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RESPONCE OF PHYSICO-CHEMICAL SOIL PROPERTIES TO WASTEWATER APPLICATION AND SUBSEQUENT EFFECTS ON THREE WOODY SPECIES PLANTS

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ABSTRACT

Water scarcity is a world-wide problem that is predict to increase as a result of increasing population and subsequent increasing the pressure on water sources. This research aimed to reach a feasible outcome for the possibility of blending industrial effluent with high quality water as a method of reducing the increasing demand on fresh water for irrigation. The study was conduct in the college of Agricultural engineering science- Forestry department from June till October of 2019 to examine the effect of blending wastewater of two types of industrial wastewater from different regions with tap water at three dilutions for each (25%, 50%, and 75%) along with the control. Factorial Randomized Complete Block Design (RCBD) was used to analyze the physical and chemical properties of water, soil and growth parameter of three species (*Platanus orientalis* L., *Eucalyptus camaldulensis* Dehn, and ***Populus nigra*** **L.). The results revealed that the soil properties (temperature, pH, electrical conductivity, potassium, nitrate, bicarbonate, sulfate, chloride, and phosphate) were directly affected by water trends since pH of R2 ww. has an acidic nature (5.3) as well the soil irrigated with this wastewater record pH value lower than 6 in all months. The EC of R1 ww. record high values so as the soil irrigated with different dilutions of it which reach 2.5 ds.m^{-1} when the concentration was 75% which was significantly different from control soil (0.5 ds.m^{-1}). Moreover, increasing the concentration of wastewater lead to form unfavorable soil for the growth of tested plants by recording lower root and shoot biomass when the concentration of wastewaters was > 25% as well as, the chlorophyl content which record an increment in eucalyptus in chlorophyl a, b, and total when irrigated with 25% R1 ww. and R2 ww. then a reduction observed when wastewater concentration increased. Aforementioned finding led to a conclusion that diluting wastewater with tap water increased the survival rate of plants and mitigate the properties of water which can be recommended to be used as a substitution for irrigation.**

KEY WORDS: Pollution, water, soil, *Platanus orientalis* L., *Eucalyptus camaldulensis* Dehn, and *Populus nigra* L

1. INTRODUCTION

Water scarcity is becoming the main threat that predict to affects about 60% of world's population by 2025 (Qadir *et al*., 2007). The continuous increasing of population and subsequent consumption of water by different sectors including domestic, agriculture, and industry has influenced the demand for water (Vorosmarty *et al*., 2000; Ercin and Hoekstra. 2014). However, the quality and the availability of water sources is predicting to be affected by the continuous growing in population, industrialization, urbanization, and climate changes (Kundzewicz and Krysanova, 2010) since not just the quantity of water is important but also the quality that is suitable for each sector is critical (van Vliet *et al*., 2017). Mekonnen and Hoekstra (2016) found that two-third of world's population partially suffer water deficiency during one year. Industry consumes a large quantity of water producing wastewater whose physical, Chemical, and biological characteristic render it usefulness for some purposes like drinking and irrigation (Amoatey and Bani, 2011). Attempt have been made to remediate wastewater by physical,

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chemical, and biological treatment each include a sequence of treatment (ESCWA, 2003). However, these techniques are costly and can't be afforded in many countries as a result wastewater from industry and municipal has been used directly for irrigation (Blumenthal *et al*., 2000; Sharma *et al*., 2007; Lahlou *et al*., 2021). Wastewater were used widely for irrigation especially where the costs of water treatment were high and it regards as a mean for increasing the productivity and fertility of soil as well as reduce the use of high-quality water (Hussain *et al*., 2001; Chang *et al*., 2009). At the same time, it considers a significant source of environmental pollution if it didn't apply carefully (Wang and Tao, 1998). Many researchers addressed the direct uses of wastewater as a critical problem since change in physicochemical properties of soils like pH, OM, EC, and heavy metals has been reported (Chen *et al*., 2004; Rehman *et al*., 2015). Studies revealed that blending different types of water (high quality water with low quality or wastewater) to produce water with acceptable characteristic as a strategy for saving high quality water (Hamdy, 2003; Kulkarani, 2011). Recently water blending gained an interest in different region because it is low-cost strategy that save fresh water (Rhoades *et al*., 1992; Tanji and Kielen, 2002). Studies emphasized that blending different sources of water is a vital method to ensure the favorable water quality for irrigation (Ben-Gal *et al*., 2008; Suwaila *et al*., 2020).

The objectives of this study were to determine the effects of blended wastewater on the physico-chemical characteristic of soil and subsequent effect on tested plants and determine the survival and tolerance of tested plants to different dilution ratio of wastewaters.

2. MATERIALS AND METHODS

Location and experimental design

This study was conduct from April to October 2019 in field of Forestry Department / Collage of Agricultural Engineering Sciences / University of Duhok located in the district of Sumail, Duhok at 473 m above sea level; Latitude: 36°51 N; and Longitude: 42°52 E. Weather patterns during study period were obtained from Sumail metrological station as shown in table (1).

Table (1):- The weather patterns for studying period (2019)

Months	Rainfall (mm)	Temperature		Humidity
		Max	Min	
January	100.1	12.25	2.845	79.09
February	52.5	14.26	3.529	78.29
March	241.9	16.1	5.755	80.45
April	149.5	14.79	8.677	75.88
May	37.7	32.94	15.11	49.76
June	0	40.6	20.58	31.15
July	0	40.75	20.68	28.71
August	0	42.45	22.64	28.34
September	0	37.06	17.45	31.95
October	30.5	31.41	14.74	46.68
November	122	22.68	6.32	49.55
December	82.4	14.99	6.013	77.86

Soil profile from field of Agricultural Engineering Sciences college was collected from the top (20 cm). Soil and loam were air dried, sieved through a 4 mm sieve, mixed together at 3 soils: 1 loam ratio. Random samples were prepared by drying, grounding, and sieving through 2 mm sieve for soil physical and chemical analysis done at soil department laboratory, Collage of Agricultural Engineering Sciences, Duhok university (Table 2).

Table(2):-The characteristic of the soil used in experiment

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Characteristics	Value	Measurement units
PH	7.4	
EC	0.242	ds.m-1
Organic matter	1.71	%
Moisture content	2.07	%
Sand	34.5	%
Silt	27.1	%
Clay	38.4	%
Texture	Clay loam	

Two years old seedling of *Platanus Orientalis* L., *Eucalyptus camaldulensis* Dehn, and *Populus nigra* L., were used with uniform length and diameter.

To study the effect of blended wastewater on soil properties and tested plants three dilutions (Wastewater blended with tap water at different concentrations) of two different wastewaters have been used along with control (tap water). The first wastewater was collected from Kashe industrial region at latitude (36.9860), longitude (42.8033) and named (R1ww.) while the second wastewater was collected from latitude (36.9848), longitude (42.7913) in Kashe industrial area (figure 1) named R2ww. Physico-chemical properties of water and soil that irrigated with wastewaters were analyzed monthly from June till October (2019).

physico-chemical parameters of water and soil

All the parameters were determined following the procedures adopted by Page *et al* (1982) , APHA (1989), and A.O.A.C, (1995) methods and analysis using SAS soft ware.

Water temperature

The temperature was measured through immersing thermometer into the sample and wait until a constant reading was obtained.

Hydrogen ion concentration (pH)

pH was deermined by pH meter Model H18417-HI8519 Microprocessor after being calibrated by standard buffers.

Fig.(1):-. Shows wastewater collection regions

Electrical Conductivity (EC)

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The EC was measured with EC-meter Model HI 9635, portable water proof multi range, conductivity / TDS meter, HANNA. Calibration of instrument was done by specific standard solutions (0.1N KCl), final results adjusted to 25 °C and expressed in $ds.m^{-1}$.

Total Dissolved Solid (TSD)

TDS was measured using pH-conductivity-TDS meter (COMBO HI model 98130).

Dissolved Oxygen (DO)

Dissolved oxygen was determined by ProODO – meter.

Potassium (K^+)

Flame photometer Model Jenway, Mode FFP7 was used.

Nitrate (NO_3^-)

Nitrate concentration of samples were determined by a special nitrate sensitive membrane electrode since the electrode responds to $NO3^-$ activity.

Bicarbonate (HCO_3)

The concentration of bicarbonate (hydrogen carbonate) was determined by titration using 0.01 N of HCl as titrator.

Sulfate (SO_4^{-2})

Sulfate ion was determined using turbidimetric method.

Chloride (CL)

Agentometric method was used for measuring chloride content.

Phosphate (PO_4)

Reactive phosphorus was determined by colorimetric method using Spectrophotometer (TU.1800, UK) according to Olsen et al (1954) which based on the extraction of phosphate from the soil by 0.5 N sodium bicarbonate solution. Hydroxide and bicarbonate competitively have the ability to desorb phosphate from soil particles then orthophosphate ion reacts with ammonium molybdate and antimony potassium tartrate under acidic conditions to form a complex. This complex is reduced with ascorbic acid to form a blue complex which absorbs light at 880 nm. The absorbance is proportional to the concentration of orthophosphate in the sample.

Experimental design

Factorial Randomized Complete Block Design (RCBD) with two factors and all possible interactions were used to test plants. Three plant species and 7 wastewaters {control (tap water); 3 dilutions from R1ww. (25%, 50%, and 75%); 3 dilutions from R2ww. (25%,50%, and 75%). 3 replications (2 observation per each replication)}

Harvesting of plants

At the end of the growing season (2019), the seedlings were uprooted carefully, root and shoot were separated and washed to remove any soil residues, air dried, then placed in oven for 72 hours at 70℃ (Arzani and Roosta, 2004) to record dry weight.

Chlorophyll content

Absolute ethanol (99%) was used to estimate chlorophylls (a, b, and total) according to Wintermans and Demots (1965) methods by using of Spectrophotometer (Pharmacia) at two wave length (665nm and 649nm) for chlorophyll a and b respectively as shown in the following equations:

Chl. a = (13.7) (A 665 nm) – (5.76) (A 649 nm)

Chl. b = (25.8) (A 649 nm) – (7.6) (A 665 nm)

Total chl. = (chl. a) + (chl. b)

RESULTS

Physico-chemical character of wastewaters

Results reveals a variation in the properties of three studied water since there was significant difference in the temperature of control water (well water) and wastewaters. The highest record 16.4, 26.6, and 25.3 were obtained in August for control, R1 ww., and R2 ww. respectively (Figure 2). R1 ww. differed significantly from R2 ww. and control.

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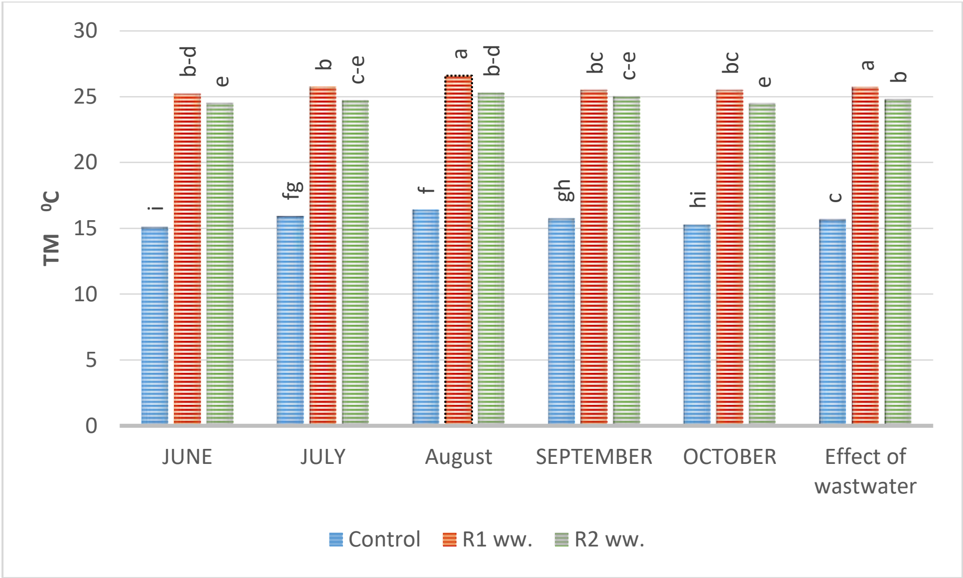

Fig.(2):-. Shows water temperature

The level of pH in control water (well water) and the R1 ww. were slightly alkaline with highest value 8 recorded in October for control. Meanwhile, wastewater from the R2 has an acidic nature with lowest value 5.3 recorded in September. Generally, the R2 ww. significantly differ from the control and R1 ww. also, insignificant differences in the level of pH observed in regard to the months in most cases (Figure 3).

Electrical conductivity records significant differences in R1 ww. comparing with R2 ww. and control (figure 4) while insignificant effect between wastewaters in different months except in R1 ww. in October.

Clear variation in the presence of total dissolved solid in studied waters hence, control water records the lowest values in all months. On the other hand, R1 ww. being the highest values with peak of 2627.3 mg.l $^{-1}$ in July while R2 ww. record 2034.7 mg.l $^{-1}$ in September (figure 5).

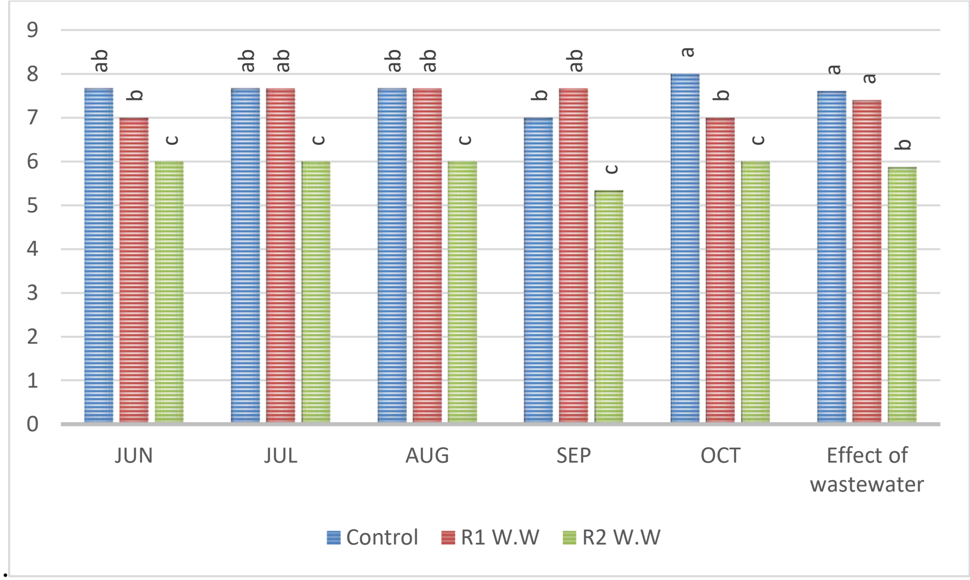

Fig.(3):-. Shows pH of tested waters

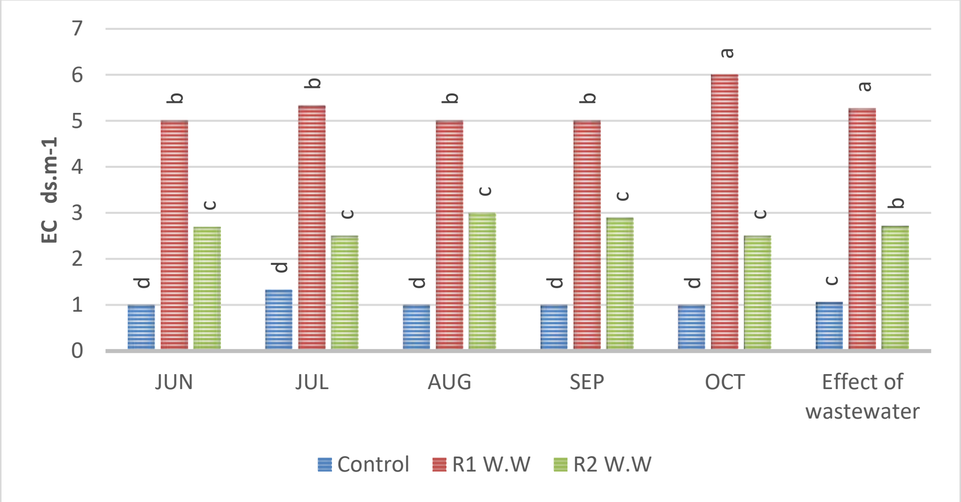

Fig.(4):-. Shows electrical conductivity of tested waters

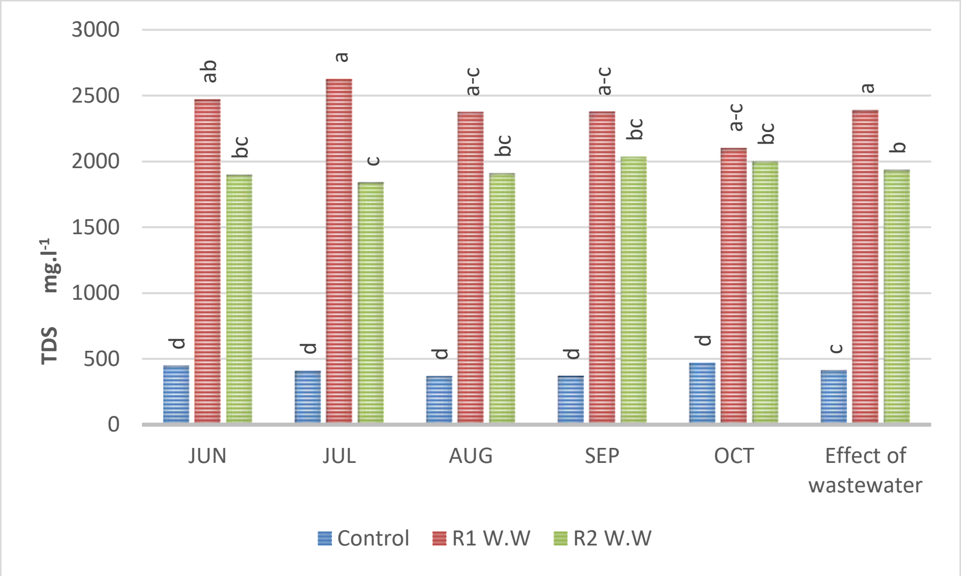

Fig.(5):-. Shows total dissolved solid in water

Figure (6) illustrate the concentration of D.O. in tested water where control water records the highest values during the study period and significantly differ from R2 ww. and R1 ww. which records the lowest content of D.O. that record 2.4 mg.l^{-1} in June and September.

Potassium, nitrate and bicarbonate contents were most abundant in R1 ww. which reached 69.29, 25.21 and 807.6 mg.l^{-1} respectively. Meanwhile, their concentration in control w. and R2 ww. were insignificantly varied except potassium in October in control (figure 7,8,9).

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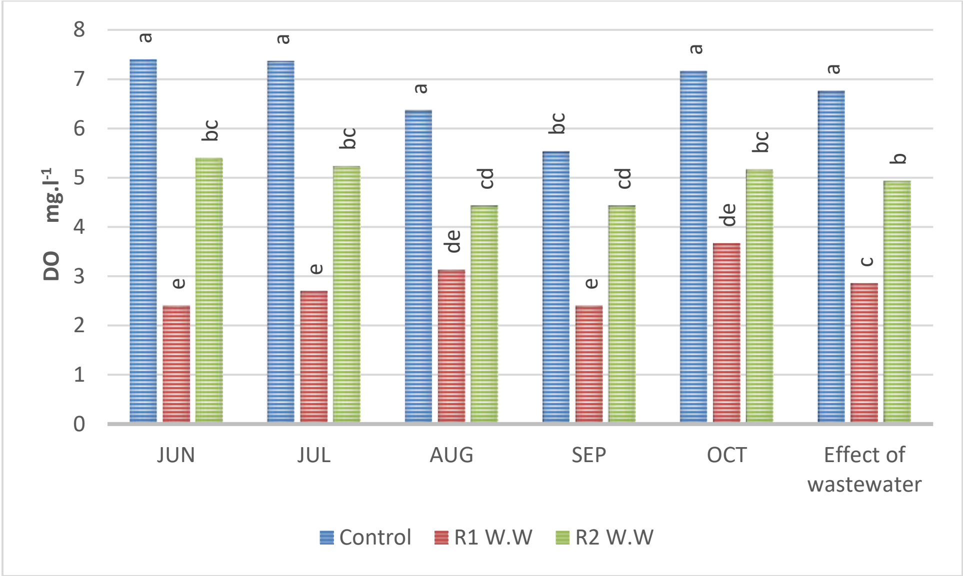

Fig.(6):-. Shows water dissolved oxygen

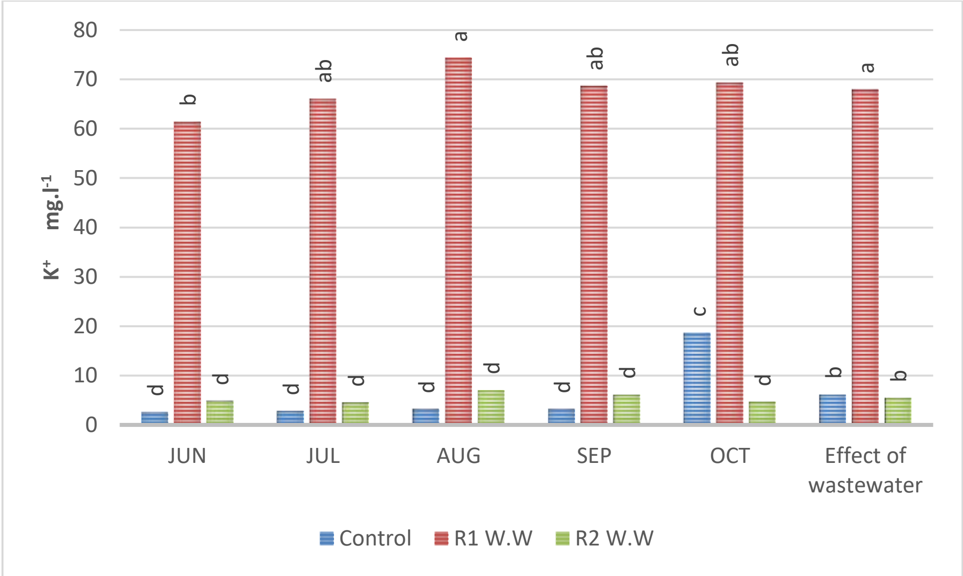

Fig.(7):-. Shows potassium content in waters

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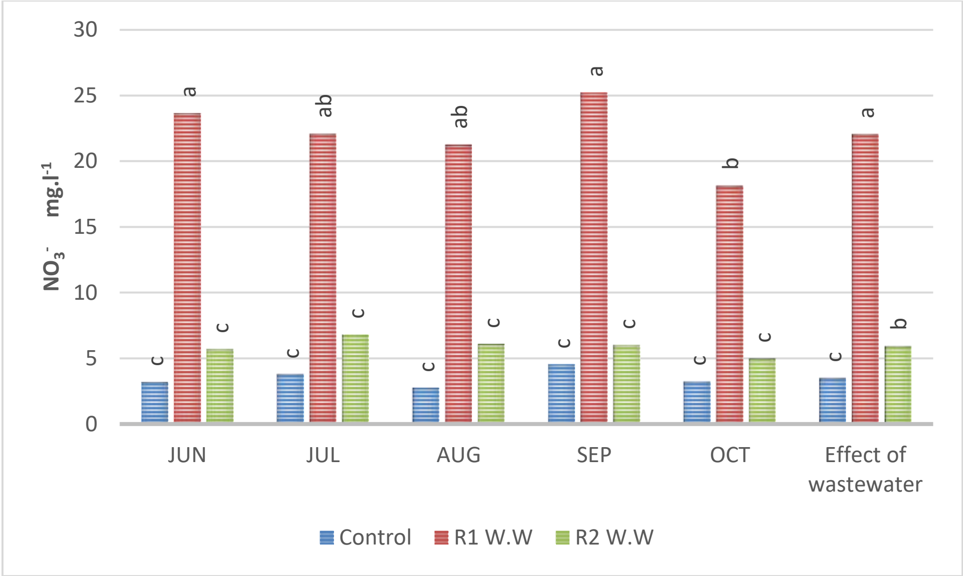

Fig.(8):-. Shows nitrate content in waters

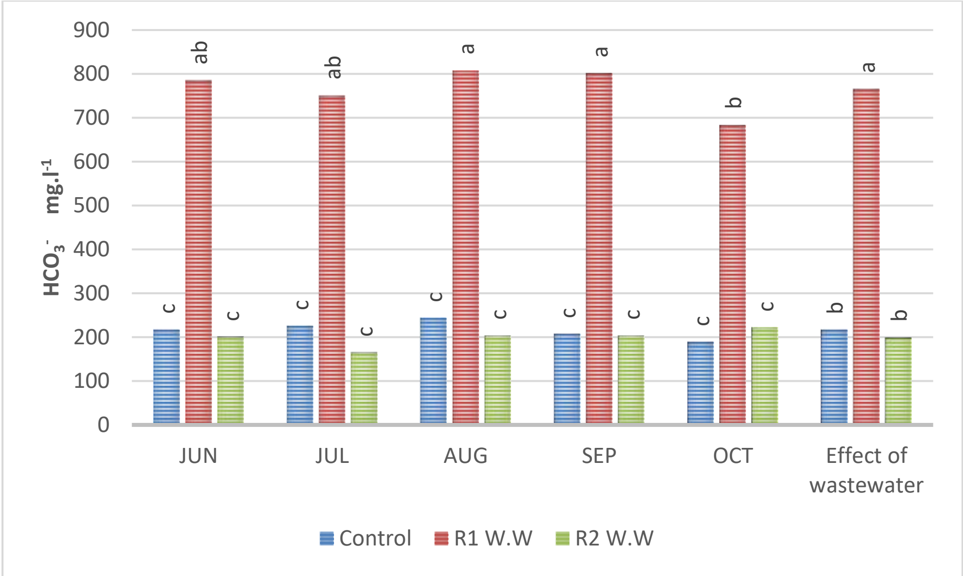

Fig.(9):-. Shows bicarbonate content of in water

Significant variation in the content of sulfate were recorded with R1ww. being the highest content followed by significant reduction in R2 ww. and control water that contain the lowest concentration as well (figure 10).

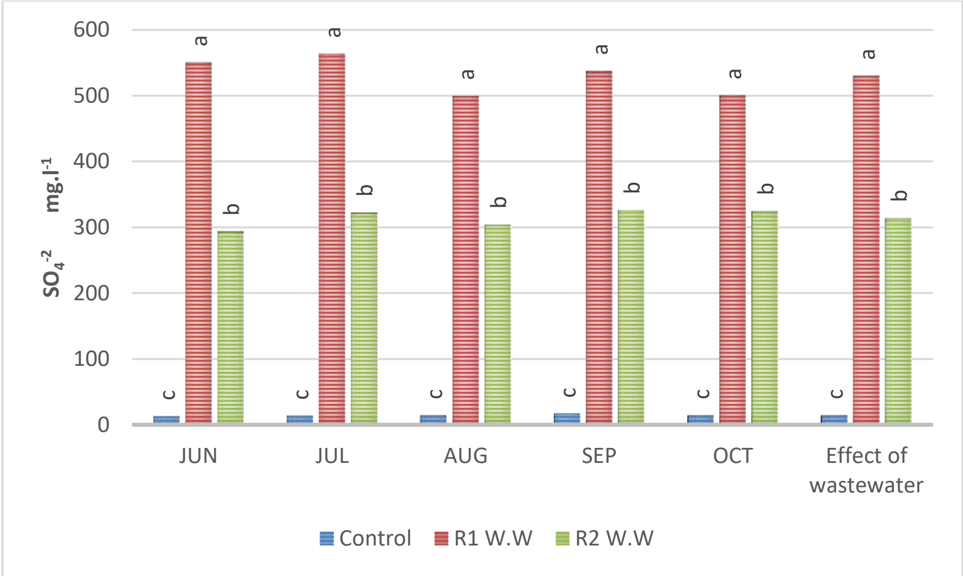

Fig.(10):-. Shows sulfate content in water

Chloride content differ in the of in R1 ww. during September and October by showing significant increment over other months (figure11). However, insignificant differences were observed between control and R2 ww. In all months except in July for R2ww..

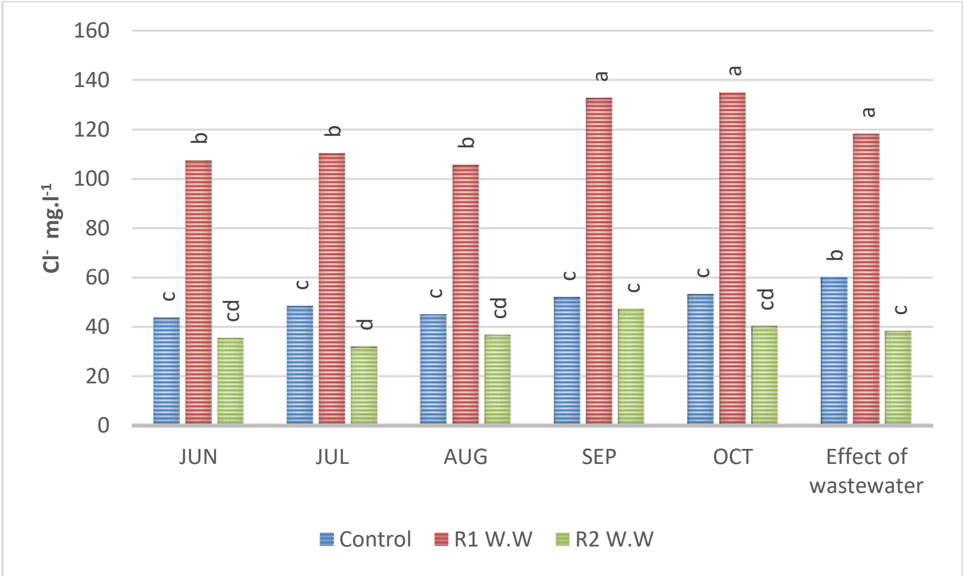

Fig.(11):-.. Shows chloride content in water

Wastewater R1 ww. contain the highest level of phosphate (figure 12) followed by R2 ww. which were significantly differed from the control water. Some variation occured in R1 ww. regarding sampling period while R2 ww. and control gain stable level during same duration.

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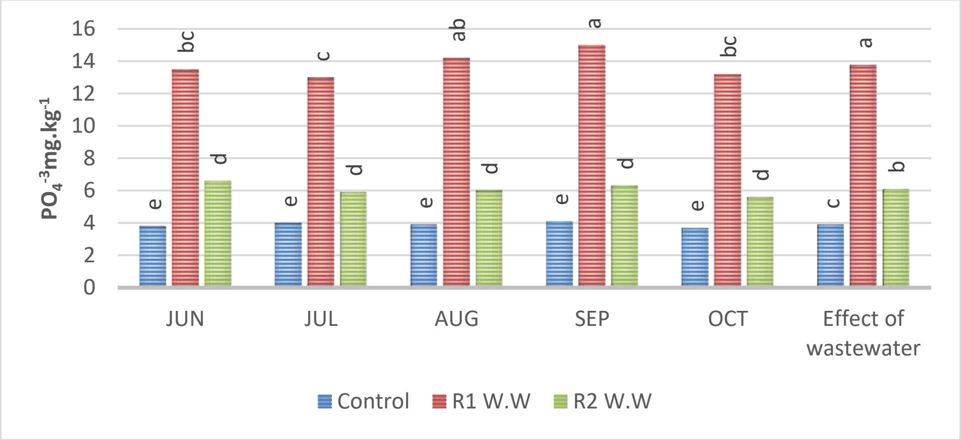

Fig.(12):-. Shows phosphate content in water

Physico-chemical properties of soil irrigated with wastewaters

The quality of water has a direct influence on the soil physical and chemical characteristics. Soil temperature was higher as the concentration of wastewaters increased in many cases (Figure 13). The highest values were records in August for all types of water and the soil irrigated with 50%, 75% of R1 ww. and 75% of R2 ww. were significantly varied from other treatments.

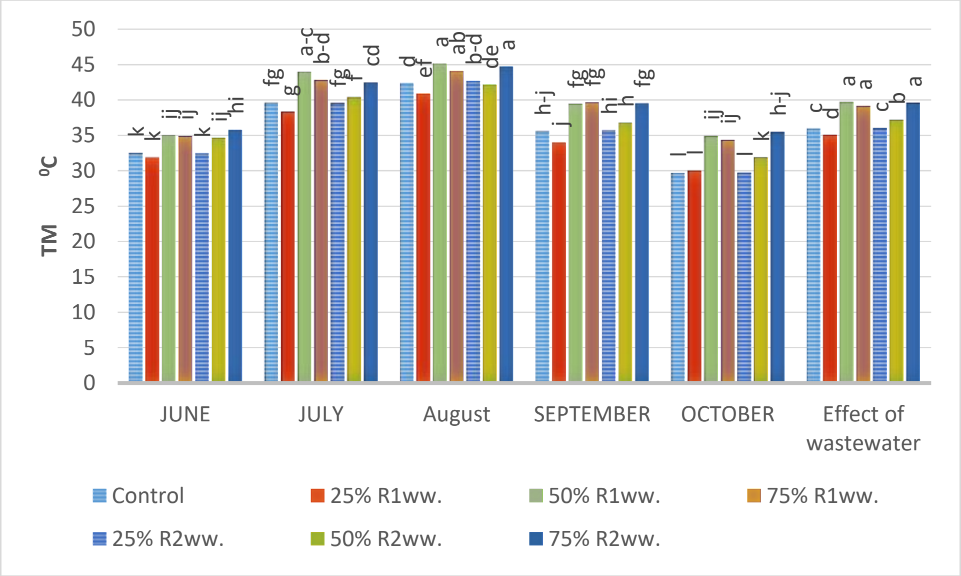

Fig.(13):-. Shows soil temperature

The pH of the soil affected directly by the pH of water (Figure 14) hence, the soils irrigated with R2 ww. tends to be acidic as a result of the acidic nature of the R2 ww. (Figure 3) while, the other soils appeared to be neutral. Significant differences between the soils irrigated by R2 ww. with the control and R1 ww. were observed as well as, some differences in the pH of tested soils in different months which were significant in little cases as in soil irrigated by 50% of R1 ww. in July ,75% of R1 ww., 50% of R2 ww. in August, and 75% of R2 ww. in July.

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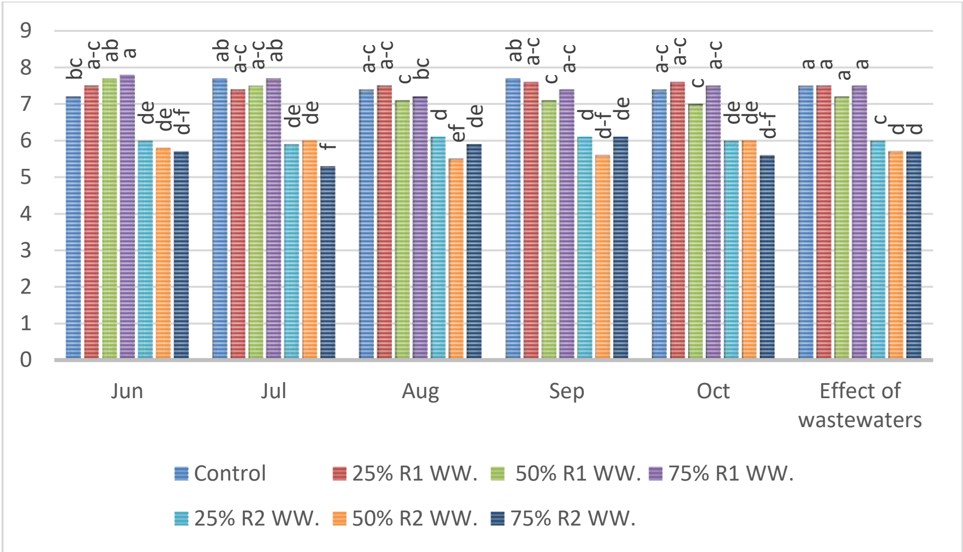

Fig.(14):-. Shows pH of soil

There was a linear correlation between the electrical conductivity of R1 ww. and EC of the soil hence, it has the highest EC so as the soils irrigated by this water records the highest values (figure 15). However, that wasn't the case for soil irrigated with R2ww. inspite having an Ec more than that of control (figure 4) the differences were not significant between them.

Variation in soil's content of potassium showed hence, the soils irrigated by R1 ww. has the highest concentration reached about 64.32 mg.kg^{-1} in July when treated with 75% (figure 16). There were differences in the concentration of K between months which in many cases reached significant levels.

As the concentration of R1 ww. increased the content of nitrate in soil increased but that was not the case with R2 ww. since although its content of nitrate was more than control but soil irrigated with it were not affected (figure 17). On the other hand, some variations were obvious as a result of sample duration.

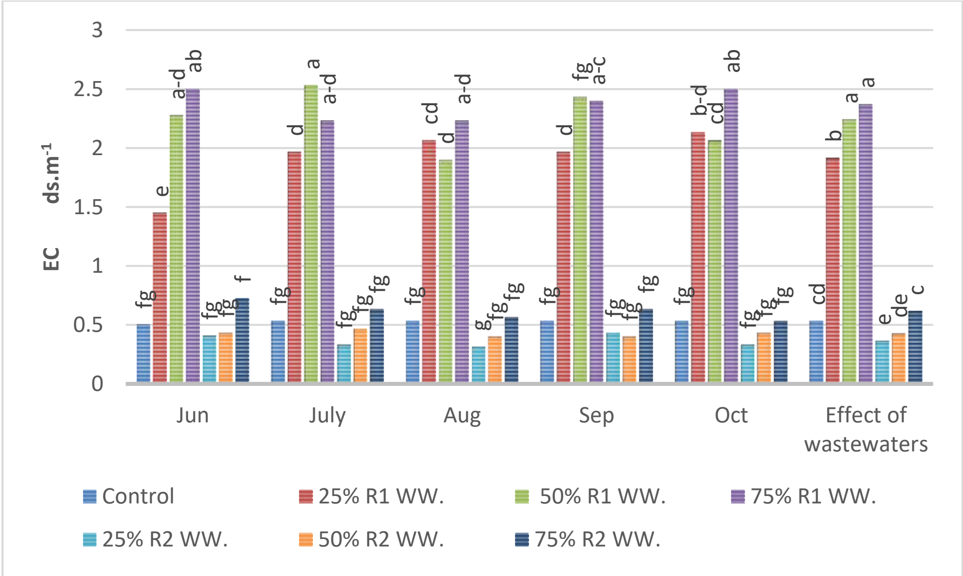

Fig.(15):-. Shows soil EC

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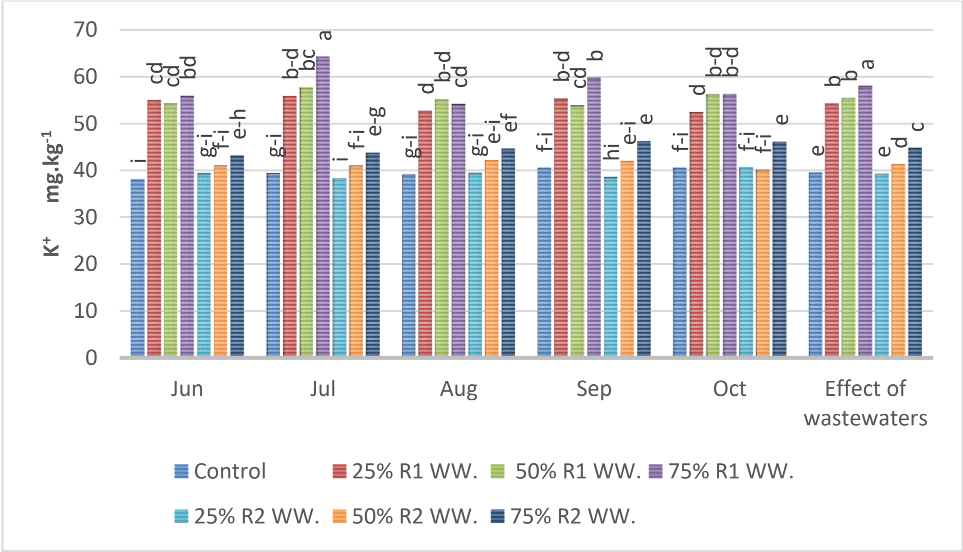

Fig.(16):-. Shows potassium content in soil

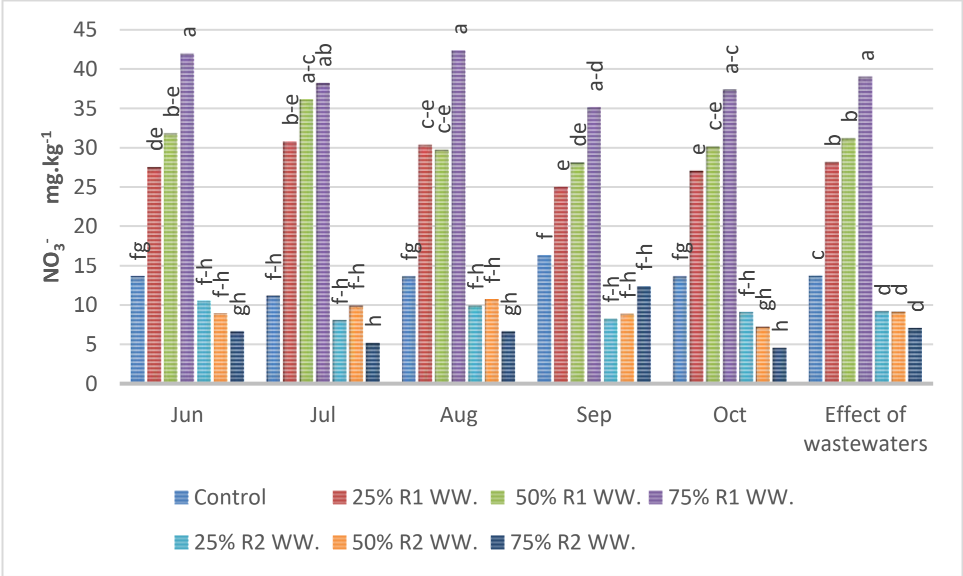

Fig.(17):-. Shows nitrate content in soil

Finding in figure (18,19) showed that the highest concentration of bicarbonate ion and sulfate generally observed in soil irrigated by R1ww. which contain the highest concentration of them but it seems there wasn't a direct relation between the content of ion in water (figure 9) and their levels in soil since R2 ww. content of each ion was more than control despite this fact the soil content in control exceeds the levels of soils irrigated with R2 ww.

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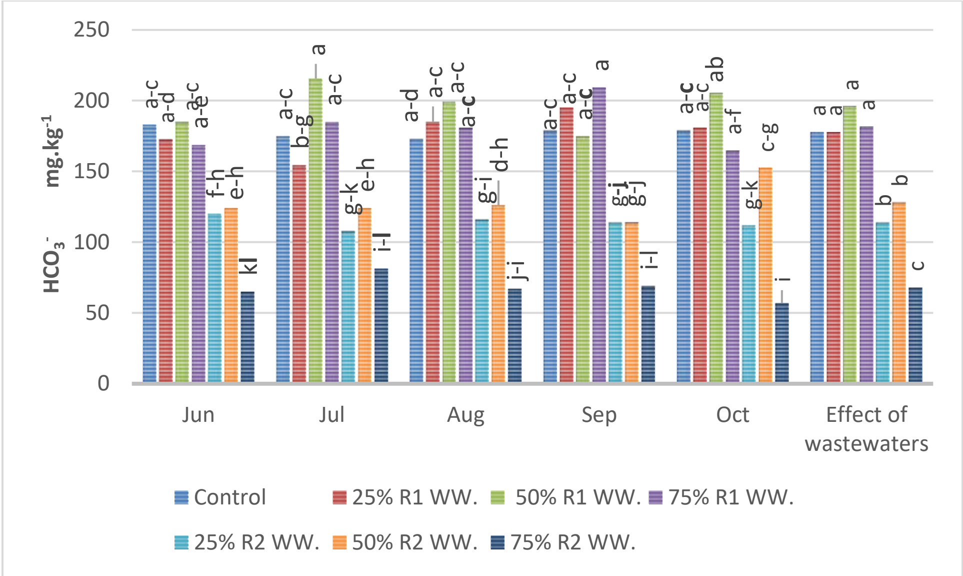

Fig.(18):-. Shows bicarbonate ion in soil

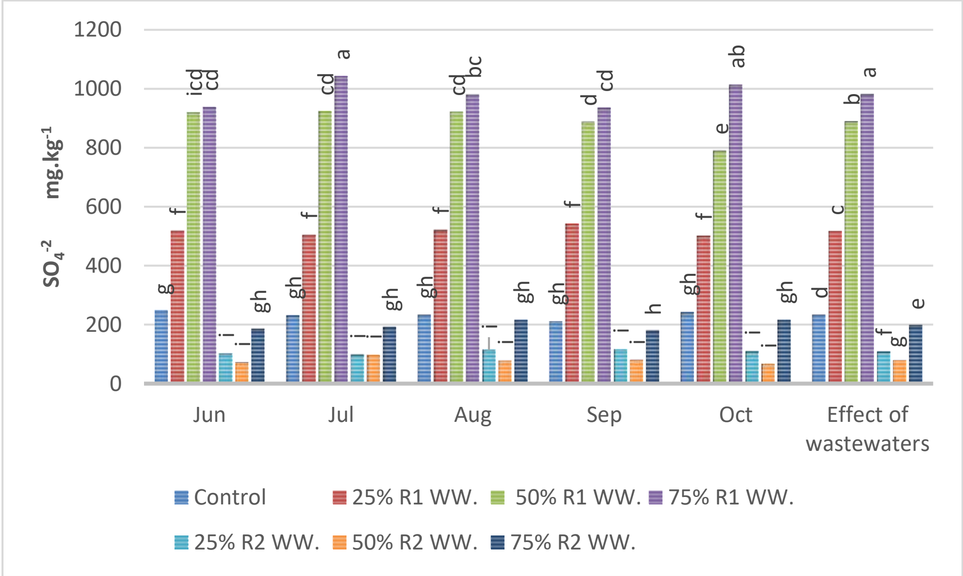

Fig.(19):-. Shows sulfate content in soil

Soil irrigated by R1ww. recorded the highest content of chloride which reached 1043.2 $mg.kg^{-1}$ in July when 75% treatment used as well as 50% and 75 % of R2 ww. chloride content was significantly differed from control. Fluctuation appeared in the content of chloride between months in some cases (figure 20).

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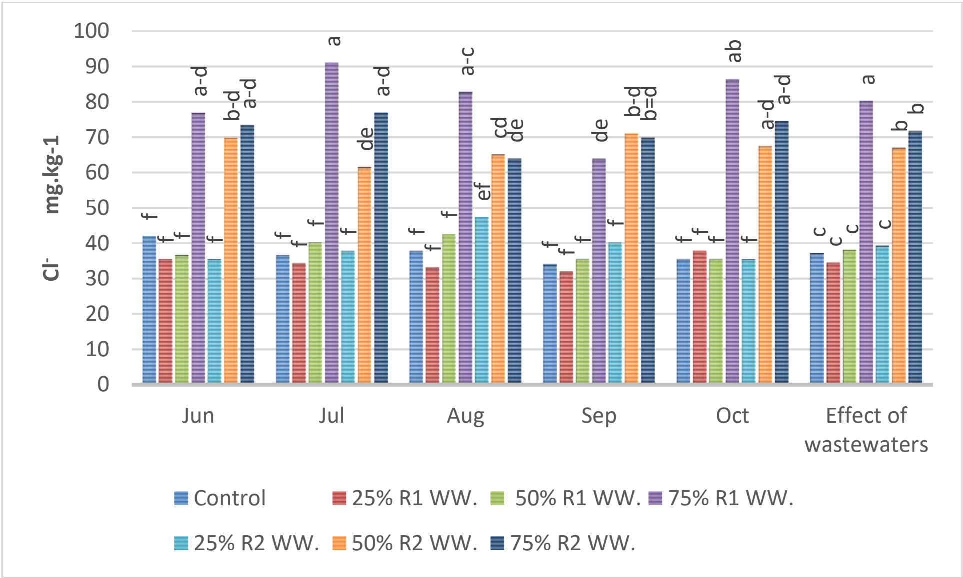

Fig.(20):-. Shows chloride content in soil

Finding in figure 21 revealed that the content of phosphate in soil was linearly correlated with its content in water. As the percentage of wastewater increased the content of phosphate increased in soil with recording the highest value 38.61 mg.kg^{-1} in October when irrigated by 75% R1ww.

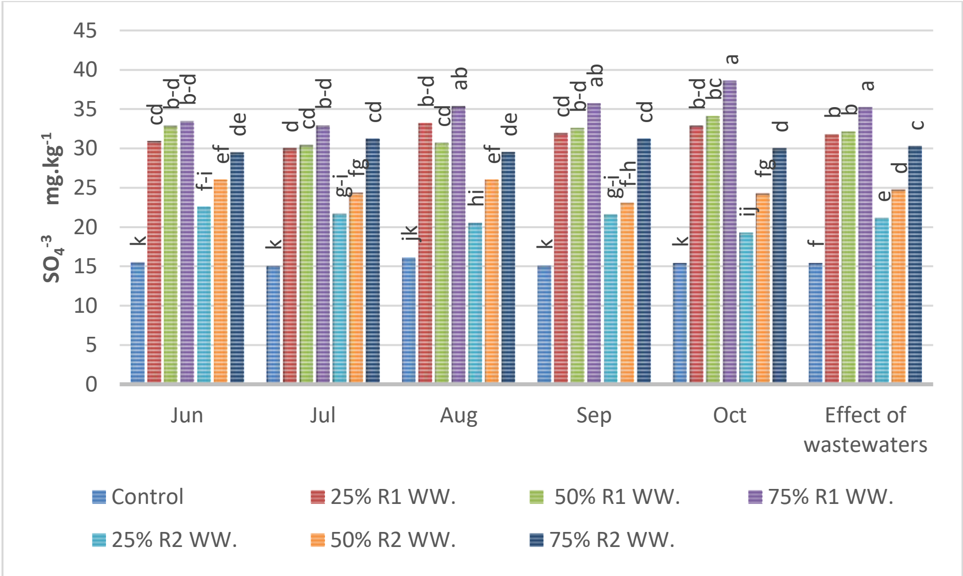

Fig.(21):- Shows phosphate content in soil

PLANT PARAMETERS

Chlorophyll content

The content of all types of chlorophyll decreases as the wastewater percentage increased (figure 22). There was a reduction in the content chlorophyl a,b, and total for *Platanus orientalis* L. which was in most cases significant comparing with the control except chlorophyl b when the plane tree irrigated with 25% R2ww. which record a higher value 3.725 mg.gm^{-1} FW than control 3.481 mg.gm^{-1} FW but it wasn't significant increment. Eucalyptus records the highest content of chlorophyl a, b, and total 8.512, 3.554, and 12.066 respectively in 25% R2 ww. as well as, 25% of R1 ww. record an insignificant increasing over the control while other treatments caused significant reduction. The effects

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of the wastewaters were clear in the chlorophyl content in *Populus nigra* L. and caused significant reduction when compared to control. Generally, fluctuation was shown in the chlorophyl content between treatments and the detrimental effect of R2 ww. exceeded the R1 ww.

Biomass

Clear reduction in the plant biomass specially when the wastewater concentration increased (figure 23). Oriental plane tree records the lowest root and shoot biomass 33.746, 105.536 gm respectively when treated with 75% R2ww. as well as, poplar tree which record 73.113 and 175.883 gm for root and shoot respectively at same dilution ratio. Meanwhile, eucalyptus reached its lowest root biomass 34.25 gm by 75% R2 ww. but shoot biomass 94.22 gm was the lowest when irrigated by 75% R1 ww**.**

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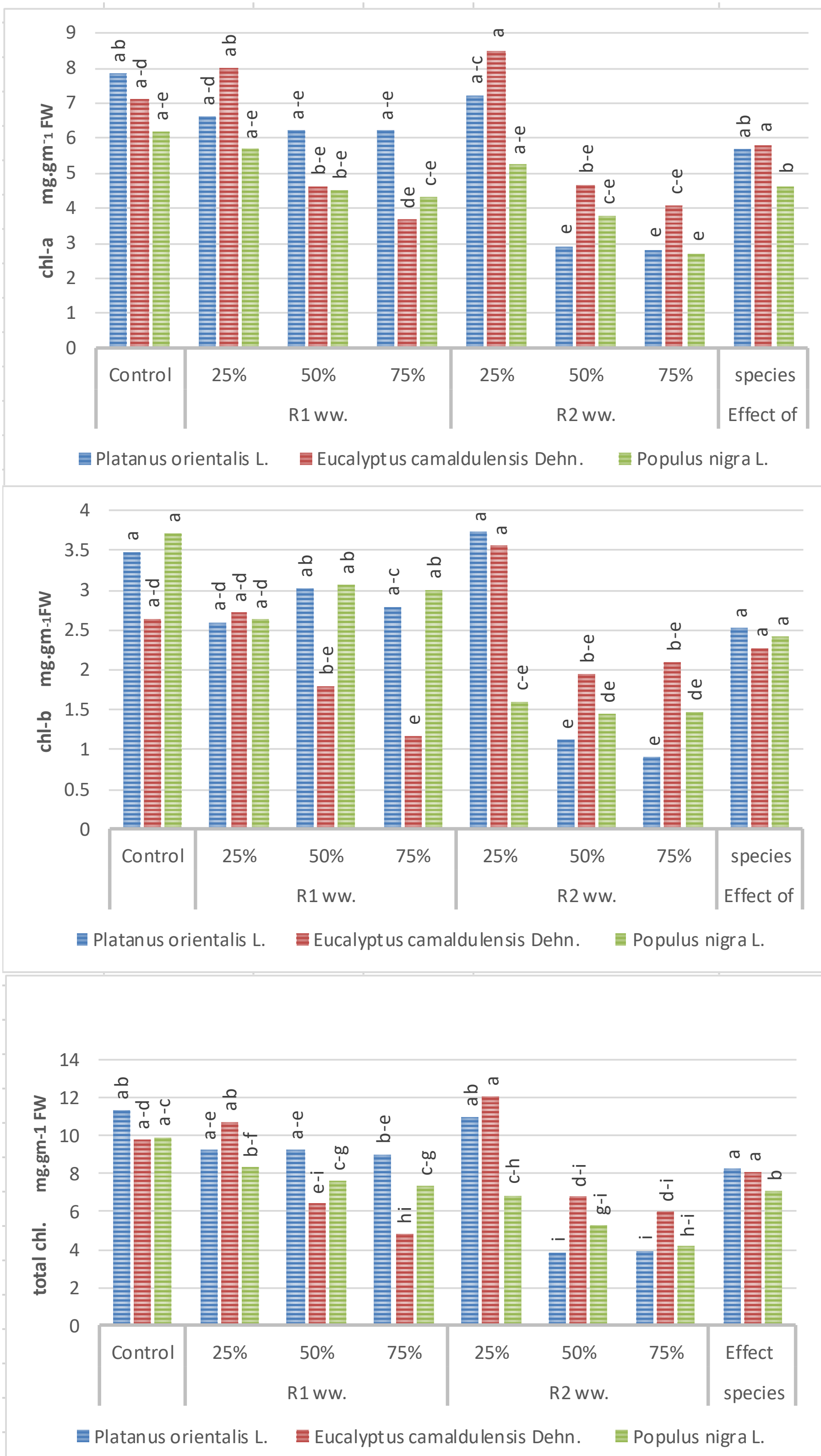

Fig.(22):-. Shows chlorophyl content in plants

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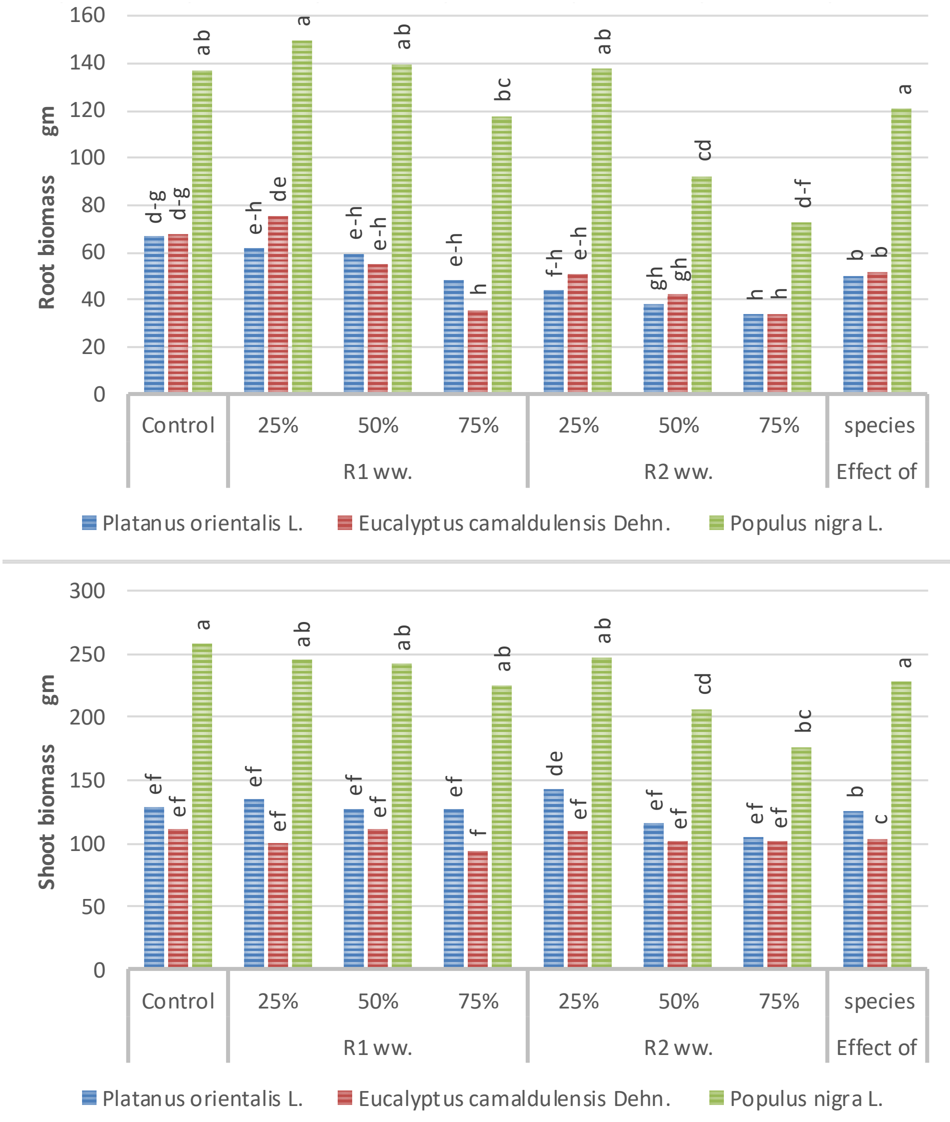

Fig.(23):-. Shows plant biomass

DISCUSSION

It was clear from this study that many soil properties influenced by water since soil irrigated by R2 ww. was slightly acidic which returns to the acidic nature of this wastewater while soils of control and R1 ww. were slightly alkaline. Effluents from industry seems to have a direct influence in the physicochemical characters of soil like pH, EC, Cl, K…..etc (Ahmad et al,. 2012). Akpoveta et al (2010) state that the soil pH increased when irrigated with effluent that had alkaline nature same result was reported by Madyiwa et al (2002) when the top layer of soil pH showed to be higher than sub soil which returns to the alkaline nature of wastewater used for irrigation. The electrical conductivity (EC) which indicate the total ions contents in water had a direct relation with the total dissolved solids (TDS) of water (Ishaya et al., 2011). Water classified according to EC in to; non saline EC < 0.7 ds/m, slightly saline EC 0.7-2 ds/m, moderately saline 2-10 ds/m, highly saline EC 10-25, very highly saline EC 25-45 ds/m, and brine EC > 45 ds/m (Rhoades et al., 1992). Aforementioned classification indicate that control water was slightly saline while R1 ww. and R2 ww. were moderately saline R1 ww. had a high EC (figure 4) so as the soil irrigated with it (Figure 16) this fact was mentioned by Khai et al (2008) since he reported that the usage of industrial

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effluent lead to raise the EC and the level of available potassium of soil. The desirable limits of TDS are from 500 mg/l to 1000 mg/l while EC is no more than 1.5 ds/m (WHO 2011). Todd and Mays (2005) classify water depending on TDS content in to four categories fresh water TDS, 1000 mg.l, brakish water TDS 1000-10000 mg/l, saline water TDS 10000-100000 mg/l, and brine water TDS> 100000 mg/l. The control water was within fresh water category while R1 ww. and R2 ww. were both brakish water.

Many soil properties like potassium, nitrate, bicarbonate, sulfate, chloride, and phosphate were higher in R1 ww. and R2 ww. than of control water as a result the soils content of these parameters were higher, same results were reported by Reddy and Rao (2003), and Josh and Santani (2012). Making dilution of the two wastewaters had a direct effect on the properties of soil. Further the more, it reduces the chances of toxic effects of wastewater on plants since the more diluted sample the more suitable and acceptable for irrigation. Many country use wastewater from domestic and industrial region as a substitution either by treated wastewater or by blending different types of water to make them more suitable for use and overcome water deficiency (Angelakis and Boutoux, 2001; Kan and Rapapaport- Rom, 2012). The impact of wastewater observed on studied plants since a reduction in chlorophyl content was observed at higher concentration. Lowest contents of chlorophyl -a were 2.818, 4.073, and 2.717 mg.gm^{-1} FW for oriental plane tree, eucalyptus, and poplar tree respectively when irrigated by 75% of R2 ww. Meanwhile, 25% of both wastewaters had a stimulatory effect in the content of chlorophyl-a and total chlorophyl content in *Eucalyptus camaldulensis* comparing with the control. Root biomass declined as the concentration of wastewater increased except in 25%, 50 % of R1 ww. and 25% of R2 ww. for poplar tree as well as its shoot biomass showed insignificant differences when comparing with control in many cases. Many researchers emphasized the reduction in chlorophyl content and plant biomass as a result of the increasing concentration of wastewaters (Nath et al., 2005; Nagajyothi et al., 2009; Radic et al., 2010; Gassama *et al*., 2015). Generally, Lower concentration of wastewater showed to suit plant irrigation since plant growth parameter showed insignificant differences comparing with control and in some cases a stimulatory influence observed. As well as, the survival rate of plant under 25% and 50% was more than that of 75% in all tested species which indicate that the dilution mitigates the properties of wastewaters.

Conclusion

This experiment emphasized that the quality of industrial effluent affects the physico-chemical properties of soil and dilution that made to mitigate the negative impact gave a positive result since the soil parameters were more suitable for the survival of tested plants.

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