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Growth Performance of Black poplar (*Populus nigra* L.) Under Drought Condition and Sewage Water Irrigation

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Abstract: The response of black poplar (*Populus nigra* L.) seedlings to the combination of both drought and sewage water irrigation have been investigated from 18-5-2019 to 18-8-2019. Two drought stress levels; D0; 90% or full water holding capacity (WHC) and D1; 30% WHC interacted with three sewage irrigation treatments; S0; 100 % of tap water as a control, S1; 50% of tap water and sewage water and S2; 100% of sewage water. The irrigation water quality index (IWQI) of S1 was 59.31 located under moderate restrictions class for irrigation purposes. Despite to its low pollution load index (PLI); 0.47. Fully irrigation to soil holding capacity with S1 (S1D0) led to a significant increase in seedling height, stem base diameter, fresh and dry biomass and moisture content in shoot system. In addition, the highest tolerance index (TI %) about 92.07 % of the seedlings recorded despite to the soil toxicity with Ni and Pb ions. Lowest accumulation and metal toxicity of Cu, Zn, Cd, Pb and Mn in the soil and leaves have been determined. Thus, diluting sewage water; 1:1 can be used to irrigate black poplar trees with high water demand and moderate to high tolerance to salts for reforestation and urban vegetation.

Keywords: Heavy metals, Seedling biomass, Sewage water, Metal accumulation, *Populus nigra*.

Introduction

It is common in arid regions of the world are generally noted for their low primary productivity which is because of a combination of low, unpredictable water supply and low soil nutrient concentrations (Peek & Forseth, 2003). Plant adaptation to dry conditions has been studied with high degree of water limitation tolerance, larger biomass allocation to roots, and greatly capable utilization of water (Patterson *et al.*, 1997). Applying of recycled wastewater in tree irrigation may assist in decreasing the problem of the limited availability of freshwater this have been proved by many authors (Bedbabis *et al.*, 2009). Hasan *et al.* (2009) stated that when metals are added in soil, turn out to be toxic as can interrupt physiology characterizes of plants and as a result plant development can be affected. Furthermore, the pigment synthesis concentrations can be reduced in the occurrence of metals, leading to decreasing photosynthetic efficiency (Maleva *et al.*, 2012). Trees in forests are commonly less exposed to metal deposition as a result lack of human activities, such as intensive agriculture, industry, waste disposal and traffic vehicles, than trees in urban areas (Hermle *et al.*, 2006).

Black poplar (*Populus nigra* L.) is a deciduous species that require high water capacity soil. The species is broadly distributed across Europe, Asia and northern Africa. It is a large fast-growing tree, with height of more than 40 m and stem diameters of up to 200 cm in native areas (de Rigo *et al.*, 2016). In Kurdistan region species is consider as an important species for producing coppicing especially for demanding local markets. It is a wind-pollinated tree species. *P. nigra* L. can be propagated both in vegetative ways (by cuttings) and generative (by wind- and water-dispersed seeds) (Prada *et al.*, 2009).

Decreased water availability related with low flows may affect the water relations of require riparian tree species and reduce growth and survival (Lambs *et al.*, 2006). Prolonged periods of poor growth and low survival will predictably lead to altered population structures and potential succession shifts in community composition (Smith *et al.*, 1991). Lambs *et al.* (2006) stated that when poplar trees are exposed to low water availability to delay dehydration, require to close their stomata, shed leaves and increase root growth, however more severe water limitation leads to cease of photosynthesis process (Kramer, 1983). Furthermore, Poplar tree leaves typically showed very large stomata conductance that lead to high transpiration rates and the character of poplar canopies moderate the amount of water actually lost through transpiration even they are poorly together to the atmosphere such as intense solar radiation and warm temperatures (Hinckley *et al.*, 1994; Dickman *et al.*, 2001). However, the species adequate high-water supply, especially during the summer season. Therefore, its planting conditioned with sufficient water supply for forestation. In some cases, the use of sewage water in urban during the active growth period, represents an alternative source not only of water but also of nutrients. However, the presence of heavy metals in sewage water; Cd, Ni and Pb could affect the viability of the plant. It is therefore important to evaluate the beneficial effects of sewage water to investigate growth performance of *P. nigra* L. under drought condition during summer season.

Materials & Methods

Treatments and experiment design

The study was conducted in the lath house in Grdarasha field of the college of Agricultural Engineering Sciences, Salahaddin University-Erbil. The seedlings of black poplar (*P. nigra* L.) were 4 months old and approximately their height ranged 30- 40 cm. Seedlings were subjected to water limitation and sewage effluent irrigation with different treatments for 90 days. The study was conducted as a Factorial experiment in a Complete Randomized design (CRD). Bearing two drought stress levels; D0; 90% or full water holding capacity (WHC) and D1; 30% WHC interacted with three sewage irrigation treatments; S0; 100 % of tap water as a control, S1; 50% of tap water and sewage water and S2; 100% of sewage water. Sewage water was taken from Erbil sewage channel near Turaq village in Erbil city. The field capacity was determined by saturating the soil in the pot, covering the tops with aluminum foil and weighing daily until there was no weight loss within 24, 48 and 72 hours' period. On this base 500mL and 150 mL water added respectively as (90% and 30% FC) field capacity (Qadir *et al*., 2019).

Studied parameters

Studied parameters of Turaq effluent:

Electrical conductivity EC (APHA, 1989)

Sodium adsorption ratio (SAR)

The most common water quality factor that affect the normal rate of water infiltration is the relative proportions of sodium (Na^{+1}) to calcium (Ca^{+2}) and magnesium (Mg^{+2}) according to sodium adsorption ratio (SAR) equation. It was calculated based on standard equation followed by Ayers & Westcott (1999).

$$SAR = \frac{Na}{\sqrt[2]{\frac{Ca+Mg}{2}}}$$ --- Ayers & Westcot (1999)

Where:

SAR: Sodium Adsorption Ratio $(meg.l^{-1})^{1/2}$

Na, Ca, and Mg: Concentration of Na^{+}, Ca^{+2}, and Mg^{+2} ions by milliequivalents per litre ($meg.l^{-1}$) units.

Irrigation Water Quality Index (IWQI)

The WQI was calculated to decide the level of pollution. In the first step, identified the parameters were considered more relevant to the irrigation use. In the second step, a definition of quality measurement values (qi) and aggregation weights (wi) was found. Values of (qi) were estimated based on each parameter value, according to irrigation water quality parameters proposed by the University Of California Committee Of Consultants-UCCC and by the criteria established by Meireles *et al*. (2010).

$$Q_i = q_{i\,max} - [(X_{ij} - X_{inf}) * q_{iamp} / X_{amp}]$$

$$IWQI = \Sigma qi\, wi$$

Where q_{imax} is the maximum value of qi for the class; x_{ij} is the observed value for the parameter; x_{inf} is the corresponding value to the lower limit of the class to which the parameter belongs; qi_{amp} is class amplitude; x_{amp} is class amplitude to which the parameter belongs. In order to evaluate x_{amp}, of the last class of each parameter, the upper limit was considered to be the highest value determined in the physical-chemical and chemical analysis of the water samples. Each parameter weight used in the IWQI was obtained by (Meireles *et al.*, 2010) as shown in table (1). The wi values were normalized such that their sum equals one.

Table (1): Weights for an IWQI parameters (Meireles *et al.*, 2010).

Parameters	WI
EC	0.211
Na +	0.204
HCO_3	0.202
Cl^-	0.194
SAR	0.189
Total	1.000

IWQI is dimensionless parameter ranging from (0 to 100), qi is the quality of the i^{th} parameter, a number from (0 to 100), function of its concentration or measurement, wi is the normalize weight of the i^{th} parameter, function of its significance illustrates the overall changeability in water quality. The categories are divided based on the proposed water quality index, which is developed according to existent water quality indexes. The hazard of water salinity, slow infiltration of soil water, in addition to toxicity to plants are summarized in the classifications developed by Bernardo (1995) and Holanda & Amorim, (1997).

Pollution load Index (PLI)

Pollution load index (PLI) is a criterion used to evaluate the heavy metals contamination in water. The PLI can be calculated by using the following equation (Ra *et al.*, 2013):

$$PLI = \sqrt[2]{CF1 * CF2 * CF3 * \ldots\ldots CFn}$$

where the CF is the contamination factor is defined as:

$C.F = C_{metal}/C_{back\ ground}$

Where; C_{metal} is the concentration of metal n, $C_{back\ ground}$ is the concentration of the metal n in the control water sample and n is the total number of the studied metals. The CF values represent the degree to which the water is contaminated.

The CF values represent the degree to which the water is contaminated. CF < 1 indicates low contamination; 1 ≤ CF ≤ 3 indicates moderate contamination; 3 ≤ CF ≤ 6 means considerable high contamination, and CF > 6 refers to very high contamination (Abdullah *et al.*, 2011).

Studied growth parameters of *P. nigra* seedlings

After nine weeks of the growing period the following parameters have been estimated:

Seedling height (cm)

The seedling heights (cm) were measured at the base of seedling until terminal buds.

Seedling base diameter

All seedlings diameter at base (mm) were measured by electronic caliper tool.

Shoot fresh and dry biomass

To calculate the fresh (FW) and dry (DW) weights of the biomasses, a digital balance was used. For DW determination, samples were oven-dried at 72 °C in the oven until a constant mass and weight of leaves and shoots (g) were attained.

Moisture content (MC %)

The moisture content of shoots was calculated depending on fresh weight (FW) and dry weight (DW) of seedlings (Zhou & Qiu, 2005).

$$MC\ \% = \frac{FW - DW}{FW} * 100$$

Tolerance index: the tolerance index (TI) was calculated depending on biomass of stressed seedlings to control seedlings (Wiszniewska *et al.*, 2017).

$$TI\ \% = \frac{Biomass\ of\ stressed\ plant\ (g)}{Biomass\ of\ control\ plant\ (g)} * 100$$

Statistical analysis

The experiment set in a factorial with a Complete Randomized Design (CRD) with three sewage irrigation treatments; S0, S1 and S2 and two drought stress levels; D0 90% and D1 20% (WHC) with six treatment combinations were obtained S0D0, S0D1, S1D0, S1D1, S2D0, S2D1 each replicated three instances. Analysis of variance (ANOVA) of the data computed using the Statistical package for the Social Sciences (SPSS) model 25. The Duncan’s test used to check the variations among the mean values of studied parameters. 5 % level of possibility for lath house measurements and 1 % degree for the laboratory measurements.

Results & Discussion

Studied parameters of Turaq effluent

The inability of the plant to compete with ions in the soil solution for water leads to physiological drought even though the soil may appear wet. The primary factor of physiological drought is the high electric conductivity (EC) of the soil solution. The higher the EC, the less water is available to plants. Because plants able to transpire “pure” water, only in the soil solution (Bauder *et al.*, 2011). The electrical conductivity (EC) value of the S2 and S2 irrigation water were; 0.94 and 0.71 $dS.m^{-1}$ (Table 2). The SAR value for S2 (100 % sewage water) and S1 (50 % sewage water) were 0.65 and 0.47. At a given SAR the infiltration rate increases as salinity increases or the other way around. Na+, Cl-, HCO3, EC and SAR were used to develop the proposed IWQI depending on (Ayers & Westcot 1999). The IWQI of S1 was 59.31 located under moderate restrictions class for irrigation purposes, allowing it to be used to irrigate plants with moderate salt tolerance. The IWQI of S2 was 51.12 located under the high restriction class (Table 3) according to Bernardo (1995), Holanda & Amorim (1997) and Meireles *et al.* (2010), S1 type of irrigation treatment can be used for irrigation of plants with moderate to high tolerance to salts with special salinity control practices, except water with low Na, Cl and HCO_3 values (Bernardo, 1995; Holanda & Amorim, 1997).

Table (2): Chemical analysis of irrigation treatments.

Parameters	**Sewage Irrigation treatments (S)**		
	Control (S0)	**50% (S1)**	**100% (S2)**
EC ($dS.m^{-1}$)	0.54	0.71	0.94
Ca ($meq.l^{-1}$)	2.55	3.1	3.8
Mg ($meq.l^{-1}$)	1.2	1.28	1.55
Cl ($meq.l^{-1}$)	0.37	0.8	1.08
Na ($meq.l^{-1}$)	0.27	0.81	1.17
K $meq.l^{-1}$)	0.03	0.06	0.11
SAR ($meq.l^{-1}$)	0.14	0.47	0.65
HCO_3 ($meq.l^{-1}$)	3.44	4.42	5.4

Table (3): Irrigation treatment Quality Index Classes.

Irrigation treatments	**IWQI**	**Water Use Restriction classes**
100% sewage water (S2)	51.12	High restriction
50% sewage water (S1)	59.31	Moderate restriction

Except for nickel, the concentration and contamination factor levels for Fe, Cu, Zn, Cd, Pb, and Mn in the treated soils with sewage irrigation and drought suggest a low degree of pollution (Tables 4 & 5). Previously described by Abdullah *et al.* (2011); the CF < 1 indicates low contamination. Ni level recorded higher than the background level in all treatment’s combinations. The highest level of accumulation of Ni; 281.16 ppm was recorded at S2D0; when the *P. nigra* L. seedlings irrigated with complete sewage irrigation (S2) but 100 % WHC % drought stress level (D0) (Table 4). Because heavy metals that are present in wastewater used for irrigation tend to accumulate in the soils where there is a potential that they could become bioavailable for the plant (Toze, 2006). Pollution severity and its variation along the treatment combinations were determined with the use of pollution load index (PLI) (Tomlinson *et al.,* 1980). PLI is presented in (Table 4).

Table (4): Combined effect of sewage irrigation and drought stress levels on metals concentrations in the soil.

Treatment	Metals concentrations (ppm)						
	Fe	**Ni**	**Cu**	**Zn**	**Cd**	**Pb**	**Mn**
S0D0	34813.49	262.74	30.98	70.95	2.85	7.65	761.60
S0D1	35730.	246.71	28.11	51.77	1.14	7.34	711.28
S1D0	38756.61	252.87	31.19	63.26	0.95	12.36	777.04
S1D1	36026.76	270.75	26.51	58.09	2.19	8.35	769.09
S2D0	37336.22	281.16	32.95	65.35	1.37	12.95	764.43
S2D1	39086.01	279.65	22.17	54.77	1.78	9.01	763.60
Background	50000	50	100	300	3	100	2000

Table (5): Combined effect of sewage irrigation and drought stress levels on contamination factor (CF) and pollution load index (PLI) in the soil.

Treatment	CF							PLI
	Fe	**Ni**	**Cu**	**Zn**	**Cd**	**pb**	**Mn**	
S0D0	0.69	5.25	0.31	0.24	0.95	0.13	0.38	0.43
S0D1	0.72	4.93	0.28	0.17	0.38	0.09	0.36	0.43
S1D0	0.77	5.62	0.31	0.21	0.72	0.12	0.39	0.47
S1D1	0.75	5.42	0.27	0.19	0.33	0.08	0.38	0.44
S2D0	0.74	5.56	0.33	0.22	0.59	0.12	0.38	0.47
S1D1	0.78	5.09	0.22	0.18	0.46	0.09	0.38	0.58

The results of pollution load index were found to be low (PLI < 1) in all the treatment combinations. This indicates the low load of heavy metals in the studied soil samples. The PLI values for all samples are less than one indicating the role of external discrete sources, vehicle exhaust, and agricultural activities of soil pollution (Elnazer *et al*., 2015; Salman *et al.,* 2019).

Studied parameters of *P. nigra* seedlings

New attempts are currently being done to enhance the use of sewage water which is a scarce resource in many places around the world this can support nutrients and regarded as an effective alternative for the irrigation of certain plants (Faizan *et al.,* 2014). However, sewage water may be regarded as a source of toxic trace elements such as cadmium, arsenic, and lead which are expected to be an environmental pollutant and toxic for animals and plants depending on its origin and quality. After 90 days of irrigation with sewage water irrigation treatments and drought stress levels a significant increase observed in the seedling height and stem base diameter (Fig. 1). The maximum height; 53.09 cm and widest base diameter of the shoot; 10.80 mm were recorded when the seedlings were fully irrigated with 50 % sewage water and 100 WHC % (S1D0) may be because of adequate ease of use of water and essential elements (Guo *et al.,* 2006). A Result was found by Rigueiro-Rodriguez *et al.* (2000) that an increase in the height and diameter of pine stem, which were planted in plots irrigated with sewage water were significantly higher than trees growing in control plots. In addition a research as documented by Ostos *et al.* (2008) on woody cutting *Pistacia lentiscus* L. found the same results.

After 90 days a similar response in fresh and dry biomass as well as moisture content of the seedlings of black poplar species were observed with fully irrigation to soil holding capacity with 50 % of sewage water (S1D0); 22.47, 8.01 g and 64,35 %, respectively (Fig. 2). The finding of the study was in accordance with a study conducted by Ali *el al.* (2011); the sewage water had a positive impact on tree growth; with providing of the soil with plant nutrients and organic matter this can cause enhancing the soil physical characteristics that give consideration to the growth by improving the cell elongation and division. Furthermore, a study performed by Othman *et al.* (2016) on *Pinus brutia* Ten. Furthermore, Sabr & Younis (2017) showed that the tap water treatment did not superior to 50 % of tap water + sewage water and 100% of sewage water in improving the growth parameters and biomass except stem dry weight of *Eucalyptus camadulensis* Dehnh. seedlings and stem fresh weight and stem dry weight of *Melia azaderach* L. seedlings. Sewage effluent had an encourage effect on vegetative growth of trees due to its role in providing the soil with plant nutrients and organic matter and upgrade the physical characteristics of the soil, that affect the growth by enhancing the cell division and elongation. The results are explained by many other investigators; Abbaas (2002) on *Casuarina glauca*, *Taxodium distichum* and *P. nigra*, El-Sayed (2005) on *Ceratonia siliqua*, *Acacia saligna* and *A. stenophylla*.

Singh & Bhati (2005) on *Dalbergia sissoo* and Ali *et al.* (2010) on *Tipuana speciosa*. Seedlings of Kurrajong tree *Brachychiton populneus* treated under the control showed higher dry weight of shoots respectively as compared to drought at both 60% and 30% (SWHC) (Karim *et al.*, 2020).

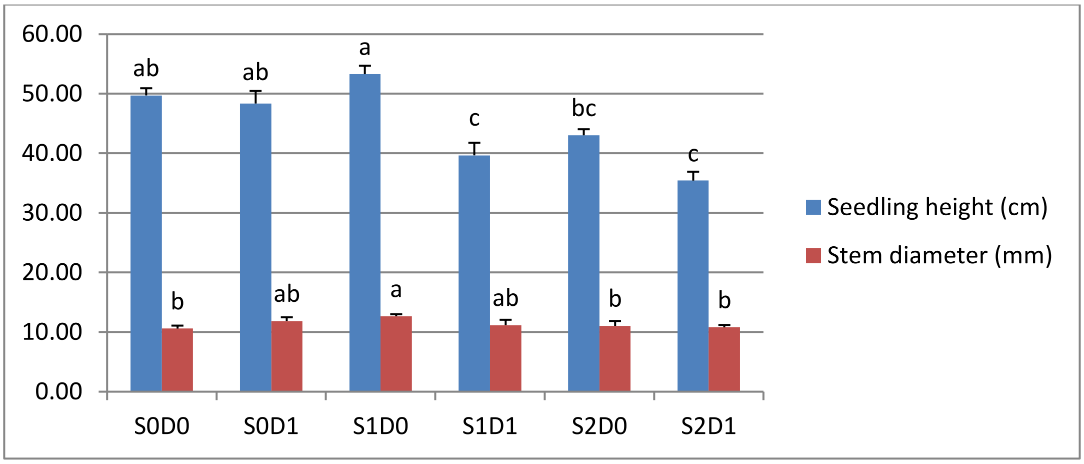

Fig. (1): Combined effect of sewage irrigation and drought stress levels on seedling height (cm) and stem diameter (mm) of *P. nigra* L. seedlings.

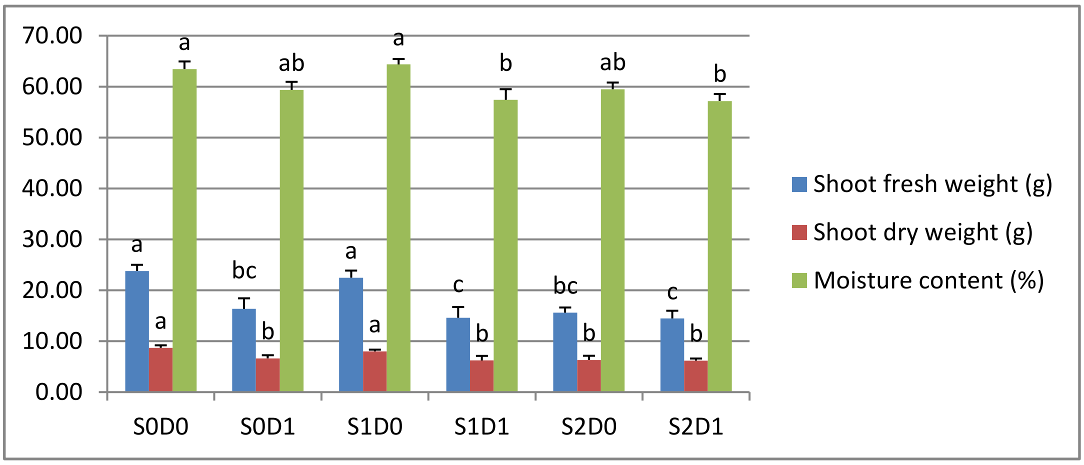

Fig. (2): Combined effect of sewage irrigation and drought stress levels on shoot fresh weight, shoot dry weight and shoot moisture content of *P. nigra* L. seedlings.

Fig. (3) shows the tolerance index of *P. nigra* L. that were irrigated for 90 days with different irrigation treatments. It was obvious that seedlings under complete water holding capacity with 50 % of tap water and Touraq effluent shows best tolerance index (92.07 %) and showed no significant difference as compared to control treatment. Metal stress effects caused leaves to fall, leading to a reduction in total biomass (Gupta *et al*., 2013). It is well documented in various poplar species such as *Populus tremula* (Vollenweider *et al*., 2011), *Populus x euramericana* (Di Baccio *et al*., 2003), *Salix* and *Populus* (Justin *et al*., 2010) and two clones of 1-year-old poplar trees (*P. nigra* cv. I-488 and *Populus alba* cv. MA-104) by Houda *et al.* (2016). The lowest accumulation of Cu, Zn, Cd, Pb and Mn was recorded 6.16, 50.45, 3.31, 32.29 32.94 ppm respectively due to S1D0 (Table 6). Cd level; 3.31 and 32.29 ppm located near the toxic accumulation level in black poplar leaves.

Table (6): Combined effect of sewage irrigation and drought stress levels on heavy metal concentration in shoots of *P. nigra* L. seedlings.

Treatments	Fe (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	Cd (ppm)	Pb (ppm)	Mn (ppm)
S0D0	00.00	00.00	18.25 ± 1.78 ab	71.59 ± 5.32 b	2.74 ± 0.91 a	34.30 ± 6.78 b	35.24 ± 4.76 c
S0D1	00.00	00.00	20.69 ± 3.12 a	75.18 ± 11.37 a	2.05 ± 1.12 a	25.69 ± 3.56 b	66.31 ± 9/12 b
S1D0	00.00	00.00	6.16 ± 1.10 c	50.45 ± 5.36 c	3.31 ± 1.87 b	32.29 ± 6.98 b	32.94 ± 5.78 d
S1D1	00.00	00.00	0.00 ± 0.00 d	59.92 ± 7.12 c	3.66 ± 1.65 b	40.31 ± 9/22 ab	70.18 ± 16.18 a
S2D0	00.00	00.00	22.41 ± 3.17 a	71.76 ± 5.76 b	2.80 ± 0.88 a	48.10 ± 11.56 a	50.55 ± 8.17 c
S2D2	00.00	00.00	16.58 ± 2.89 b	78.37 ± 12.13 a	4.58 ± 2.11 c	44.28 ± 13.54 a	69.63 ± 18.33 a

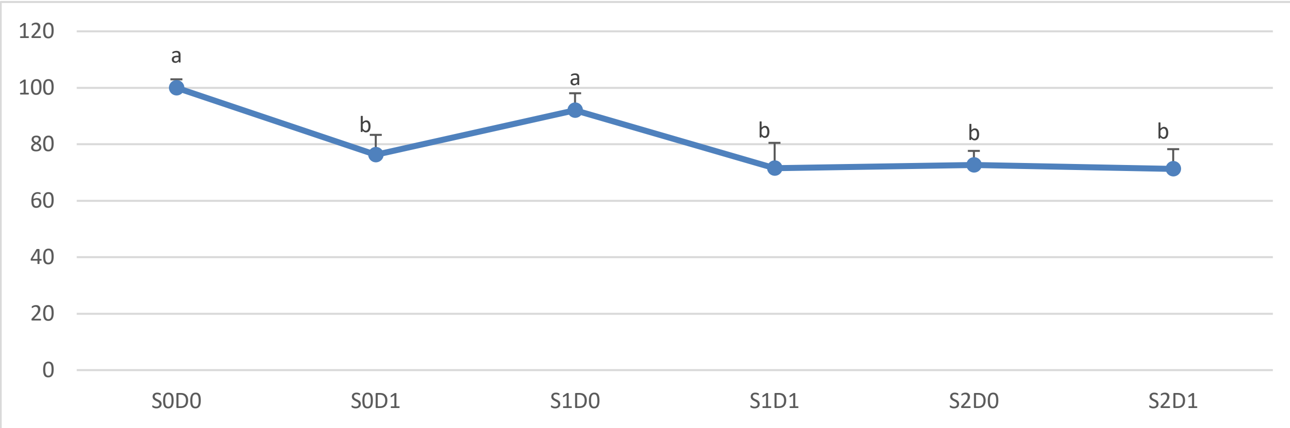

Fig. (3): Combined effect of sewage irrigation and drought stress levels on tolerance index (TI %) of *P. nigra* L. seedlings.

However, it still was able to acclimatize as the Cd contamination level was greater than normal range without any reduce of morphological growth and biomass. Obviously, may be many genotypes of tree species can itself supply adequate biochemical diversity to make available low level of constituent metal tolerance (Turner & Dickinson, 1993). Shi & Cai (2009) documented that once Cd concentration in the plant tissue extends 3-10 mg. kg^{-1} that plants can experience toxic effects as many previous researches have recognized. Hajar *el al.* (2014) explained that heavy metals were in a normal range in plants except for Cd and Pb. However, lead and cadmium concentrations in shoots were alleviated with the adding of sewage water supply in a soil.

Conclusion

Wastewater irrigation of urban fringe of large cities becomes a good practice, particularly in arid and semi-arid regions because of fresh water shortage. The irrigation solution composed of mixed with tap water 1:1 increased the growth and improved morphological and biomass production of black poplar seedlings. As well as being better acclimatize as the Cd contamination level in spite being greater than normal range without any reduce in morphological and biomass characters.

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Conflict of interest

The authors declared that they have no conflict of interest.

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أداء نمو القوغ الاسود *Populus nigra* L. تحت ظروف الجفاف و الري بمياه المجاري

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المستخلص: تم دراسة استجابة شتلات القوغ الأسود *Populus nigra* L. للري بمياه المجاري و ظروف الجفاف من 18-5-2019 الى 18-8-2019. اذ تم اختيار مستويين من الجفاف: 90% ;D0 كعامل الكونترول و 30% ;D1 للسعة الحقلية للتربة كعامل الجفاف مع ثلاثة مستويات من الري: S0: بدون معامله, S1: 50% من مياه المجاري و 50% من ماء الحنفية و العامل الثالث S2 100% من مياه المجاري. كان الثابت النوعي لماء الري (IWQI) للعامل S1 بقيمة 59.31 تقع ضمن الصنف المتوسط لتصنيف مياه الري. بالأضافة الى أحتواءها الدنيا للتلوث (PLI) بقيمة 0.47. ان معاملة الري للسعة الحقلية الكاملة بماء المجاري المخفف بنسبة 50% (S1D0) أدى الى زيادة معنوية في طول النبات و القطر السفلي للساق و الوزن الطري و الجاف و المحتوى الرطوبي للمجموع الخضري. بالأضافة الى الحد الأعلى لثابت المقاومة (TI %) للشتلات كان % 92.07 على الرغم من تلوث التربة بالعنصرين: Ni و Pb مع الحد الأدنى للسمية و تجمع عناصر: Cu, Zn, Cd, Pb and Mn في التربة و الأوراق. لذلك تخفيف ماء المجاري بنسبة 1:1 يمكن استخدامه لري شتلات القوغ الأسود الذي يحتاج للري بكثرة والمقاومة المتوسطة لملوحة التربة حيث يمكن التوصية بزراعتها لصيانة الغابات و تشجير المدن.

الكلمات المفتاحية: المعادن الثقيلة، الكتلة الحيوية الشتلة، مياه الصرف الصحي، تراكم المعادن، *Populus nigra* L.