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Evaluation of Quality of Some Well Waters Used in Agricultural Irrigation in terms of Plant Nutrition

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Abstract

In this study, where the suitability of groundwater for irrigation in terms of soil and plants was evaluated, samples were taken from 11 drilling wells used for irrigation in some regions of Kahramanmaraş province. Chemical parameter values such as pH, EC, RSC, SAR, TDS, TH, Na%, PI, SSP, MR, KR, PS were determined in the assessment of irrigation water quality. According to irrigation water quality criteria, all samples except for two samples were in the medium salt/low sodium water (C2S1) class in terms of EC values. TH values were determined as soft water in all well waters. It was determined that the well waters were not suitable for irrigation in terms of plants and soils, including 3 in terms of Na%, SSP, MRI and KR values, 2 for Boron, SAR and RSC values, and one each for pH and PI values. As a result, these wells, which are evaluated problematic for soil and plants in terms of special ionic, salinity and alkalinity, should be used by taking the necessary precautions or should not be used for irrigation.

Keywords: Kahramanmaraş, irrigation water quality parameters, plant and soil, salinity and alkalinity, SAR

Tarımsal Sulamada Kullanılan Bazı Kuyu Sularının Kalitelerinin Bitki Besleme Açısından Değerlendirilmesi

Öz

Yeraltı sularının toprak ve bitkiler açısından sulama için uygunluğunun değerlendirildiği bu çalışmada, Kahramanmaraş ilinin bazı yörelerinde sulama amacıyla kullanılan 11 adet sondaj kuyusundan örnekler alınmıştır. Sulama suyu kalitesinin değerlendirilmesinde pH, EC, RSC, SAR, TDS, TH, Na%, PI, SSP, MR, KR, PS gibi kimyasal parametre değerleri belirlenmiştir. Kalite kriterlerine göre, iki örnek dışında tüm örnekler EC değerleri bakımından orta tuzlu/az sodyumlu su (C2S1) sınıfında yer almışlardır. TH değerleri, bütün kuyu sularında yumuşak su olarak saptanmıştır. %Na, SSP, MR ve KR değerleri bakımından 3, Bor, SAR ve RSC değerleri için 2, pH ve PI değerleri bakımından ise birer adet olmak üzere kuyu sularının bitki ve toprak açısından sulamaya uygun olmadığı tespit edilmiştir. Sonuç olarak, özel iyonik, tuzluluk ve alkalilik açısından toprak ve bitkiler için problemli olarak değerlendirilen bu kuyular gerekli önlemler alınarak kullanılmalı ya da sulama amaçlı kullanılmamalıdır.

Anahtar Kelimeler: Kahramanmaraş, sulama suyu kalite parametreleri, bitki ve toprak, tuzluluk ve alkalilik, SAR

INTRODUCTION

The quality of irrigation water is very important in terms of soil fertility and plant nutrition, and it is adversely affected by the mixing of agricultural (fertilizers and pesticides), industrial and domestic wastewater with underground and surface waters, as it varies depending on the geology of

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its location (Kaykıoğlu and Ekmekyapar, 2005). The amount of cations and anions dissolved in the irrigation water determines the quality of that water and plays an important role directly and indirectly in terms of plant nutrition. It is an indirect effect that salt accumulated in the soil with water increases the osmotic pressure in the soil and causes physiological drought. The fact that elements and chemical compounds such as B, Cl, Na and HCO_3 in the irrigation water accumulate in the plant in large amounts and the growth of the plant slow down to the point, which it stops, is also direct effect (Grismer, 1990; Arslan et al., 2007; Jalali and Merrikhpour, 2008; Laz et al., 2018). However, the quality of irrigation water may also vary according to plant types such as halophyte and glycophite plant groups. In determining the quality of irrigation water; Electrical Conductivity (EC), anion (HCO_3^-, CO_3^{-2}, Cl-, SO_4^{-2}), cation (Na^+, K^+, Ca^{+2}, Mg^{+2}) content, various parameters [(Sodium Adsorption Rate (SAR), Residual Sodium Carbonate (RSC), Percent Sodium (Na%), Kelley Ratio (KR), Magnesium Content (MR), Permeability Index (PI), Total Hardness (TH), Potential Salinity (PS)] and graphical methods (Piper, US salinity, Wilcox diagrams, etc.) are used. Many researchers have used SAR, RSC, KI, PI, MR, PS and Na% values to evaluate the use of surface and groundwater as irrigation water (Arumugam and Elangovan, 2009; Ishaku et al., 2012; Nag and Ghosh, 2013; Wanda et al., 2013; Vincy et al., 2015; Al-Omran et al., 2017). In this study, it was aimed to determine for the suitability of the quality of groundwater taken from 11 wells used for agricultural irrigation in terms of plant nutrition in Onikişubat, Dulkadiroğlu, Göksun and Çağlayancerit regions of Kahramanmaraş in 2019 and 2020.

MATERIAL AND METHOD

Taking Groundwater Samples from Wells

In line with the demands of the farmers and water samples from 11 different boreholes used for irrigation in their fields at the locations and dates indicated in Table 1 two samples were taken from each well in line with the criteria determined by Ayyıldız (1990). Water samples were stored in 250 ml sterilized polyethylene plastic bottles at +4 °C in the refrigerator until analysis time.

Table 1. Locations and dates of samples taken from wells
Çizelge 1. *Kuyulardan alınan örneklerin lokasyonları ve tarihler*

Well Number	Taken place (district-neighborhood)	Year	Month
1. Well	Onikişubat - Suçatı	2019	April
2. Well	Onikişubat - Kümperli	2019	April
3. Well	Dulkadiroğlu - Çınar	2019	August
4. Well	Onikişubat - Kılavuzlu	2019	September
5. Well	Oniki şubat - Ilıca	2020	April
6. Well	Göksun - Taşoluk	2020	April
7. Well	Çağlayancerit - Fatih	2020	August
8. Well	Dulkadiroğlu - Çokyaşar	2020	August
9. Well	Dulkadiroğlu - Osman Bey	2020	August
10. Well	Onikişubat - Hacımustafa	2020	August
11. Well	Onikişubat - Kürtül	2020	August

Analysis of Taken Water Samples

In order to determine the properties of the samples taken, EC, pH, Na, Ca, K, Mg, CO_3, HCO_3, Cl and SO_4 analyzes were made. Their pH was determined by Mettler Toledo Seven Compact pH meter and electrical conductivity (EC) by Ezdo PL-700 AL brand EC meter devices. Taken from wells, concentrations of 4 major elements (Na, K, Ca, Mg) (me L^{-1}) and 12 trace elements (Al, B, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, and Zn) (mg L^{-1}) were measured by Agilent 5100 SVDV brand ICP-OES device (APHA, 1989). CO_3^{-2}, HCO_3^-, SO_4^{-2} and Cl^- concentrations were determined by titration method (Richards, 1954). The following 10 equations were used to determine the suitability of the well waters in terms of quality classes and plant nutrition:

Residual sodium carbonate (RSC): $(CO_3^{-2}+HCO_3^{-2})-(Ca^{+2}+Mg^{+2})$ (*meq* L^{-1}), (*Eaton*, 1950; Ragunath, 1987; *Aghazadeh and Mogoddam*, 2010). (1)

***Sodium adsorption rate (SAR)*:** $[Na/\sqrt{((Ca+Mg)/2)}]$ (*meq* L^{-1}), (*Catrol*, 1962; *Freeze and Cherry*, 1979). (2)

***Total amount of dissolved matter (TDS)*:** 0.64**EC* (*mg* L^{-1}), (*Catrol*, 1962; *Freeze and Cherry*, 1979). (3)

Total hardness (TH): 2.497*Ca+4.115*Mg (*mg* L^{-1} *Ca* CO_3), *Sawyer and McCartly*, 1967; *Todd*, 1980). (4)

Exchangeable sodium percentage (Na%, ESP): $[Na^{+}/(Na^{+}+K^{+}+Ca^{+2}+Mg^{+2})]*100$ (%), (*Wilcox*, 1955; *Todd*, 1960). (5)

Permeability index (PI): $[(Na^{+}.\sqrt{HCO_{3}^{-}})/(Na^{+}+Ca^{+2}+Mg^{+2})]*100$ (%), (*Doneen*, 1964). (6)

Soluble sodium percentage (SSP): $[(Na^{+}+K^{+})/(Na^{+}+K^{+}+Ca^{+2}+Mg^{+2})]*100$ (%), (*Todd*, 1960). (7)

Magnesium ratio (MR): $[Mg^{+2}/(Mg^{+2}+Ca^{+2})]*100$ (%), (*Szabolcs and Darab*, 1964; *Raghunath*, 1987). (8)

Kelley ratio (KR): $Na^{+}/(Ca^{+2}+Mg^{+2})$ ($meq\ L^{-1}$), (*Kelley*, 1963). (9)

Potential salinity (PS): $Cl^{-} + {}^{1}/_{2}.SO^{-2}$ ($meq\ L^{-1}$), (*Doneen*, 1964). (10)

Statistical Analysis

Descriptive statistical analyzes of the data obtained as a result of laboratory studies were made using IBM SPSS Statistics 25.0 program.

RESULTS AND DISCUSSION

Descriptive Statistics of Chemical Parameters of Well Waters

Descriptive statistical data of chemical analysis of samples uptaken from wells are given in Table 3. The calculated coefficient of variation (CV) values were the highest parameter, RSC (817.42%), while the lowest parameters were Cd (0.00%), Co (0.00%), Cu (0.00%), Ni (0.00%) and Zn (0.00%) is. Generally, it shows low variability if CV <10%, moderate variability if 10%< CV< 100%, and high variability when CV> 100% (Zhou et al., 2012; Ağca, 2014). According to this classification, pH, Cd, Co, Cu, Ni and Zn values of waters are low variability, and RSC, Boron, Na, K, Cl, SO4, Al, Cr, Fe, Mn, Pb, %Na, PI, SSP, KR and PS values showed high variability, while other parameters also showed moderate variability (Table 3). Low CV values indicate homogeneous distribution of parameters, while high CV values indicate non-homogeneous distributions (Ağca, 2014). While the cation sequences were from large to small, $Na^{+} > Ca^{+2} > Mg^{+2} > K^{+}$, the anion sequences were determined as $HCO_{3}^{-} > Cl^{-} > SO_{4}^{-2}$. The sequence in the trace elements was also obtained as Al> Fe> Pb> Cd = Co = Cr = Cu = Mn = Ni = Zn (Table 3). Piper (1944) diagram was used to classify the types of according to the major anions and cations of the well waters used in this study. According to this; it was determined that wells of 1, 2, 4, 5, 6, 8 and 9th were Mg-HCO_3 type, wells 3 and 7 were Na-Cl type, well of 10th was mixed type and well of 11th was Na-HCO_3 type waters. Since the mineral content of the water varies according to the rocks it is in contact with and the dissolving conditions affecting these rocks, it is closely related to the interaction also with the bedrock and parent material it passes through (Karataş et al., 2016). Dissolved ions in excessive amounts in irrigation water adversely affect the chemical and physical structure of the soil and the growth of plants. The suitability of groundwater for irrigation in terms of plant nutrition depends on the effect of mineral concentrations on the soil and plants (Ekmekçi et al., 2005). Increased the concentration of dissolved ions in its content increases the electrical conductivity value (EC) and thus the total dissolved matter amount (TDS). TDS amount of water increases depending on natural resource, agricultural, urban, sewage and industrial wastewater (WHO, 2003). Since the hardness (TH) of the water is caused by the dissolved Ca^{+2} and Mg^{+2} ions, the excess of these ions has an enhancing effect TDS and EC.

Quality Parameters of Well Water and Suitability for Irrigation

pH: It affects the heavy metal content, carbonate balance and relative proportion of nitrogen components, thus soil quality and plant growth. In acidic waters, calcium and magnesium cannot be absorbed sufficiently by plants. Alkaline waters provide a better environment for plants to absorb various metals and plant nutrients. However, basic waters are responsible for the accumulation of calcium carbonate, which affects the physical structure of water (Şimşek and Gündüz, 2007). The absence of CO_3 in water indicates that pH is mainly related to HCO_3 hydrolysis (Zhou et al., 2012). The pH of the wells in this study varies between 7.20-9.70 and they are slightly alkaline waters with an average value of 7.83 (Table 3). Ayers and Westcot (1985) stated that the appropriate pH value for irrigation water is between 6.50-8.40. For this reason, only the third well out of the 11 sampled wells are not suitable for irrigation (Tables 2 and 4).

Electrical conductivity (EC): The EC concentrations of the waters taken from the wells are 345-2100 μS cm^{-1}, and the average is 740.55

Table 2. Classification of irrigation water quality criteria
Çizelge 2. *Sulama suyu kalite kriterlerinin sınıflaması*

Parameter	Range	Water class	Parameter	Range	Water class
pH[1]	6.5-8.4	Appropriate	PI (%)[9]	<25	Class III-Not suitable
				25-75	Class II-Good
EC (µmbos cm^{-1})[2]	0-250	C1 Slightly saline water		>75	Class I-Excellent
	250-750	C2 Moderately saline water			
	750-2250	C3 Strongly saline water	SSP (%)[8]	0-20	Excellent
	>2250	C4 Very strongly saline water		20-40	Good
RSC (me L^{-1})[3]	<1.24	Safe		40-60	Permissible
	1.24-2.5	May vary depending on the plant		60-80	Suspicious
	>2.5	Not available		>80	Not available
SAR[2]	0-10	S1 Less sodium water	MR (%)[10-11]	<50	Appropriate
	10-18	S2 Moderately sodium water		>50	Not available
	18-26	S3 Strongly sodium water	KR (me L^{-1})[12]	<1	Appropriate
	>26	S4 Very strongly sodium water		1-2	Suitable marginally
TDS (mg L^{-1})[4-5]	<1000	Fresh water		>2	Not available
	1000-10000	Brackish water	PS (me L^{-1})[13]	<5	Excellent
	10000-100000	Slightly Saline		5-10	From good to harmful
	>100000	Very strongly saline water		>10	Not available
TH (mg L^{-1} $CaCO_3$)[6-7]	<75	Soft	Cl^- (meL^{-1})[14]	<4	Excellent
	75-150	Moderately hard		4-7	Good
	150-300	Hard		7-12	Permissible
	>300	Strongly hard		12-20	Suspicious
% Na[8]	<20	Excellent		>20	Not available
	20-40	Good	SO_4^- (me L^{-1})[14]	<4	Excellent
	40-60	Permissible		4-7	Good
	60-80	Suspicious		7-12	Permissible
	>80	Not available		12-20	Suspicious
				>20	Not available

	Bor (mg L^{-1})[3]			
	Sensitive plants	Moderately sensitive plants	Resistant plants	Evaluation
	0-0.32	0-0.66	0-0.99	None (Very good)
	0.33-0.66	0.67-1.32	1.00-1.99	Slighly (good)
	0.67-0.99	1.33-1.99	2.00-2.99	Moderately (Available)
	1.01-1.25	2.00-2.50	3.00-3.75	Much (Suspicious)
	>1.25	>2.50	>3.75	Too Much (Unavailable)

[1]Ayers ve Westcot (1989); [2]Tüzüner (1990); [3]Tuncay (1986); [4]Catrol (1962); [5]Freeze and Cherry (1979); [6]Sawyer and McCartly (1967); [7]Todd (1980); [8]Todd (1960); [9]Doneen (1964)); [10]Szabolcs and Darab (1964); [11]Raghunath(1987); [12]Kelly (1963); [13]Doneen (1962); [14]Ayyıldız (1983)

µS cm^{-1} (Table 3). 1., 2., 3., 4., 6., 7., 8. and 9. wells are in class C2 (medium salt water), 5., 7., 10. and 11. wells are in class C3 (high salt water) (Tables 2 and 4). C3 class waters cannot be used in lands with insufficient drainage. Even if the drainage is good, salt-resistant plants should be

selected and special precautions should be taken to control salinity.

Boron: It is an element found in all waters, necessary for plant growth, but toxic at concentrations above the appropriate value. Although 0.2 mg L^{-1} boron is required in water for some plants, 1-2 mg L^{-1} can be toxic (Anonymous, 2020). Boron values in our water samples varied between 0.01-2.90 mg L^{-1}, and average is 0.48 mg L^{-1} (Table 3). Accordingly, the 7th and 11th wells are not suitable for irrigation for plants sensitive to boron (Tables 2 and 4).

Sodium percentage (Na%): It is used to determine the suitability of groundwater for agricultural irrigation (Wilcox, 1955). High amounts of Na in irrigation water are adsorbed by clay particles and replaced by Mg and Ca ions. The increase the Sodium Adsorption Rate (SAR) in irrigation water, means an increase also the SAR value of the soil saturation extract. As a result of this, the exchangeable sodium percentage (ESP) of the soil increases and the soil shows to tend to sodification (Sağlam and Adiloğlu, 1995). Na% concentrations of uptaken well waters, It varied between 1.92-95.64% and its average was determined as 32.60% (Table 3). Therefore, it has been determined that the 3rd, 7th and 11th well waters are not suitable for soil and plants according to Todd (1960) (Tables 2 and 4).

Sodium adsorption rate (SAR): Since it measures the danger of alkali/sodium, it is an important parameter that determines the appropriateness of the use of groundwater for irrigation water purpose (Subrahmani et al., 2005). The excess Na^+ makes the tillage difficult by reducing the permeability of the soil and negatively affects the plant growth (Todd, 1980; Todd and Mays, 2005; Berhe et al., 2015). For well waters SAR values, it was between 0.06-17.14, and its average also determined as 4.30 (Table 3). According to Table 2, the waters of the 3rd and 7th wells are in S2 class (medium sodium water), the others are in S1 (low sodium water) class (Table 4). In S1 class water can be used safely for irrigation of almost every type of soil. However, harmful amounts of sodium may accumulate in the bodies of stone fruit trees such as almond and apricot that are too sensitive to sodium. Class S2 waters have high cation exchange

Table 3. Descriptive statistical data of well water parameters (n = 11)
Çizelge 3. *Kuyu suyu parametrelerinin tanımlayıcı istatistiksel verileri (n=11)*

	n	Minimum	Maximum	Mean	Std. Deviation	Coefficient of variation (CV)
pH	11	7.20	9.70	7.83	0.67	8.51
EC (µmbos cm^{-1})	11	345.00	2100	740.55	507.97	68.59
Bor (mg L^{-1})	11	0.01	2.90	0.48	0.95	198.24
Na^+ (meq L^{-1})	11	0.08	21.94	4.05	6.57	162.24
K^+ (meq L^{-1})	11	0.00	0.12	0.03	0.03	112.55
Ca^{+2} (meq L^{-1})	11	0.09	5.67	2.71	1.49	55.24
Mg^{+2} (meq L^{-1})	11	0.16	6.70	2.43	2.19	90.42
HCO_3- (meq L^{-1})	11	2.27	9.21	5.51	2.06	37.38
Cl^- (meq L^{-1})	11	0.03	19.24	2.97	5.60	188.59
SO_4^{-2} (meq L^{-1})	11	0.04	3.25	0.72	0.90	124.42
RSC (meq L^{-1})	11	-5.11	6.15	0.39	3.14	817.42
SAR	11	0.06	17.14	4.30	6.73	156.53
TDS (mg L^{-1})	11	220.80	1344	473.95	325.10	68.59
TH (mg L^{-1} $CaCO_3$)	11	0.85	35.57	16.73	11.09	66.33
%Na	11	1.92	95.64	32.60	38.08	116.83
PI (%)	11	3.68	231.7	76.78	86.44	114.06
SSP (%)	11	2.12	96.03	32.89	38.21	116.18
MR (%)	11	6.46	75.67	44.60	19.10	42.83
KR (meq L^{-1})	11	0.02	24.1	3.33	7.24	217.65
PS (meq L^{-1})	11	0.05	19.68	3.33	5.65	169.79

capacity (CEC) and can therefore be used in coarse and organic soils with high permeability.

Soluble sodium percentage (SSP): It helps to determine the Na hazard of irrigation water. When the Na^+ concentration is excess, it is adsorbed by clay particles and replaced by Ca^{+2} and Mg^{+2} ions. This change reduces permeability in the soil and causes poor internal drainage (Saleh et al., 1999; Collins and Jenkins, 1996) and can stop plant growth (Joshi et al., 2009). SSP values of the wells studied, it varied between 2.12-96.03%, and its average was found to be 32.60% (Table 3). Quality classes, 1., 2., 6., 8., 9. and 10. wells excellent, 4. and 5. wells good but, 3., 7. and 11. wells are not suitable for irrigation (Tables 2 and 4).

Residual sodium carbonate (RSC): It is used to determine the effect of carbonate and bicarbonate in irrigation water on water quality. In soils irrigated for a long time with irrigation waters of which RSC value exceeds 2.5 me L^{-1}, Na accumulation causes salinization and sodification problems in soils over time. The RSC values of groundwater uptaken from the wells were between -5.11-6.15 me L^{-1}, and its average was also found 0.38 me L^{-1} by us (Table 3). Accordingly, the 5th and 11th wells are not suitable, the 3rd, 4th and 7th wells differ depending on the plant, the other wells have been determined in the safe class (Tables 2 and 4).

Total amount of dissolved matter (TDS): It is another indication of salinity in water. When there is excessive amount of salt coming from major ions in irrigation water, it affects the osmotic activities of plants and prevents adequate aeration (Obiefuna and Sheriff, 2011). The calculated TDS values of the well waters ranged between 220.80-1344 mg L^{-1}, and its average was also found to be 473.95 mg L^{-1} (Table 3). According to the class values in Table 2, it was determined that only the 7th well water is brackish water and the others are in the fresh water class (Table 4).

Total hardness (TH): The hardness of the waters comes from the ions of calcium and

Table 4. Chemical analysis data of well waters
Çizelge 4. *Kuyu sularının kimyasal analiz verileri*

Parameter	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
pH	8.00	7.49	9.70	7.92	7.20	7.55	7.68	7.55	7.91	7.40	7.71
EC (µmhos cm^{-1})	345.00	434	433	490	1050	388	2100	580	560	935	831
Boron (mg L^{-1})	0.01	0.01	0.04	0.13	0.32	0.01	2.90	0.05	0.03	0.03	1.76
Na^+ (me L^{-1})	0.08	0.10	5.81	2.68	3.80	0.09	21.94	0.20	0.20	0.99	8.61
K^+ (me L^{-1})	0.01	0.01	0.02	0.04	0.05	0.00	0.12	0.01	0.01	0.02	0.04
Ca^{+2} (me L^{-1})	2.84	2.99	0.09	2.50	4.12	3.47	1.64	2.15	3.11	5.67	1.17
Mg^{+2} (me L^{-1})	1.07	2.10	0.16	1.91	1.86	0.24	1.63	6.70	4.96	5.21	0.83
CO_3^{-2} (me L^{-1})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^- (me L^{-1})	3.36	4.41	2.27	6.64	9.21	3.72	5.20	6.45	5.48	5.76	8.14
Cl^- (me L^{-1})	0.48	0.50	0.55	0.45	0.11	0.03	19.24	2.24	2.22	5.18	1.67
SO_4^{-2} (me L^{-1})	0.16	0.29	3.25	0.04	0.52	0.06	0.89	0.37	0.59	0.94	0.83
RSC (me L^{-1})	-0.55	0.68	2.03	2.23	3.23	0.01	1.92	-2.40	-2.60	-5.11	6.15
SAR	0.06	0.06	16.73	1.80	2.20	0.06	17.14	0.10	0.10	0.42	8.63
TDS (mg L^{-1})	222.80	277.76	277.12	313.60	672.00	248.32	1344.00	371.20	358.40	598.40	531.84
TH (mg L^{-1} $CaCO_3$)	11.49	16.11	0.85	14.11	17.94	9.66	10.82	32.93	28.20	35.57	6.31
% Na	2.00	1.92	95.64	37.56	38.67	2.29	86.61	2.22	2.46	8.30	80.90
PI (%)	3.68	4.05	144.66	97.34	117.97	4.41	198.41	5.64	5.77	19.96	231.70
SSP (%)	2.25	2.12	96.03	38.12	39.19	2.37	87.07	2.32	2.57	8.44	81.28
MR (%)	27.37	41.26	64.73	43.35	31.07	6.46	49.85	75.67	61.45	47.88	41.52
KR (me L^{-1})	0.02	0.02	24.10	0.61	0.64	0.02	6.70	0.02	0.03	0.09	4.32
PS (me L^{-1})	0.56	0.65	2.18	0.47	0.36	0.05	19.68	2.42	2.52	5.65	2.09
Water class	C2S1	C2S1	C2S2	C2S1	C3S1	C2S1	C3S2	C2S1	C2S1	C3S1	C3S1

magnesium, which were dissolved in it (Varol et al., 2005; Boysan and Şengörür, 2009). It is measured in German, French, American and British degrees of hardness. The THs of the sampled well waters were found between 0.85-35.57 mg L^{-1} $CaCO_3$ and the average was determined as 16.73 mg L^{-1} $CaCO_3$ by us (Table 3). Hard waters are preferred in terms of irrigation water quality. Because, hard water forms soft soil and soft water forms hard soil (Sağlam and Adiloğlu, 1997). Since the waters of all the wells studied are <75 mg L^{-1} $CaCO_3$, they are in the soft water class (Tables 2 and 4). Therefore, continuous use of these waters will cause problems for plants as they will harden the soil over time.

Permeability index (PI): PI value is used to determine the possible effect of water quality on the physical properties of the soil. PI values in the water samples uptaken ranged from 3.68% to 231.70% and the average was found to be 72.78% (Table 3). Accordingly, the 1st, 2nd, 6th, 8th, 9th and 10th wells are not suitable for irrigation for plants (III. Class), and the 3rd, 4th, 5th, 7th and 11th wells are It has been identified as perfect water (Class I) (Tables 2 and 4).

Magnesium ratio (MR): High Mg^{+2} ratio in water makes the soil salty and negatively affects plant growth and yield (Joshi et al., 2009; Venugopal et al., 2009). The MR rates of the well waters varied between 6.46-75.67% and the average was determined as 44.60% (Table 3). According to these data, except the 3rd, 8th and 9th wells, the others were found to be suitable for irrigation (Table 4).

Kelley ratio (KR): Against the amount of Na^{+}, it is expressed as Ca^{+2} and Mg^{+2} ratio. Water with a Kelley ratio of <1 is considered suitable for irrigation. The KR values of the examined wells varied between 0.02-24.10 me L^{-1}, and the average was found to be 3.32 me L^{-1} (Table 3). According to these values, the 3rd, 7th and 11th wells are not suitable for irrigation (Tables 2 and 4).

Potential salinity (PS): Depending on the chlorine and sulfate, it determines the danger of the high amount of salt that will occur. The PS amounts of the well waters uptaken was found between 0.05 me L^{-1} and 19.68 me L^{-1} and its average as also 3.33 me L^{-1} by us (Table 3). The potential salinity classes of well waters, the 7th well is not suitable for irrigation, the 10th well varies from good to harmful and the other wells are determined as excellent water. According to the analysis results, it was determined that the waters uptaken from 11 wells are suitable for continuous irrigation in every soil in terms of trace elements such as Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn. Because the determined concentrations of these elements were found to be far below the upper limit values that should be found in irrigation water (Table 5). Since the trace elements cannot accumulate in the soil with irrigation water, it will not be a problem for the plants.

CONCLUSIONS

In this study, the suitability of groundwater for irrigation in terms of plant nutrition was

Table 5. Trace element tolerance limits in irrigation water and irrigation duration
Çizelge 5. *Sulama suyunda iz element tolerans sınırları ve sulama süresi*

		1. Well	2. Well	3. Well	4. Well	5. Well	6. Well	7. Well	8. Well	9. Well	10. Well	11. Well	Continuous for every soil (mg L^{-1})	Short term in fine textured soils (mg L^{-1})
Al	(mg kg^{-1})	0.01	0.01	0.02	0.01	0.32	0.03	0.00	0.00	0.00	0.00	0.02	1.00	20.00
Cd		0.000	0.000	0.000	0.001	0.002	0.000	0.001	0.001	0.001	0.001	0.001	0.005	0.05
Co		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	10.00
Cr		0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.00	0.00	5.00	20.00
Cu		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	5.00
Fe		0.00	0.00	0.01	0.01	0.26	0.01	0.01	0.01	0.01	0.01	0.01	2.00	5.00
Mn		0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	2.00	20.00
Ni		0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.50	2.00
Pb		0.00	0.00	0.12	0.01	0.01	0.00	0.01	0.03	0.01	0.02	0.01	5.00	20.00
Zn		0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	5.00	10.00

evaluated, belonging to 11 different wells used in Kahramanmaraş. In determining the use of well waters as irrigation water, evaluations were made using chemical parameters such as pH, EC, TDS, SAR,% Na, RSC, SSP, MR, KI, PI, PS, TH. Accordingly, 5 out of 11 wells showed low variability, 8 of them moderate and 17 of them high variability. From this situation, it is understood that the waters have a partially homogeneous distribution (in 5 wells). In terms of pH, it was determined that all well waters except well number 3 are suitable for irrigation in terms of plant nutrition and soil fertility. In terms of EC values, wells 5 and 7 are respectively in strongly saline/low sodium water (C3S1) and strongly saline/moderately sodium water (C3S2) class. Since C3S1 type waters is not suitable as irrigation water, salt-resistant plants should be selected, regular washing and special soil cultivation programs should be applied. Since C3S2 type waters are not suitable for irrigation, salt-resistant plants should be chosen and they should be used in coarse-textured or organic soils, rich in gypsum with good permeability. Other wells are C2S1 type waters (moderately saline/ low sodium water) and can be used for all plants. It was determined that the 7th and 11th wells were not suitable for irrigation for Boron sensitive plants. Except for the 7th well, the TDS values of other 10 wells were classified as fresh water. TH values were determined as soft water in all well waters. In terms of Na% and SSP values, 8 wells other than the 3rd, 7th and 11th wells were found to be in the appropriate class for soil and plants. According to the SAR values of the well waters, 9 wells except the 3rd and 7th wells are low sodium water (S1). In terms of PI values, 1st, 2nd, 6th, 8th, 9.ve 10th wells are not suitable for irrigation for plants (III. class), 3rd, 4th, 5th, 7.ve 11th wells are excellent waters in feature (I. Class). According to the RSC values, the wells other than the 5th and 11th wells, according to the MR values the wells other than the 3rd, 8th and 9th wells, according to the KR values, the wells other than the 3rd, 7th and 11th wells and according to PS values the wells other than the 7th well have been found suitable for irrigation. In the evaluations made, determined as problematic for soil and plants in terms of special ion, salinity and alkalinity, and the well waters given its numbers above should be used by taking the necessary precautions or not used for irrigation.

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