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Effect of Collected Rainwater on Crop Growth in Greenhouses with in the Erbil Province of Iraq

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ABSTRACT

This study examined the physical and chemical characteristics of rainwater from 15 sites in Kurdistan-Iraq between March and April 2009 and compared the growth of crop plants (*Triticum duarium, Lens esculenta, Cicer arietinum and Bracica oleraceae*) using rainwater. Results were analyzed using a factorial experiment which was replicated three times using a randomized design set-up. Results revealed that plant growth varied with 22.89 ± 3.54 cm recorded at the Bahirk's village site and 5.33 ± 0.764 cm recorded at the Erbil Kirkuk road site, respectively. Fresh shoot dry weight ranged between 1.181 ± 0.054 gm and 0.023 ± 0.011gm; fresh root weight was between 1.38 ± 0.07 gm and root dry weight was 0.0519 ± 0.021 gm respectively. Determination of nutrient content of rainwater revealed that N^{-3}, P^{-3}, K^+, and Na^+ concentrations ranged between (6.98 - 3.53; 2.28 - 2.17; 106.51 - 38.41; and 19.55 - 12.94) mg/L, respectively. Results revealed that rainwater can be applied for agricultural purposes as plant characteristics and the nutrient content did not fundamentally change when compared with use of Tab water.

Key word*:* Rainwater, chemical and physical properties, plant height, fresh and dry weight, finally nutrients.

INTRODUCTION

Air pollution is a pollutant which primarily results from human activities (anthropogenic sources) such as burning of fuels, automobile emissions, transport agents, industrial activities, agriculture production and urban societies (Seinfeld and Pandis 2012). However, natural sources such as, volcanoes, evaporation from hot springs, decay of organic matter and dust storms (dry deposition) are other potential sources of air and environmental pollution (Kabata-Pendias 2010).

Pollutants of air such as sulphur gas compounds (H_2S, SO_2 or SO_4), nitrogen compounds (NO_2, NO_3, NH_3), hydrogen halides (HF, HCl) and carbon oxides (CO and CO_2) are produced as a direct result of car exhausts; presence of these compounds can contribute to making atmospheric conditions acidic (Heck and Farrauto 2001). These pollutant sources also contain particulates such as lead particles (Harrison and Yin 2000). Research into the different aspects of air pollution such as acid rain has led to the development of technologies to reduce the impact of this pollution (Holmes, Singh *et al.* 1993). In addition, to airborne chemicals and pollutants which fall to the earth, airborne acids can travel as part of mist, fog, snow, rain and even in dry air (Seinfeld and Pandis 2012). When carbon, sulphur and nitrogen oxides are emitted into the atmosphere, they come in to contact with water and are converted into acidic sulphates or nitrate compounds (Berner and Berner 2012).

Acid rain can affect plant growth resulting in abnormal growth or reduced seed germination (Lavender 1984). Nitrogen-fixation alters amino acid synthesis and protects against injuries to chlorophyll production and the resulting acid can be diluted which harms the plant directly (Maclachlan and Zalik 1963; Fageria, Baligar *et al*. 2010). However, the effect of air pollution on forests is difficult to determine and has previously been over-estimated (Altshuler 1984; Bewley and Black 2012).

There are many indicators which can be used to determine the effect of rainwater on organisms, however, an assessment of the impact on vegetation can be considered a good indicator as ground and air conditions always have initial impacts on vegetation before any deleterious effects on animals or humans (Bates, Kundzewicz *et al*. 2008).

The objective of this study was to determine the composition of rainwater in 15 regions of Iraq and to examine the effect of use of rainwater at four selected sites on seed germination and growth on four species of crop plants Triticum duarium, Lens esculenta, Cicer arietinum and Bracica oleraceae. A further aim of the study was to determine the effect of rainwater on plant (root and shoot) including plant height, plant weight (both shoot and root), and nutrient composition of the studies crop plants.

This study aimed to critically appraise whether rainwater could be an alternative to Tab water for the irrigation of crop plants, this is a common use of rainwater in these regions of Iraq.

MATERIALS AND METHODS

The study was conducted on rainwater which was collected in September 2008-April 2009 from 15 sites the sampling was carried out monthly, and rainfall was collected approximately once a month. Rainwater was collected in plastic vessels placed onto roofs before being transferred into 2 L plastic polyethylene bottles. The 15 sites were (Shorish, City centre, Erbil -Kirkuk road, Erbil -Mousl road, Ankawa, Bahirka village, Salahaddin (Massif), Shaqlawa, Aquban Ulea village, Soran, Choman, Aski Kalak, Makhmur, Qushtapa, and Koya town) all these sites are within the Kurdistan province of Iraq.

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The water used to investigate the effect of rainwater on plant growth was collected between March and April 2009, as rainfall increased during these months, rainfall collected was placed into 20 L polyethylene bottles. Rainwater was collected from 4 sites (Erbil Kirkuk road, Erbil- Mosul road, Bahirka village and Shaqlawa); these sites were chosen because Bahirka and Shaqlawa are agricultural sites while Erbil Kirkuk road, Erbil-Mosul road were in the capital of Kurdistan and were considered to be in regions with higher inherent pollution levels.

Collector designs

Precipitation samples were collected using bulk or wet designed collectors. Bulk sample refers to collection of both wet and dry components of rainfall. The bulk sampling system typically consisted of a bucket or funnel and bottle configuration which is open to the atmosphere during precipitation events and during dry periods (Durst, Davison *et al*. 1991). The rainwater collectors were large cans or soda bottles in which the top had been excised, these vessels were then washed prior to use and placed in a ring of small rocks to ensure stability (Demirak 2007).

All collection buckets linear, funnel/ bottle device and storage bottles were constructed in such a manner to avoid contamination and to avoid adsorption of organic ions. High density linear polyethylene, which has been shown to be suitable for collection and storage, was used. Collection site were located at least 100 m from routine air ground or any obstruction such as power line or trees were not interfere with sample collection (Topçu, Incecik *et al*. 2002)

For the present study, rainwater collected from the 15 selected stations was used to determine the following parameters:

Temperature, humidity (obtained from Erbil Agricultural Directorate), the climate of Erbil area is similar to that of other parts of Kurdistan region, which is semi-arid and characterised by hot dry summers and moderately rainy cold winters.

Turbidity was measured using the Nephelometric method using a HACH company turbidimeter model (2100 A,USA) calibrated before each sampling by using of standard solution of 0.61, 1, 10, 100, and 1000 NTU, and the results were expressed as Nephelometric Turbidity Units (NTU) (Rand, Greenberg *et al*. 1976).

Hydrogen ion concentration was measured in the laboratory using a portable pH-meter (CCMD 625, COMB1NED EC/PH, Hanna, USA). The instrument was calibrated before each sample by use of standard buffer solutions (pH: 4, 7 and 10).

Electrical conductivity (EC) of water was measured in the lab using a portable EC-meter (equipped with an automatic temperature corrector) model (EU. TECH, CON 510 /TDS/C/F/Meter, Hanna, US). The instrument was calibrated before each sampling with standard solutions prepared by the Hanna Company, USA (The results were expressed in $\mu s.cm^{-1}$).

Total acidity was determined by titration method as described (Rand, Greenberg *et al*. 1976).

Carbon dioxide content of rainwater was measured using titration method as described (Sawyer and McCarty 1978) and results were expressed in mg $CaCO_3$/L.

Total alkalinity was determined using a titration method (Rand, Greenberg *et al*. 1976) and results were expressed in mg/L

Total hardness was determined using the ethylene-diamine-tetra-acetic-acid (EDTA) titrimetric method (Rand, Greenberg *et al*. 1976). Titration was carried out using 0.01 M EDTA (disodium salt) using Erichrome Black T *(*Sigma Aldrich) as an indicator and pH 10 as a buffer solution. Results were expressed as mg $CaCO_3$/L.

Cations and anions

Sodium (Na^+) and potassium (K^+) ions were determined using a flame photometer instrument (C1378, Elico, Flame photometer) as described (Kalra 1997), the results were expressed in mg/L. Sulphate (SO_4^{-2}) concentration was determined using a Unicam Sp6-550 Uv/Vis Spectrophotometer (Pye, UK) as described and compared with a standard curve (Rump and Krist 1988). The results were expressed as mg/L. Nitrite concentrations (NO_2^- and NO_3^-) were determined; the absorbance of the solution was measured at wavelengths of 543 nm (NO_2^-) and 395 nm (NO_3^-) respectively using (UNICAM SP 6-550, Pye, UK) the results was expressed in mg/L. The indole method was used as described (Rand, Greenberg *et al*. 1976).

Plant studies

The seeds of 4 SPP (*Triticum duarium*, *Lens esculenta*, *Cicer arietinum* and *Bracica oleraceae*) were obtained from the Agricultural Research Centre (ARC) in Kurdistan–Iraq. The irrigated water was collected as stated previously. Performance in terms of seed germination and growth using rainwater was compared with Tab water as a control and nutrients (N, P, K and Na) were analysed.

Seed germination for 10 seeds from each species was determined by placing seeds into pots, at a depth of 2 – 3 cm into loam soil which had previously been fumigated and sterilized by formalin. Then transferred into pots with a 3 kg capacity, 10 seeds were added into each pot, soil was added, and the seeds were irrigated daily by rainwater for 7 weeks in greenhouses, finally the shoot system was separated from the root system. The root system was washed carefully and wet weight determined directly, while dry weight was determined after drying in an oven until the roots had reached a constant weight. For the shoot system, wet and dry weight was estimated; the fresh weight determined directly after harvesting while the dry weight was after drying in an oven, the dry shoot system was taken forward for further analysis such as nutrients in a plant tissue. 0.5 gm of samples were ground using an iron mortar and digested using a wet digestion method using 7 mL of concentrated H_2SO_4 (98 %) and 7 mL of H_2O_2 (36 %), as described by (Novozamsky, Houba *et al*. 1983).

Growth parameters measurements

Vegetation growth parameters were recorded for the four studied plant species in each replicate. Plant height was measured weekly for seven weeks from the contact point at the soil surface to the growing point of the main stream. Fresh shoot weight was determined. The dry weights of the shoots was determined following drying in an oven at 70-75^oC for 48 hours. Root fresh weight was measured after separation from the soil by washing. Root dry weight was determined using same oven conditions as mentioned previously.

Nutrient measurement in plant irrigated by rainwater

The samples were digested and sodium (Na^+) and potassium (K^+) concentrations were determined using a flame photometer (digital flame analyzer) and samples were prepared as described previously (Kalra 1997). Nitrogen was determined using the Kjeldahl method as described previously (Ryan, Estefan *et al*. 2007). Phosphorus was determined using a spectrophotometer method at 410 nm, as described previously (Ryan, Estefan *et al*. 2007), following a sample preparation described previously (Allen, Grimshaw *et al*. 1974).

RESULTS

Physical and chemical properties of collected rain water

Analysing air temperatures data at the different collection sites revealed that there was a marked fluctuation in air temperature which was significantly different (P<0.01) for both sampling dates and between the four collection sites. The highest recorded air temperature (32±1.25 ^oC) was at Makhmur during September, 2008, while the lowest (4.3 ± 0.98^oC) was at Soran site in December, 2008 (Table 1).

Relative humidity revealed that the highest value (78 ± 9.2 %) was at the Aski kalak site, December, 2008 and the lowest value (30.9 ± 3.2 %) was recorded at Makhmur, during September, 2008.The high humidity value at Makhmur might be as a result of evaporation of a nearby river resulting in an increase in humidity. There were significant differences (P<0.01) observed between sampling times and other studied sites.

Determination of turbidity revealed that there were significant difference between time and sites (P<0.01) with the highest turbidity values (120 ± 20.5 NTU) recorded at Erbil centre during March, 2009 and the lowest value (6.9 ±0 .4 NTU) recorded at the Bahirka village site in November, 2008.

A determination of pH revealed that there was significant differences (P<0.01) between both temporally studied samples times and sampling sites with the highest values (7.6 ± 1.5) recorded at the Ankawa site (September 2008) while the lowest reading (5.2 ± 0.8) was recorded at the Aski kalak site (April 2009).

Determination of EC revealed significant variations (P<0.01) between time and studied sites, the highest EC value (994 ± 88.5 µs.cm^{-1}) was at Makhmur site (February, 2009) while lowest value (18.5 ± 3.2 µs.cm^{-1}) was recorded at Erbil centre (November, 2008) (Table 1).

Results determining total acidity and total alkalinity revealed that there were significant differences in collected samples at different times and sites(P<0.01) with the highest level for acidity (79 ± 0.14mg $CaCO_3$/L) was recorded at Choman (March, 2009) and the lowest value recorded at the Bahirka village site was (4.3 ± 0.47 mg CaCO3/L) (April, 2009). Determining alkalinity revealed that the maximum value was recorded at the Massif site during September, 2008 was 94 ± 5.2 mg$CaCO_3$/L, while lowest was recorded at the Aski kalak site was 8 ±1.25 mg $CaCO_3$/L during March, 2009 (Table 1).

Total hardness showed significant difference between time and sites (P<0.01), the highest value (322 ± 84.2 mg/L) was at Makhmur during April, 2009, the lowest at Koya town recorded during December, 2008 was 20.5 ± 2.5 mg/L.

Determination of concentrations of sodium in rainwater revealed that there were significant differences (P<0.01) between studied sites with the highest concentration (70.2 ±5.24 mg/L) recorded at Makhmur and the lowest concentration (0.5 ± 0.014mg/L) recorded at Shorish, Erbil-Kirkuk road, Bahirka and Aquban (Table 1).

Potassium concentration revealed that there were significant differences (P<0.01) between the studied sites and the sampling times, the lowest value was (0.2 ± 0.011mg/L) recorded at Massif site during November 2008, while the highest value (37.6 ± 6.24 mg/L) was at Makhmur site during Mar.2009.

Sulphate concentration results of all studies revealed variation which was significantly different (P<0.01) for both study sites and sampling times with the highest concentrations recorded at Makhmur (February, 2009) and the lowest recorded value recorded at the Erbil-Mosul road site (April, 2009). Determination of nitrite concentrations revealed that there were significant difference between collection times and sites (P<0.01). The highest nitrite concentration was recorded at Makhmur during Mar. 2009, while the lowest were recorded at Massif, Shaqlawa, Soran during September, 2008. There was also a significant fluctuation in nitrate concentrations (P<0.01) during the time period assayed for (Table 1). The lower level was recorded at the sites of Bahirka and Koya town during October, and November, 2008, while higher level was recorded at the Erbil centre site during December, 2008.

Table (1): Physio- Chemical Parameters for rain water collected in 15 sites.

Parameter (Mean)	Records	Value	Site No.(Name)	Significance	
				Time	Sites
Air temperature °C (10.02)	*Max*	*32*	*Makhmur*		
	Min	*4.3*	*Soran*	*	*
Relative humidity (%) (39.29)	*Max*	*78*	*Aski Kalak*		
	Min	*30.9*	*Makhmur*	*	*
Turbidity NTU (55.71)	*Max*	*120*	*Erbil center*		
	Min	*6.9*	*Bahirka village*	*	*
pH (6.37)	*Max*	*7.6*	*Ankawa*		
	Min	*5.2*	*Aski Kalak*	*	*
EC Ms.cm-1 (235.35)	*Max*	*994*	*Makhmur*		
	Min	*18.5*	*Erbil centre*	*	*
Acidity mg CaCO2/L -(28.98)	*Max*	*79*	*Choman*		
	Min	*4.3*	*Bahirka village*	*	*
Alkalinity mg $CaCO_2$/L –(33.57)	*Max*	*94*	*Massif*		
	Min	*8*	*Aski Kalak*	*	*
Total Hardness mg/L(101.77)	*Max*	*322*	*Makhmur*		
	Min	*20.5*	*Koya town*	*	*
	Max	*70.2*	*Makhmur*		
Sodium mg/L (6.62)					
	Min	*0.5*	*Shorsh, Erbil-Kirkuk road , Bahirka, Aquban*		*
	Max	*37.6*	*Makhmur*		
Potassium mg/L (3.77)					
	Min	*0.2*	*Massif*	*	*
	Max	*100*	*Makhmur*		
Sulphate SO_4 mg/L –(22.87)					
	Min	*2.1*	*Erbil-Mosul road*	*	*
	Max	*21.8*	*Makhmur*		
Nitrite NO2 mg at N-NO2/L(4.5)					
	Min	*0.4*	*Massif, Shaqlawa, Soran,*	*	*
	Max	*20.1*	*Erbil centre*		
Nitrate NO3 mg at N-NO2/L (8.47)					
	Min	*3.3*	*Bahirka, Koya town*	*	

Effect of rainwater on germination of plant seeds

We measured the effect of using collected rain water on the germination of plant seeds using a series of growth parameters criteria such as plant height, shoot root weight and presence of essential elements. Determining plant height revealed that there was significant differences (P<0.05) between species only (Table 2). The highest value of plant height recorded was 22.89 ± 3.54 cm for *T. duarium* comparing with the control (Tab water), while the lowest value (5.33 ± 0.76cm) was recorded for *B. oleraceaes* species when compared with the control (Tab water) the other two species showing better performance comparing with their control. Determining shoot weight (fresh and dry) revealed significant differences (P<0.05) between species and sites (Tables 3 and 4).

Statistical analysis of shoot fresh weight revealed that the lowest value (0.097 ± 0.0142 gm) was recorded at Erbil-Kirkuk road for *B. oleraceae comparing* with the control (Tab water). The highest value was (1.18 ± 0.098 gm) recorded at Bahirka village site for *C. arietineum* species comparing with the control, for the other two species in some of sites was higher and in some other was lower comparing with their control (Tab water). Determining shoot dry weight for four cultivated plants revealed that the highest value (0.186 ± 0.024gm) recorded was using Tab water with *C. arietineum*, while the lowest value recorded (0.023 ± 0.011gm) was at Erbil-Kirkuk road with *B. oleraceae* comparing with the control. Results revealed that by using rainwater plant height did not correlate with an improvement when compared with using Tab water. However, fresh shoot weight did reveal that use of rainwater was beneficial for the growth of *C. arietineum* at the Bahirka site when compared with use of Tab water at the same site

Determination of root weights (fresh and dry) revealed significant differences (P<0.05) between species and irrigated rain waters for fresh root weights (Table 5); the highest value (1.38 ± 0.07 gm) was recorded by using Tab water with *C. arietineum* and the lowest value (0.072 ±0.001 gm) was recorded at Bahirka village with *B. oleraceaes* comparing with plant species treated with Tab water

However, dried root samples only revealed significant differences between species (P<0.05) (Table 6). The highest value (0.32 ± 0.024gm) was recorded for *C. arietineum* species, while the lowest value (0.0519 ± 0.021 gm) was recorded for *B. oleraceaes*. In general, use of rainwater correlated well with use of Tab water indicating that rainwater could have a use in an agricultural setting.

Table (2): The effect of rain water on plant height (cm) of the four cultivated plants.

	Type of species					
Sites	***Triticum duarium***	***Lens esculenta***	***Cicer arietinum***	***Bracica oleraceae***	**Mean**	**SD ±**
Erbil -Kirkuk road	19.28	10.92	15.52	5.33	12.76	5.54
Erbil -Mosul road	21.018	10.89	16.34	7.67	14.82	6.428
Bahirka village	22.89	11.655	16.759	6.38	16.02	9.04
Shaqlawa	22.811	14.06	17.132	6.542	15.53	6.083
Tab water	22.538	7.3833	17.0502	6.5427	13.21	6.197
Mean	22.814	11.65	17.21	6.21	14.47	
SD ±	3.634	2.329	1.493	1.466		6.639

LSD (0.05) for studied sites =5.54, LSD (0.05) for species =2.33, LSD(0.05) for interaction=3.54

Table (3): The effect of rain water on shoot fresh weight of the four cultivated plants.

	Type of species					
Sites	***Triticum duarium***	***Lens esculenta***	***Cicer arietinum***	***Bracica oleraceae***	**Mean**	**SD ±**
Erbil -Kirkuk road	0.159	0.102	0.872	0.097*	0.308	0.358
Erbil - Mosul road	0.234	0.13	1.029	0.145	0.48	0.469
Bahirka village	0.367	0.197	1.098	0.137	0.57	0.507
Shaqlawa	0.387	0.256	1.181*	0.169	0.65	0.53
Tab water	0.396	0.221	1.0111	0.177	0.223	0.179
Mean	0.42	0.17	1.001	0.187	0.448	
SD ±	0.207	0.115	0.533	0.113		0.444

LSD (0.05) for studied sites =0.466, LSD (0.05) for species =0.289, LSD (0.05) for interaction=0.27008, *=highest and lowest value

Table (4): The effect of rain water on shoot dry weight (gm) of the four cultivated plant.

	Type of species					
	Triticum	***Lens***	***Cicer***	***Bracica***		
Sites	***duarium***	***esculenta***	***arietinum***	***oleraceae***	**Mean**	**SD ±**
Erbil -Kirkuk road	0.0466	0.0406	0.165	0.023*	0.068	0.06
Erbil -Mosul road	0.0548	0.107	0.177	0.025	0.083	0.067
Bahirka village	0.127	0.057	0.18	0.023	0.151	0.21
Shaqlawa	0.1145	0.056	0.1857	0.0249	0.088	0.072
Tab water	0.131	0.0505	0.186*	0.0248	0.092	0.091
Mean	0.188	0.0266	0.0232	0.0105	0.096	
SD ±	0.125	0.046	0.189	0.025		0.114

LSD (0.05) for studied sites =0.093, LSD (0.05) for species =0.0936, LSD (0.05) for interaction=0.208*=highest and lowest value

Table (5): The effect of rain water on root fresh weight of the four cultivated plant.

	Type of species					
	Triticum	***Lens***	***Cicer***	***Bracica***		
Sites	***duarium***	***esculenta***	***arietinum***	***oleraceae***	**Mean**	**SD ±**
Erbil -Kirkuk road	0.221	0.117	0.809	0.075	0.305	0.32
Erbil -Mosul road	0.295	0.107	1.0921	0.0864	0.514	0.62
Bahirka village	0.4051	0.113	1.1177	0.0723*	0.512	0.502
Shaqlawa	0.416	0.138	0.0951	0.0824	0.67	0.736
Tab water	0.42	0.139	1.254*	0.0761	0.548	0.655
Mean	0.44	0.144	1.38	0.075	0.511	
SD ±	0.169	0.069	0.457	0.05		0.578

LSD (0.05) for studied sites =0.479, LSD (0.05) for species =0.2409, LSD(0.05) for interaction=0.3622, *=highest and lowest value

Table (6): The effect of rain water on root dry weight of cultivated plant.

	Type of species					
	Triticum	***Lens***	***Cicer***	***Bracica***		
Sites	***duarium***	***esculenta***	***arietinum***	***oleraceae***	**Mean**	**SD ±**
Erbil -Kirkuk road	0.1806	0.084	0.288	0.064	0.153	0.098
Erbil -Mosul road	0.216	0.073	0.306	0.069	0.227	0.173
Bahirka village	0.255	0.0715	0.281	0.0564	0.165	0.142
Shaqlawa	0.246	0.073	0.282	0.058	0.16	0.1
Tab water	0.069	0.067	0.321*	0.0519*	0.137	0.118
Mean	0.2509	0.1008	0.274	0.048	0.168	
SD ±	0.083	0.139	0.0562	0.0316		0.129

LSD (0.05) for studied sites =0.141, LSD (0.05) for species =0.085, LSD (0.05) for interaction=0.1805, *=highest and lowest value

Table (7): The effect of collected rain water on Nitrogen (ppm) of the four cultivated plant

	Type of species					
Sites	***Triticum duarium***	***Lens esculenta***	***Cicer arietinum***	***Bracica oleraceae***	**Mean**	**SD ±**
Erbil -Kirkuk road	3.8766	5.27	5.12	3.683	4.48	1.611
Erbil -Mosul road	3.878	4.707	4.904	3.534*	3.94	0.762
Bahirka village	3.835	4.502	4.899	3.776	4.24	1.409
Shaqlawa	4.34	6.986*	5.41	3.93	6.34	1.721
Tab water	4.733	4.033	5.585	3.828	5.16	2.252
Mean	4.966	4.8406	5.717	3.854	4.836	
SD ±	1.793	1.889	1.698	1.369		1.785

LSD (0.05) for studied sites =1.329, LSD (0.05) for species =1.654, LSD (0.05) for interaction=3.334, *=highest and lowest value

Effect of rainwater and site on minerals

Statistical analysis of nitrogen revealed significant differences (P<0.05) between sites, the minimum value was 3.53 ± 0.18 mg/L recorded at site (Erbil-Mosul road) for *B. oleraceae*. Variation of nitrogen level in this survey reflected local and seasonal variation; the highest value recorded was 6.986 ± 0.14 mg/L at Shaqlawa for *L. esculenta* (Table 6).

Determination of phosphorus revealed that the interaction between species and site was significantly different (P<0.05), the lowest value recorded was 2.17 ± 0.18 mg/L recorded at (Tab water) for *B. oleraceae*. Variation of phosphate level in this study correlated with local and seasonal variation, the highest value recorded was 2.28 ± 0.24 mg/L at Shaqlawa for *T. duarium* (Table 8).

Potassium **c**oncentration varied significantly between species and sites. The highest recorded value was 106.5 ± 24.5 mg/L at site (Tab water) for *T. duarium*, while the lowest recorded value was 38.4 ± 9.2mg/L for (Tab water) and *L. esculenta* (Table 9). Sodium concentrations in crop plants revealed a highest value at Erbil - Kirkuk road of 19.5 ± 2.54 mg/L for *L. esculenta*, and the lowest value was 12.94 ± 3.25 mg/L recorded at Erbil - Mosul road for *T. duarium*. Statistical analysis revealed a significant difference between water quality and interaction between sites and species (Table 10). Generally the result revealed that rainwater at the Shaqlawa site was the highest in N and P, these elements accumulated in a plant tissue but at concentrations which would not prevent use of rainwater for agriculture purposes.

Table (8): The effect of collected rain water on phosphor (ppm) of the four cultivated plant.

	Type of species					
Sites	***Triticum duarium***	***Lens esculenta***	***Cicer arietinum***	***Bracica oleraceae***	**Mean**	**SD ±**
Erbil -Kirkuk road	2.271	2.203	2.216	2.186	2.204	0.022
Erbil -mussel road	2.239	2.207	2.204	2.178	2.19	0.02
Bahirka village	2.223	2.213	2.198	2.176	2.18	0.03
Shaqlawa	2.283*	2.205	2.199	2.176	2.26	0.294
Tab water	2.267	2.196	2.197	2.172*	2.16	0.019
Mean	2.26	2.18	2.19	2.17	2.203	
SD ±	0.26	0.04	0.015	0.018		0.133

LSD (0.05) for studied sites =0.109, LSD (0.05) for species =0.129, LSD (0.05) for interaction=0.292, *=highest and lowest value

Table (9): The effect of collected rain water on potassium (mg/L) of four cultivated plant content .

	Type of species					
Sites	***Triticum duarium***	***Lens esculenta***	***Cicer arietinum***	***Bracica oleraceae***	**Mean**	**SD ±**
Erbil -Kirkuk road	90.053	39.543	58.74	65.28	67.57	27.47
Erbil -mussel road	103.85	43.66	55.708	75.922	78.29	33.22
Bahirka village	105.69	46.422	55.49	66.38	65.06	28.96
Shaqlawa	105.43	41.512	56.32	67.437	67.46	32.14
Tab water	106.51*	38.41*	56.84	68.1	66.35	37.13
Mean	111.24	37.68	57.12	69.92	68.95	
SD ±	10.005	14.755	5.46	25.407		31.22

LSD (0.05) for studied sites =26.155, LSD (0.05) for species=15.34, LSD (0.05) for interaction=28.09, *=highest and lowest value

DISCUSSION

Determining the composition and impact of rainwater on seed germination and leaf/shoot production has allowed us to study the importance of rainwater on plant viability. Assessing for rainwater at different sites in Northern Iraq has further allowed us to look at geographical differences in terms of plant response. Looking at the physical variation at the various sites revealed that air temperature variability is ecologically very important, and its influence is universal as it effects plant growth resulting in zonation and stratification that usually occurs in water bodies and on land (Osborne 2000). Fluctuations in air temperature at sites assayed for this study correlated with altitude of the site such as 32^{o}C for Makhmur which is at a lower altitude than Soran (4.2^{o}C). Seasonal and altitude variations are characterised by having lower air temperatures than those at lower altitudes (Gong and Ho 2002; Smith, Smith *et al*. 2006). Differences in air temperature has also been correlated with the amount of solar radiation which reaches the ground along with air temperature other factors such as topographic, position, cloud and vegetative cover and other factors influence the amount of solar radiation plants receive (Necchi Júnior and Alves 2005). Presence of dust particles in the atmosphere also have an impact on air temperatures as presence of particulates reduces temperatures and amount of solar energy plants receive (Qian, Quan *et al*. 2002)

The amount of vapour water (humidity) is an important ecological factor, since it influences organism activity and their distribution (Bursell 1974; Szewczyk, Osterweil *et al*. 2004). The highest recorded level of humidity was recorded at the Aski kalak collection site which correlates with evaporation from river water while the lowest value was recorded at Makhmur which correlated with this area experiencing very low rainfall for the previous three years before the samples were collected (Brady and Weil 1996).

Turbidity is a measurement of water resistance to light passage and is caused by the presence of suspended and colloidal matters (Leggett, Fennessy *et al*. 2001). Turbidity is affected by the natural components present in water bodies such as silt, clay, silica and human activities (Sawyer and McCarty 1978) (Fowler, Phillips *et al*. 2005). The low turbidity values recorded at Bahirka village may be due to low human activity, low vehicle use and the area being densely covered by trees, the effect of human activity on low turbidity values has been reported previously (Wang and Tao, 1996).

Rain is relatively unpolluted water, however, snow, hail, mist, rain and fog can contain significant concentrations of dust, dissolved solids and gases (Jackson and Jackson 2000). This study determined the hydrogen ion concentration using pH as an index of hydrogen ion activity in water (Sawyer and McCarty 1978). We observed that low pH correlated with the presence of industries such as oil refineries and factories at the collection site. We also correlated increases in CO concentration in this area which maybe as a result of wind carrying pollution, this result agreed with a study carried out in India where pH of rain was determined to be 5.7 (Teixeira, Migliavacca *et al*. 2008) (Silva and Manuweera 2004). The low pH in this study maybe due to high population density and moderately high annual rain fall (Silva and Manuweera 2004).

Electric Conductivity is numerical expression of the ability of an aqueous solution to carry an electrical current (Rhoades, Chanduvi *et al*. 1999) and is reliant on factors such as climate, seasonal variation, soil source and total concentration of ionic salts content such as calcium, magnesium and nitrate (Prosser, Rutherfurd *et al*. 2001). This variation was manifest in this study as the highest EC value was found at Makhmur during (February 2009) which may be due as a result of dust mixing with rainwater. The EC value was very high (994 $\mu S.cm^{-1}$) at the Makhmur site when compared with values recorded elsewhere in Erbil or 160 $\mu S.cm^{-1}$ in the Appalachian mountains in USA by (Pierson, Brachaczek *et al*. 1986)

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A low EC value recorded for the centre of Erbil may be due to the dust precipitation at that site covered by buildings and parks, also rainfall in Erbil is higher than in Makhmur which agrees with a previous study which showed a variation in the conductivity of rainwater through the duration of dust storms as well as between rain events (Kobori, Kumazawa *et al*. 2005).

This study looked at total acidity and total alkalinity and revealed that total acidity fluctuated in each season, these fluctuations maybe as a result of geological site for each site

(Muhammad and Ali 2013). In this study, a low acidity value was recorded in Bahirka village which maybe as a result in the decrease in industrial facilities and an increase in alkaline substances in rain water sample (Bowman, Cleveland *et al*. 2008). Conversely, we found a weak correlation between presence of hydrogen ions and SO_4^{2-} or NO^{3-} ions and for all seasons due to neutralizations of these ions with alkaline particles (Topçu, Incecik *et al*. 2002). A high acidity value was recorded at Choman near the Iranian border, Iran is an industrial area in which winds can bear most of the pollutant materials from this area to Choman; higher acidity in that region could also be a result of low dust storms which have been shown to carry alkaline particles which help to neutralise acidic rainwater (Kulshrestha, Kulshrestha *et al*. 2003).

Alkalinity is influenced by soil (dust particles which contain Cl^- and Ca^{+2}) and environmental conditions (Humbert, Gallard *et al*. 2005; Aziz and Al-Dabagh 2012). In addition, the cations such as calcium, magnesium has been measured in a same period in Erbil by (Aziz and Al-Dabagh 2012; Williams 2013).

In the studied areas, there was a variation in alkalinity between sites, which maybe as a result of dust from– dust storms mixing with rainwater containing limestone (CaCO3) or CaO particles, this mixing has been shown to increase alkalinity (Larsen, Jørgensen *et al*. 2001). In addition, variation may be due to the variation in the amount and type of dusts in the studied area, since the dust is the main source for elements which affect rainwater, variation may also be a result of plant cover decreasing the effect of dust fall or agricultural activities causing neutralization of rainwater and decrease the acidity in the rainwater (Topçu, Incecik *et al*. 2002). The lowest value probably relates to that dust particles were lower in the atmosphere during the rain collection time, as has been observed previously (Kulshrestha, Kulshrestha *et al*. 2003).

Presence of hardness in rainwater samples in this study is affected by many factors such as human activities and geological formation of soil (Wetzel 2001). Normal range of hard water is from 150 - 300 mg/L (Sawyer and McCarty 1978). We observed variation in total hardness which may be due to high concentrations of Ca^{+2} and Mg^{+2} present in Makhmur, presence of these cations was reflected in a high value for hardness when compared with other sampling sites. Makhmur is characterized by higher amounts of dust fall, small amounts of rainfall, unpaved roads, and non-agricultural areas that leads to the condensation of the ionic substances in the water sample (Wei and Wang 2005). Total hardness varied seasonally, it increased during the rainy seasons which maybe as a result of connect between water with dust particles in the atmosphere (Radojevic and Bashkin 1999).

In this study, the lowest value for divalent cations which cause hardness was detected in Koya, this value may reflect that this site experiences lower dust fall due to the presence of large amount of trees in the city and its site near Dokan Lake. This result agrees with a previous study (Sawyer and McCarty 1978).

Sodium is a common element present in water, it is the sixth most abundant element and is present to some extent in most natural waters (Hounslow 1995). The permeability of agricultural soil is harmed by a high ratio of sodium ions to total cations (Bartram and Ballance 1996). Normal range of sodium in rainwater was 0.02 - 0.3 mg/L (Allen, Grimshaw *et al*. 1974). Sodium is naturally present in water after passing through certain mineral deposits and rock strata (Khopkar 2007; Way 2012). Normal range of sodium in soil ranges from 0.2 - 15 mg/L (Allen, Grimshaw *et al*. 1974) The minimum value recorded here may be as a result of the lower amounts of dust fall that month, this results agreed with a previously published study (Silva and Manuweera 2004). The maximum value may be as a result in the presence of large amount of dust and low rainfall in January that year and low rainfall rate occurring in February, 2009.

Potassium ion concentration is a structural element of many soil minerals, and the normal range of potassium in rainwater ranges between 0.1 - 1.0 mg/L and the concentration in soil is between 5 - 50 mg/L (Allen, Grimshaw *et al*. 1974). In this study, there were sites in which potassium was not recorded which maybe as a result of high altitudes, distance from the source of dust fall and high rainfall recorded in Massif.

Maximum potassium levels agreed with maximum value observed in New York state due to increase amount of dust fall carrying potassium and other nutrients was 0.313 mg/L may be due to presence of anions and cations particles in the atmosphere (Harrison and Yin 2000).

Sulphate is one of the major anions occurring in natural water; it is abundant in the earth crust (Bartram and Ballance 1996). Sulphur in rain water ranges from 0.4 - 4 mg/L (Allen, Grimshaw *et al*. 1974). However, sources of sulphate could be through industrial wastes or through atmospheric decomposition (Brandt and Van Eldik 1995). Sources of sulphate are soil minerals, atmosphere, rainwater and the Earth crust (Bartram and Ballance 1996).

In this study the maximum value is may be due to the distinctive of SO_4^{2-} contribution during winter and sulphur levels dropped to a minimum level in the summer because SO_2 emissions were more prevalent in the winter (Wei and Wang 2005).

The maximum value recorded in Makhmur during this study maybe as a result of pollutants during February because no rainfall was detected in this month at this site or might be due to the high concentration of gypsum in Makhmur.

The low value of sulphate at recorded times of the month are probably as a result of sulphate concentrations decreasing over time and it is estimated that the average SO_4^{2-} concentration is extremely high during the first ten minutes of the precipitation event (Saylan, Toros *et al*. 2002).

Nitrite in rainwater is regarded as an unstable intermediate stage in the nitrogen cycle; formed by either oxidation of ammonia or reduction (denitrification) of nitrate (United 2004), the maximum values recorded were at Makhmur and Massif, Shaqlawa and Soran, the data in the present study was close nitrite concentrations in natural water. Nitrite is normally present at low concentrations which immediately oxidizing to nitrate or is further reduced to ammonia (Wetzel 2001), the low value recorded in a study correlated with sampling at unpolluted sites (Radojevic and Bashkin 1999). Makhmur is recorded as the most polluted site, because of the concentration of NO^{2-} during the rainy months can be attribute to erosion and discharge of nitrite sources into the water (Neal, House *et al*. 2006).

In the present study the minimum nitrate value was recorded in Koya town and Bahirka village during Oct. and Nov. 2008, nitrate levels dropped over the period of the study. While, the highest nitrate value correlated with the highest nitrate values ever recorded (Root, Jones *et al*. 2004).

In the mountains of Kurdistan region, vegetation varies with altitude, rain and slopes. In Erbil, vegetation is rain-fed and the cultivated alluvium is dependent on irrigation, results from the studies revealed that plant growth is affected by water quality. Plants watered with rainwater performed the least well, with the smallest average shoot dry weight root fresh weight and root dry weight when compared with Tab water watering. In regards, to plant height and shoot fresh weight, watering with rainwater correlated with a better performance on growth when compared with using tab water. We can conclude from our testing that the reason the plants grow so well when watered with rainwater is because rainwater has more nutrients present as suspended particles. There was a small positive correlation between root and stem length for the plants treated with rainwater. The main reasons which accounted for use of rainwater not increasing the weight of shoot system, might be due to the low pH of the rainwater, which maybe too acidic for crop plants to tolerate (Bouchard, Harmon *et al*. 2007).

The plants were watered by rain water and recorded higher nitrogen, phosphorus and sodium content was compared against use of Tab water.

Potassium is essential for all plants cell and membrane organization and protein synthesis, it appears to be the only major ion with a structural function in living organisms the concentration range normally in plant material 0.5 - 3 % (Gunning and Steer 1996). Potassium is present in all plant parts and held mainly in solution, it can therefore be readily translocated to young tissue when it is in short supply. Potassium is involved in the formation of carbohydrates and proteins and as a regulator of plant processes, the highest and lowest values for potassium in a current study plant tissues recorded when Tab water is used may due to the presence / absence potassium in a Tab water of salts even after water treatment (Epstein 1972)

The concentration of phosphorus in plant materials ranged between 0.05 - 0.3 %, it has been shown that plant growth is limited by the amount of phosphorus available (John 1970). In most waters, phosphorus is a growth–limiting factor, because it is usually present in very low concentration as it quickly binds with organic matter and soil particles, for this reason phosphorus was found to be high when using rainwater which then accumulated into plant tissues.

Rainwater has also been shown containing high concentrations which leads to accumulation in the plant tissue due to seawater evaporation which carries salts (Topçu, Incecik *et al*. 2002).

Higher airborne nitrate and ammonium concentrations from various industrial activities increase the wet and dry deposition rates of nitrogen in rain water. Increased atmospheric deposition can affect natural and agricultural systems and leads to increase the nitrogen content in a plant tissue comparing with tab water (Jones, Larbey *et al*. 1969; Galloway, Townsend *et al*. 2008)

In general, the use of rainwater on plants was better for seed growth than use of tab water because rain water contain many different types of elements as it becomes mixed with dust particles making it more suitable for plant growth (Topçu, Incecik *et al*. 2002).

CONCLUSION

Based on the result of this study the following conclusions and recommendations can be drawn; total acidity of rain water was neutral and determination of total hardness revealed that rainwater can be denoted as being between potable to relatively unpotable. The water from rainfall is rich in sodium and potassium. The results indicated that the chemical properties of rainfall were mostly attributed to dust fall or dry deposition. The concentration of study parameters was higher in south part in Erbil centre, Aski Kalak and east part Makhmur for rain water.

From our assessment of crop plant growth with different sources of water we can conclude that using collected rain water for plants irrigation will not encourage significant plant growth but did not damage crop plants as the water was at an acceptable pH range. This is important information for farmers and gardeners who are interested in growing plants using rain water in Iraq, these growers could rely on the rainwater for culturing crop plants and try to avoid using ground water which can be in short supply. With regards to nutrient, rainwater could be used to improve soil quality as rainwater contains suspended soil particles carried by atmosphere due to dust storms which are common in Iraq.

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