; Russo and Baker, 1987).

Moving from the less abundant irrigation regime ($IRC_{75\%}$) to the more intense ($IRC_{100\%}$ $LR_{100\%}$), in the first year the quantity of grain per ear increased from 163 to 229 g and from 145.3 to 218.4 g, while in the third year on the crop rotation one from 195.8 to 269.1 and from 144.6 to 204.4, irrigating with fresh water and brackish water respectively (Table 4). As a result, grain yield with 13.5% humidity, passing from the less abundant irrigation regime to the more intense, increased in 1st year by 34.8% and 33.8% and in 3rd year by 30.3% and 21.9% by irrigating with fresh and brackish water, respectively (Table 4).

In both years the yield obtained in $IRI_{75\%}$ did not deviate from that obtained in $IRC_{75\%}$. These results are in agreement with what was found by Sadeghi and Rahimi (2015). Also

Elsworth et al. (1992) found in the maize plant the ability to deepen the roots in the soil to use the stored water reserve keeping a water content in the plant tissues high and stable.

3.2. Irrigation water use efficiency

Since irrigation water use efficiency is a useful indicator for an effective planning of irrigation water management, particularly in arid and semiarid areas (Dehghanisanij et al. 2009; Igbadun et al. 2006; Qureshi et al. 2010; Wang et al. 2015), it was considered appropriate to investigate this parameter. The irrigation water use efficiency (IWUE) values, calculated for the different treatments, are shown in Fig. 6. In 1st year the IWUE on average was equal to 2.34 kg m^{-3}, without showing significant differences between salinity levels. In 3rd year, instead, the values were higher when the crop was irrigated with fresh water (on average 2.99 kg m^{-3} versus 2.01 kg m^{-3}). In any case, the highest IWUE was recorded in $IRC_{75\%}$.

3.3. Maize grain quality

In the first year, no difference was observed in the composition of the kernels with the variation in the quality of irrigation water (Table 5). In the third year, instead, by irrigating with brackish water, the grain protein content increased by 6.9% and the moisture content decreased of 9.3%, compared to the grain obtained by irrigating with fresh water. This latter aspect could be an advantage as low-humidity of grain maize makes it less susceptible to fungal pathogens with consequent reduction of mycotoxins contamination risk (Weinberg et al., 2008).

While other authors have found that soluble proteins increase with salinity in many plants and decrease in many others (Agastian et al., 2000; Parida et al., 2004). Goudarzi and Pakniyat (2009) also report that, under saline conditions, protein accumulation was generally higher in stress tolerant maize crops than susceptible ones.

In both years, no significant effects of irrigation regimes and of the interaction between salinity level and irrigation regimes were observed on the grain composition (average values of grain moisture, starch, protein and fats were of 15.4, 71.9, 9.0, 4.1% in the 1st year and 15.3, 71.6, 8.9, 4.2% in the 3rd year).

4. Conclusions

From the results of research on a maize cultivation, for two years in Southern Italy, within of a maize-sunflower-maize crop rotation, on sandy clay loam soil, shallow (0.30 m), resting on fissured calcareous rock, irrigated by furrows, with two salinity levels of irrigation water and five irrigation regimes (of which two with contribution of leaching requirements), to evaluate the productive response of the crop in an environment characterized by an average annual rainfall of 450 - 500 mm, the following conclusions can be drawn. The production of grain obtained in the first year was not influenced by the level of salinity, while in the third year of crop rotation, when the EC_e had doubled, there was a reduction of 34%. For both irrigation water salinity levels the best production results were obtained by supplying 100% of the ETc. The supply of leaching requirements did not help to improve yield. The highest IWUE was registered by supplying 75% of the ETc.

Variations in the grain composition were evident only in second crop cycle of maize, irrigating with brackish water, reducing the moisture content and increasing the protein content. The rainfall that occurred during the trial period was not sufficient to leach all the salts supplied with irrigation, from which a different response of the maize crop to salinity in the two years was achieved. In both years there were no changes in grain composition related to watering regimes, while significant effects of interactions between salinity level and irrigation regime were observed.

Contrary to the literature, the supply of more water as leaching requirement do not reduce the soil salinity and the harmful effect of salinity on maize crop yield because of the more salts supplied by more irrigation volume. Therefore, in the management of irrigation in the presence of brackish water, to avoid the excessive accumulation of salts in the soil or the consumption of too much water, it is necessary to know well the pedoclimatic conditions in which it operates.

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CAPTION TO FIGURES

Fig. 1. Monthly mean temperatures and total monthly rainfall during the maize cropping cycles.

Fig. 2. Electrical conductivity of the saturation soil extract (ECe) at the end of the rainfall season (March) and at the end of the irrigation season (August), in the 1^{st} and 3^{rd} year of crop rotation.

Fig. 3. Mean height of maize plants related to the quality of irrigation water, in the 1^{st} and 3^{rd} year of crop rotation. Different letters accompanying each bar indicate a significant difference according to Duncan test ($p = 0.01$).

Fig. 4. Length of maize ears related to watering regimes in the 1^{st} and 3^{rd} year of crop rotation. IRC75% = Seasonal irrigation volume of 75% of the crop evapotranspiration; IRI = Seasonal irrigation volume irregular. Different letters accompanying each bar indicate a significant difference according to Duncan test ($p = 0.05$).

Fig. 5. Maize yield related to irrigation water salinity, in the 1^{st} and 3^{rd} year of crop rotation. Different letters accompanying each bar indicate a significant difference according to Duncan test ($p = 0.01$).

Fig. 6. Irrigation water use efficiency (IWUE) for maize related to water regimes in the 1^{st} and 3^{rd} year of crop rotation. IRC75% = Seasonal irrigation volume of 75% of the crop evapotranspiration, IRI = Seasonal irrigation volume irregular. Different letters accompanying each bar indicate a significant difference according to Duncan test ($p = 0.05$).

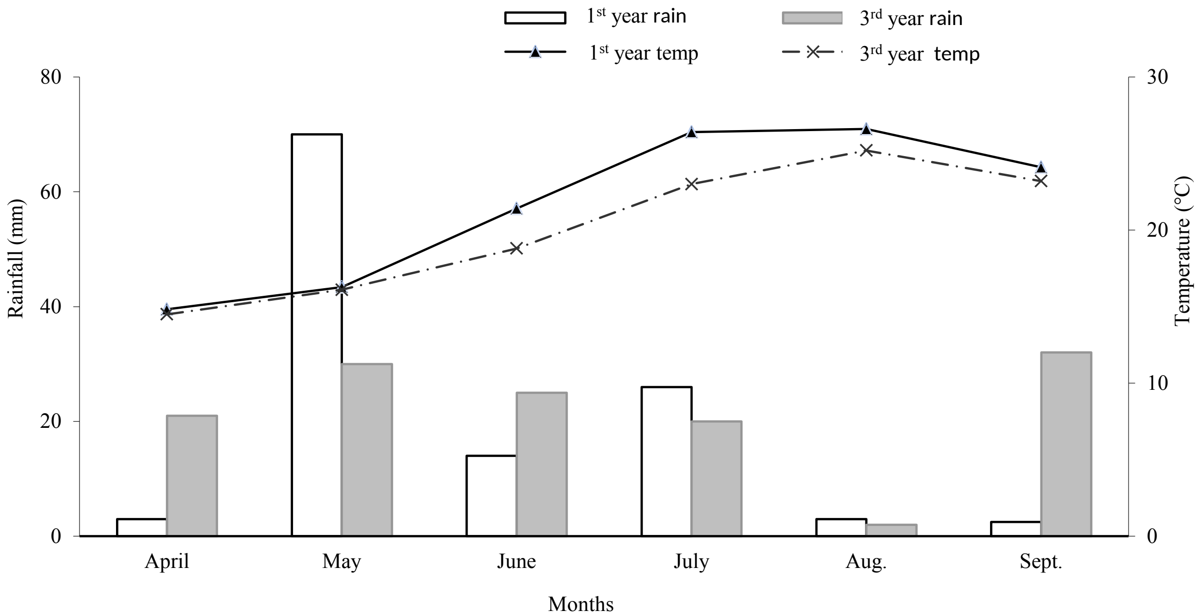
1st year rain
3rd year rain
1st year temp
3rd year temp
80
60
40
20
0
30
20
10
0
Rainfall (mm)
Temperature (°C)
April
May
June
July
Aug.
Sept.
Months

Fig. 1.

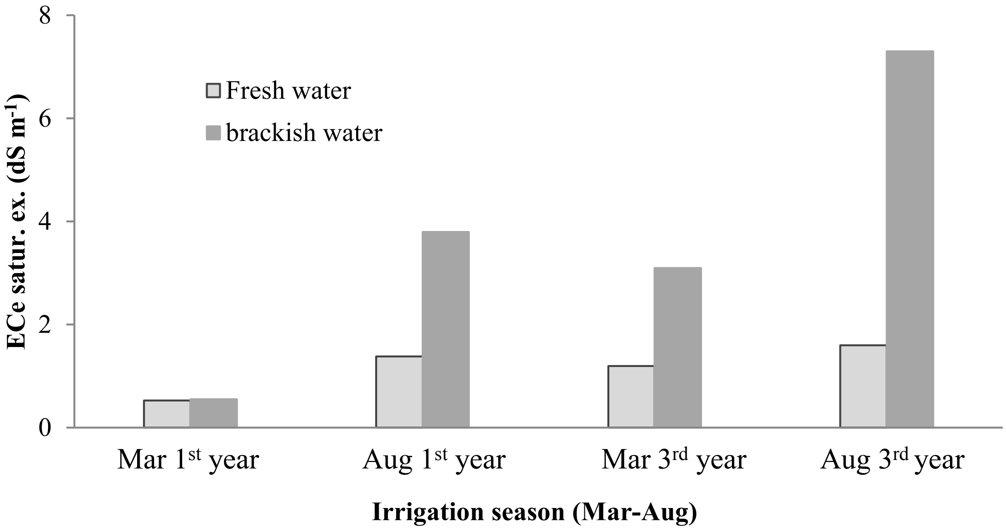
8
6
4
2
0
ECe satur. ex. (dS m-1)
Fresh water
brackish water
Mar 1st year
Aug 1st year
Mar 3rd year
Aug 3rd year
Irrigation season (Mar-Aug)

Fig. 2.

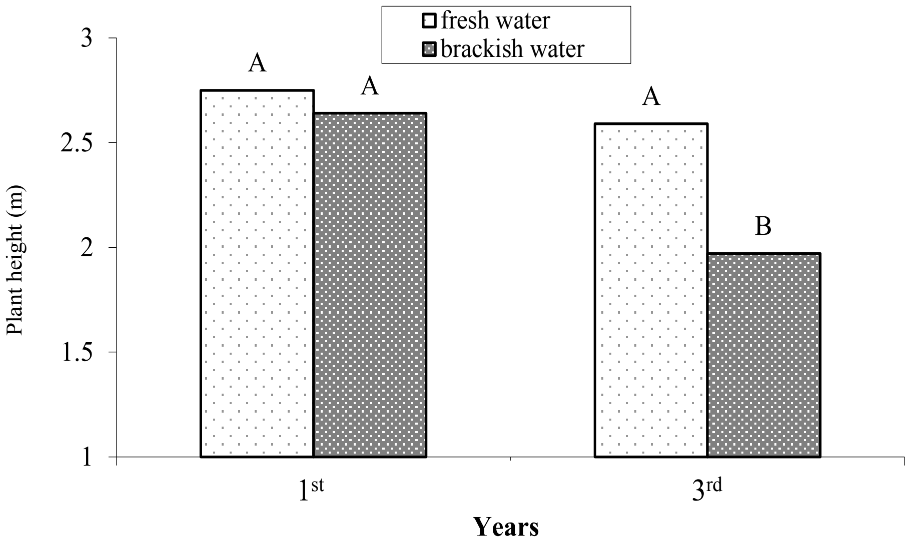
fresh water
brackish water
3
2.5
2
1.5
1
Plant height (m)
A
A
A
B
1st
3rd
Years

Fig. 3.

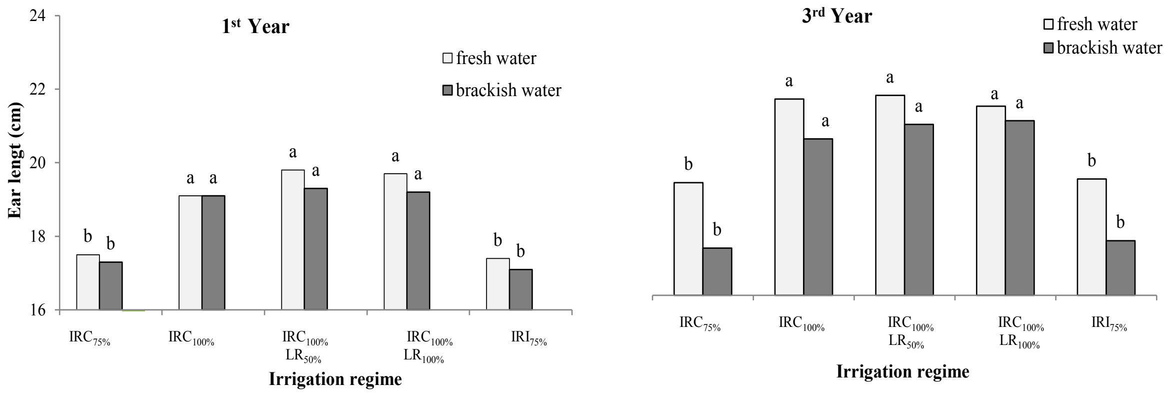
1st Year
3rd Year
fresh water
brackish water
Ear lengt (cm)
24
22
20
18
16
a
b
IRC75%
IRC100%
IRC100% LR50%
IRC100% LR100%
IRI75%
Irrigation regime

Fig. 4.

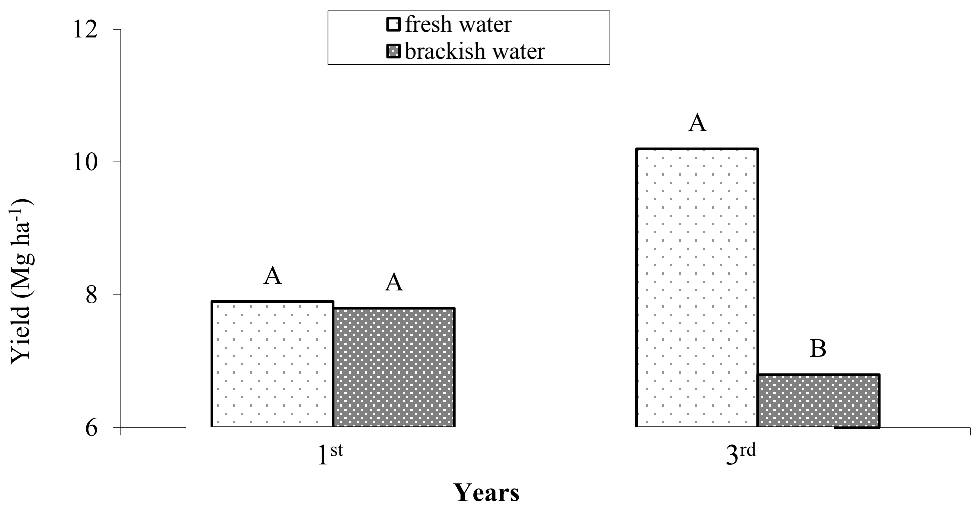
fresh water
brackish water
12
10
8
6
Yield (Mg ha-1)
A
A
A
B
1st
3rd
Years

Fig. 5.

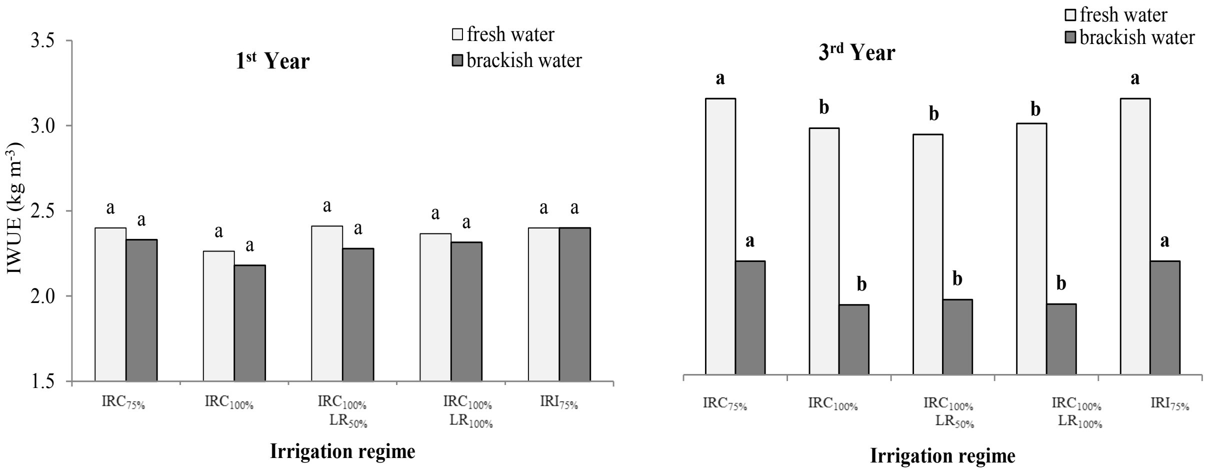
1st Year
3rd Year
fresh water
brackish water
IWUE (kg m-3)
3.5
3.0
2.5
2.0
1.5
IRC75%
IRC100%
IRC100% LR50%
IRC100% LR100%
IRI75%
Irrigation regime
a
b

Fig. 6.

Table 1. Water quality characteristics

Type of water	EC (dS m^{-1})	Na^+	Ca^{2+}	Mg^{2+}	$HC0_3^-$	$C0_3^{2-}$	adj SAR[(a)]
		(meq L^{-1})					
Fresh water	1.2	2.3	4.9	1.2	4.7	0.4	1.4
Brackish water	5.0	35.5	9.9	5.0	6.6	1.2	14.5

Adj SAR = adjusted Sodium Adsorption Ratio, [(a)]Calculated according to the indications by Suarez (1981)

Table 2. Seasonal irrigation volumes (m^3 ha^{-1}) applied to maize using two types of water.

Irrigation regime	Type of water: electrical conductivity (dS m^{-1})			
	Fresh water: 1.2		Brackish water: 5	
	Years		Years	
	1[st]	3[rd]	1[st]	3[rd]
$IRC_{75\%}$	2275	3135	2275	3135
$IRC_{100\%}$	3024	3976	3024	3976
$IRC_{100\%}LR_{50\%}$	3174	4142	4038	5091
$IRC_{100\%}LR_{100\%}$	3330	4300	5050	6200
$IRI_{75\%}$	2275	3135	2275	3135

IRC = Seasonal irrigation volume of % of the maximum crop evapotranspiration, IRI = Seasonal irrigation volume irregular, LR = leaching requirements.

Table 3**.** Amount of salts supplied to the soil through irrigation water in the 3 year trial (Mg ha^{-1}) [(a)]

Irrigation regime	Type of water (dS m^{-1})	
	1.2	5.0
$IRC_{75\%}$	6.54	28.42
$IRC_{100\%}$	8.23	36.21
$IRC_{100\%}LR_{50\%}$	8.59	47.86
$IRC_{100\%}LR_{100\%}$	8.99	59.36
$IRI_{75\%}$	6.54	28.42

[(a)] The amount of salts brought to the soil through irrigation water were calculated by using the relationship reported in Richards (1954), between the electrical conductivity of a solution and the corresponding average salt concentration.

Table 4. Effect of water salinity and irrigation regime on morphological and production parameters of maize in the first (1[st]) and third year (3[rd]) of crop rotation.

Years	Irrigation regime	Ear length (cm) [(a)]		Kernel per row (N)		Yield ear^{-1} (g)		Weight of 1000 kernel (g)		Yield (Mg^{-1} ha)[(b)]	
		FW	BW	FW	BW	FW	BW	FW	BW	FW	BW
1[st]	$IRC_{75\%}$	15.6b	15.4b	29.5b	27.2b	163.0b	145.3b	275.6c	261.4c	6.9b	6.7b
	$IRC_{100\%}$	16.4a	16.4a	32.7a	29.3a	181.8ab	175.8ab	289.8b	284.9b	8.2ab	7.9ab
	$IRC_{100\%}LR_{50\%}$	16.8a	16.7a	34.3a	34.5a	200.6a	201.3a	295.2b	291.3b	8.7a	8.6a
	$IRC_{100\%}LR_{100\%}$	16.7a	16.6a	35.1a	36.1a	229.0a	218.4a	318.1a	312.0a	9.3a	9.1a
	$IRI_{75\%}$	15.4b	15.3b	30.1b	28.2b	163.2b	146.2b	281.3c	271.4c	6.9b	6.9b
3[rd]	$IRC_{75\%}$	16.5ab	16.3ab	35.1ab	28.9ab	195.8b	144.6b	292.6c	251.2c	8.9b	6.2b
	$IRC_{100\%}$	17.0a	16.8a	37.8a	32.1a	249.7a	178.6a	324.2b	279.8b	10.6a	7.0a
	$IRC_{100\%}LR_{50\%}$	17.8a	17.2a	39.2a	34.7a	258.2a	181.8a	331.1b	284.7b	10.9a	7.3a
	$IRC_{100\%}LR_{100\%}$	17.1a	16.9a	39.1a	34.6a	269.1a	204.4a	345.3a	292.1a	11.6a	7.5a
	$IRI_{75\%}$	16.6ab	16.2ab	34.6ab	29.8ab	180.4b	134.7b	306.4c	257.5c	8.9b	6.1b

FW = Fresh Water, BW = Brackish Water, [(a)] fertile part of the ear, [(b)] Moisture content of 13.5%. Different letters accompanying each bar indicate a significant difference according to Duncan test (p = 0.05).

Table 5. Grain quality of maize related to the different quality of irrigation water of maize in the first (1st) and third year (3rd) of crop rotation.

Years	Water quality	Grain moisture (%)	Starch (%)	Protein (%)	Fats (%)
1st	Fresh Water	15.5a	71.8a	8.9a	4.1a
	Brackish water	15.2a	72.1a	9.1a	4.2a
3rd	Fresh Water	16.1a	71.7a	8.6b	4.3a
	Brackish water	14.6b	71.6a	9.2a	4.1a

Different letters accompanying each bar indicate a significant difference according to Duncan test ($p = 0.05$).