Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 12 (3): 109-118, 2013
ISSN 1682-3974 / DOI: 10.3923/ajps.2013.109.118

Growth Characteristics and Some Wood Quality of *Tamarix aphylla* Seedlings Irrigated with Primary Treated Wastewater under Drought Stress

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Abstract: Drought stress and water quality are the main causes of alteration in plant physiological processes and reduction of plant growth. The aim of this study is to evaluate the response of *Tamarix aphylla* seedlings to two types of irrigation and three periods of water regime under greenhouse condition. The effect of Primary Treated Wastewater (PTW) compared with Well Water (WW) at drought stress using three intervals irrigation on growth, biomass production and its allocation, physical properties and chemical constituents of wood is studied. The experiment was carried out during the successive season of 2010/2011. The results indicate that fresh weight of stem and foliage are increased without any significant for the seedlings irrigated by PTW compared to WW. However, fresh weight of roots and oven-dry weight of foliage are significantly increased. No significant differences are observed for the specific gravity and fiber length of wood produced from seedlings irrigated by either WW or PTW. The results indicated that irrigation with PTW influenced the chemical composition of *T. aphylla* wood. Under drought stress, all growth parameters and biomass production are decreased by increasing the irrigation periods from one to five weeks. Chemically, the contents of lignin and ash are significantly increased under drought stress; however, the cellulose, extractive and hemicellulose contents express inverse trends. The study conclude that the use of PTW significantly increase the produced biomass and some of wood quality. Planting seedlings under drought stress have significant effects on the properties of one year-old *Tamarix* seedling.

Key words: Wastewater, well water, drought stress, growth, biomass production, chemical constituents, specific gravity

INTRODUCTION

Water has become an increasingly scarce resource in many arid and semi-arid regions, thus necessitating development of water resources through untraditional ways (Selim, 2006). Wastewater reuse in agriculture practice has been started at the beginning of the last century in several countries worldwide. In many developing countries, including Saudi Arabia, acute shortage of water necessitates the development of new water sources. Land application of wastewater is considered to be the best solution for covering this shortage of water. The domestic wastewater generated from Riyadh City has increased from 420,000 m^3 day^{-1} in 1993-538, 500 m^3 day^{-1} in 2007 (Al-Othman, 2009). As well as, the treated wastewater increased from 396,300 m^3 day^{-1} to 536,330 m^3 day^{-1} in the same period (GDWRR, 2008).

Saudi Arabia does not have adequate forest treasury to cover their requirements for wood industry like fuel wood, industrial wood, sawn wood and wood-based composition panels. The annual cost of wood and wood products import in Saudi Arabia was estimated at 115 million dollars in 2004 and 305 million dollars in 2007. In order to meet the increasing demand of wood products, Saudi Arabia has planted fast growing tree species in many areas of the country (Aref and El-Juhany, 2005). The use of treated wastewater as a new resource of irrigation has been encouraged in Saudi Arabia during the last two decades to increase the efficient use of water irrigation in crop production (Alderfasi *et al*., 2002) and forest trees (Nasser *et al*., 2010).

Wastewater after primary treatment is safe for irrigation of tree plantations, forestlands, green belts around the cities and non-food crops (Hassan *et al*., 2006; Tabari and Salehi, 2009). These authors reported that using the irrigating with sewage effluent improved the soil properties because it is considered as a rich source of nutrients. Several studies related to the influence of irrigation with sewage effluent on some growth parameters such as wood specific gravity, fibre length and volumetric shrinkage of forest trees as well as biomass potential and its allocations have been investigated (Szopa *et al*., 1977; Guang-Cheng *et al*., 2010;

Ali *et al*., 2011). On the other hand, a slight effect on wood specific gravity and fibre length was detected in *Melia azedarach* species as a result of using sewage effluent (Kayad *et al*., 2005).

Water stress is the main cause of alteration in plant physiological processes and reduction of plant growth, which considerably affects tree seedling performance immediately after plantation and during the whole establishment stage, causing serious losses and affecting tree regeneration and, consequently, future stand productivity. Severe water stress conditions significantly decreased the growth of high plants. Therefore, several plants show some modifications of their morphological and physiological attributes to overcome drought stress. Some of these modifications are visible and relatively easy to measure which in turn reflect physiological adaptation (Rao *et al*., 2008; Liu *et al*., 2011).

Tamarix aphylla (Athel) is one of forest trees, fast growing, drought resistant and salt-tolerant species, planted throughout the Saudi Arabia (Al-Mefarrej, 1985). Their wood characteristics are close-grained, light-coloured and fairly hardwood with high shock strength resistance. In addition, their wood is used for firewood and charcoal purposes (Orwa *et al*., 2009).

There is a little information in the available literature about the basic effect of wastewater irrigation and drought stress on the properties of wood (Kayad *et al*., 2005; Abdel-Aal *et al*., 2008). It is important to evaluate the chemical composition of wood in order to ascertain its proper utilization. This will help to give suggestion to wood users how the wood suitable for wood industries (such as, pulp and paper; wood composite panels), fuel and construction purposes. Accordingly, the objective of this study, therefore, is to determine the biomass production and allocation, growth parameters and the main physical and chemical properties of wood of one year old *T. aphylla* seedling grown in the greenhouse as affected by primary treated wastewater irrigation and drought stresses.

MATERIALS AND METHODS

This study was carried out in the greenhouse at the nursery of the Agricultural Experimental Station, College of Food and Agricultural Sciences, King Saud University, Dirab, 60 km south of Riyadh. The site has the following characters: 24°6’ N, latitude; 46°5’ E, longitude; temperature (as an average of season) ranged between 10°C in winter and 41°C in summer; and 50 mm rainfall annually (Aref and El-Juhany, 2005).

Plant material: Cuttings of *Tamarix aphylla* were carefully selected from healthy mother trees grown in the nursery of the Agricultural Experimental Station. They were planted in plastic pots, 30 cm length and 25 cm in diameter, containing 25 kg of sandy loam soil to about 2 cm from the rim. After plantation, they were watered with well water until they attained 3-months-old. Two treatments were applied, namely water quality (well water and primary treated wastewater) and irrigation periods (weekly, two and five weeks intervals). Each seedling was irrigated with about 600 mL by either Primary Treated Wastewater (PTW) or Well Water (WW). PTW used to irrigate the plantation was derived from industrial and municipal sources and was treated-primary before irrigation. The irrigation was given at specific time according to treatments.

Growth parameters and biomass production: The height and diameter of the seedlings were measured at the beginning and the end of the experiment. Seedlings are carefully lifted from the pots. Soil particles were carefully removed from the roots by washing first with tap water and then with distilled water. To calculate the biomass production and their allocation, the total fresh weight was taken and then each seedling was separated into three parts: Foliage, stem and root. Fresh and dry weights of each part were recorded. The dry weight was determined for all after drying at 70°C in an oven to a constant weight and shoot/root ratio was calculated.

Foliar analysis: The stem and leaves of the seedlings were oven-dried at 70°C to constant weight. They were separately grounded using Willey mill into fine powder. Samples of 0.3 g of the ground material were digested using sulfuric acid and hydrogen peroxide. The digested samples were used to measure the nitrogen, phosphorus, potassium, sodium, cadmium, zinc, nickel and lead content (Evenhuis and Dewaard, 1980).

Water analysis: Water samples were taken from the two types of water used for irrigation (municipal and primary treated wastewater) and then were transferred immediately at 4°C to the laboratory for analysis. Water analysis was performed according to the standard methods (APHA, 1995).

Soil analysis: One sample of soil was taken before the beginning (virgin soil) and another sample at the end of the experiment. All soil samples were air-dried, crushed gently, sieved through 2 mm sieves and stored for analysis. Total carbonate was determined according to Nelson (1982). Available levels of N and P were determined. The concentrations of heavy metals were quantified through atomic absorption spectrophotometer (Perkin Elmer model, 3080). Sodium and potassium were determined by using flame photometer (Black *et al*., 1965).

Chlorophyll determination: Total chlorophyll content was determined in fresh leaf samples using N,N-dimethyl formamide (Moran and Porath, 1980).

Specific gravity and fiber length determination: One sample strip, 2-cm length free from any natural defects was machine-cut from the stem bases of each seedling used in this study. Specific Gravity (SG) of each sample was then evaluated using the equation developed by Smith (1954). Samples for fiber length measurements were cut from the region 10 cm above the ground. Each sample is prepared and measured according to Franklin (1945).

Wood chemical analysis: About 2 g (40-60 mesh) of air-dried wood meal was extracted using a Soxhlet apparatus in successively three steps with benzene-ethanol mixture, ethanol and distilled water (ASTM, 1989). The other main wood components of wood (cellulose, hemicellulose and lignin) were determined using extractive-free wood meal according to the methods described by ASTM (1989).

Experimental design and data analysis: The experimental design was a split-plot in RCBD with three replications. Comparison among treatment means were calculated following the Duncan Multiple Range Test at 0.05 level of probability.

RESULTS AND DISCUSSION

Table 1 is showing the physical and chemical properties of the two types of water used for the irrigation of the experiment. It can be noted that although there are differences in their physicochemical properties between the two types of water used, PTW has the higher values. Electrical Conductivity (EC) of the PTW was 1.87 dS m^{-1} as compared to the limit of FAO (1992) which indicating a low salinity level. Irrigation with low salt concentration (>5 dS m^{-1}) is often used without considering the negative effects of poor quality water on seedlings growth and productivity. In addition, PTW has high chloride (312.4 mg L^{-1}) and sodium levels (219.2 mg L^{-1}). However, the concentrations of the heavy metals in the two types of water are under the maximum recommended concentrations and the pH values are within the level recommended by FAO (1992), which falling within the 6.5-8.4 pH range appropriate for irrigation reuse.

The soil of the site was calcareous with low clay silt and its chemical properties are shown in (Table 2). It can be noticed that under the *T. aphylla* experiment, there are changes in soil properties occurred as a result of irrigation using the two types of water quality. It is clear that the values of soil pH were close to the virgin soil before planting. However, the EC of the soil differ by different types of water quality, it ranged from 1.41 dS m^{-1} before planting to 5.63 and 9.35 dS m^{-1} for WW and PTW, respectively. The EC values in the soils after planting were higher compared to those in virgin soil (before planting). This indicates that some salt accumulation might occur as a result of evaporation. PTW have had high chloride (312.4 mg L^{-1}) and sulfate levels (369.6 mg L^{-1}). The increase in SO_4^{-2} concentration with PTW irrigation may be due to the biological oxidation of the protein sulphur in the sewage (Waly *et al.*, 1987). On the other hand, the contents of heavy metals increased strongly related to the irrigation treatment. Generally,

Table 1: Some physicochemical properties of the types of water used in irrigation

	Type of water		Limits**
Properties	Municipal water	PTW*	FAO (1992)
pH	7.72	8.22	6.5-8.4
EC (dS m^{-1})	0.14	1.87	3.0-7.0
TDS (mg L^{-1})	90	1193	1920-4480
Soluble cations (mg L^{-1})			
Ca^{2+}	n.d	151	-
Mg^{2+}	n.d	44.2	-
K^+	0.78	9.36	-
Na^+	15.9	219.2	-
Soluble anions (mg L^{-1})			
CO_3^{-2}	n.d	37.5	-
HCO_3^-	30.5	144.9	91.5-518.5
Cl^-	26.6	312.4	-
SO_4^{-2}	17.3	369.6	-
Total heavy metals (mg L^{-1})			
Cd	0.003	0.009	0.01
Ni	0.030	0.061	0.20
Pb	0.012	0.208	5.0
Zn	0484	0.352	2.0

ND: Not detected, *PTW: Primary treated wastewater, **Limits of wastewater for agricultural reuse FAO (1992)

Table 2: Chemical characteristics of the soil used for the experiment

	Before	After irrigation with	
Properties	Planting	Municipal water	PTW*
pH	8.63	8.69	8.37
EC (dS m^{-1})	1.41	5.63	9.35
Soluble cations (mg L^{-1})			
Ca^{2+}	6.05	30.6	30.7
Mg^{2+}	4.14	20.8	14.64
K^+	0.11	0.56	1.79
Na^+	4.42	22.00	69.94
Soluble anions (mg L^{-1})			
CO_3^{-2}	0.5	1.0	n.d
HCO_3^-	2.25	2.00	2.50
Cl^-	6.25	19.5	51.5
SO_4^-	5.78	47.57	51.52
Available nutrients (mg kg^{-1})			
N	12.64	40.71	62.14
P	0.10	3.97	4.45
K	1.51	3.64	3.26
Total heavy metals (mg kg^{-1})			
Cd	n.d	n.d	n.d
Ni	0.200	0.148	0.037
Pb	0.036	0.314	0.090
Zn	3.840	1.040	1.100

*PTW: Primary treated wastewater, ND: Not detected

PTW exhibited an increase in the basic nutrients (N, P and K) contents of the soil. This means that the PTW enriched the soil with important elements, which are very necessary for plant growth and improve the soil chemical characteristics under *T. aphylla* plantation. These results are in agreement with that have been found by Singh and Bhati (2005) and Ali *et al.* (2011).

Growth characteristics: The growth characteristics are represented by the seedlings height, diameter and fresh and dry weights of each seedling components. The results of the analysis of variance in Table 3 reveal that the effect of irrigation periods and water quality on all the tested characters is significant. However, the interaction between irrigation periods and water quality was not significant except for fresh weight of stem and root.

Effect of water quality on growth: Table 4 showed the effect of water quality on the growth and biomass weight of *Tamarix aphylla* seedlings. It can be noted that all the growth characters were significantly increased under irrigation with PTW compared to WW (Table 4). There are a significant increment in stem diameter and seedling height due to irrigation with PTW (68.92 and 61.89%, respectively) compared with WW irrigation (20.49 and 39.44%, respectively). Irrigated seedlings with WW record the highest values of biomass production in fresh and dry states for the three components of the seedlings (stem, foliage and root), compared to seedlings irrigated with PTW. These results indicate that PTW enhanced the growth and biomass production by increasing all growth parameters. This finding is in correspondence to what have been stated by different authors (Kayad *et al.*, 2005; Bedbabis *et al.*, 2010; Ali *et al.*, 2011). The beneficial reuse of PTW in irrigation enriched the soil with nutrients and organic matter which decreased soil bulk density (Guo and Sims, 2000). On the other hand, Bhati and Singh (2003) concluded that greater growth production may be due to sufficient availability of water and essential elements by sewage effluent.

Effect of irrigation period on growth: It can be seen from Table 5 that all the growth parameters for the seedlings irrigated by either WW or PTW have been decreased significantly as the irrigation period increased from one to five weeks. The percentage increment of stem diameter and height markedly decreased as drought stress intensified from one to five weeks (Table 5). It is obvious from this table that the seedlings which received high level of irrigation (weekly irrigated) gave the highest significant increment in stem diameter and height as well as fresh and dry weight of the three components of the seedling. These results are in harmony with those obtained by Elfeel and Al-Namo (2011) on three arid zone species. The decrease in growth parameters with drought intensity in the current study may be due to the decline in net photosynthesis assimilation which brought by decreased leaf water potential (Rao *et al.*, 2008).

Table 3: Analysis of variance of the growth characteristics of the *T. aphylla* seedlings

		Increment of		Stem weight		Foliage weight		Root weight	
Source of variation	df	Diameter	Height	Fresh	Dry	Fresh	Dry	Fresh	Dry
Block	2	18.36	33.41	7.22	9.67	2.22	2.64	2.91	1.39
Irrigation period (IP)	2	552.9**	997.4**	452.08**	259.04**	855.59**	122.57**	204.64**	65.29**
Error (a)	4	4.96	54.48	24.94	6.62	0.97	1.70	3.08	0.59
Water quality (WQ)	1	8683.4**	2900.7**	243.62**	21.28*	63.06**	22.51**	117.10**	5.89*
WQ*IP	2	51.60^{NS}	7.33^{NS}	47.51**	1.07^{NS}	10.85^{NS}	0.07^{NS}	21.76**	0.71^{NS}
Error (b)	6	8.48	37.03	3.98	2.92	2.19	0.997	1.26	0.47

*,**: Significant at 0.05 and 0.01 level of probability, respectively, NS: Not significant

Table 4: Effect of water quality on growth and biomass weight (g plant^{-1}) of *Tamarix aphylla*

	Increment (%) of		Stem weight		Foliage weight		Root weight	
Water quality	Diameter	Height	Fresh	Dry	Fresh	Dry	Fresh	Dry
WW	20.49^{B}	39.44^{B}	57.88^{B}	31.69^{B}	24.22^{B}	8.58^{B}	23.78^{B}	12.48^{B}
PTW	68.92^{A}	61.89^{A}	65.24^{A}	33.86^{A}	27.96^{A}	10.81^{A}	28.88^{A}	13.63^{A}

Each value is an average of 9 samples, WW: Well water, PTW: Primary treated wastewater, Means with the same letters in a column are not significantly different at 0.05 level of probability according to Duncan's multiple range test

Table 5: Effect of irrigation period on fresh and dry weights of the seedlings of *Tamarix aphylla*

	Increment (%) of		Stem weight		Foliage weight		Root weight	
Irrigation period	Diameter	Height	Fresh	Dry	Fresh	Dry	Fresh	Dry
Weekly	56.65^{A}	68.04^{A}	71.10^{A}	39.83^{A}	39.62^{A}	14.49^{A}	32.79^{A}	16.19^{A}
Two weeks	46.00^{B}	47.10^{B}	59.47^{B}	31.67^{B}	21.60^{B}	9.07^{B}	24.76^{B}	13.39^{B}
Five weeks	31.46^{C}	36.85^{C}	51.62^{B}	24.83^{C}	16.54^{C}	5.52^{C}	21.43^{C}	11.09^{C}

Each value is an average of 6 samples, Means with the same letters in a column are not significantly different at 0.05 level of probability according to Duncan's multiple range test

Table 6: Analysis of variance for specific gravity, fiber length and chlorophyll of *T. aphylla*

		Basic	Chlorophyll (μmol L^{-1})				Fiber
Source of variation	df	SG	A	B	AB	df	Length
Block	2	0.0005	0.005	0.002	0.003		
Irrigation period (IP)	2	0.0046*	2.25**	0.613**	3.451**	2	0.012^{NS}
Error (a)	4	0.00033	0.004	0.001	0.005	147	0.005
Water quality (WQ)	1	0.0033^{NS}	0.616**	0.262**	0.728**	1	0.012^{NS}
WQ*IP	2	0.0024^{NS}	0.019^{NS}	0.026*	0.150**	2	0.025*
Error (b)	6	0.0014	0.005	0.002	0.003	147	0.005

*,**: Significant at 0.05 and 0.01 level of probability, respectively; NS: Not significant

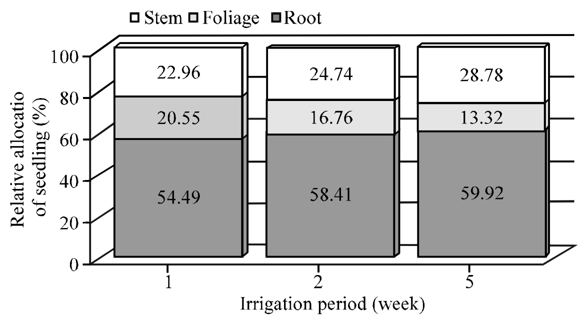

Fig. 1: Effect of irrigation periods on the dry relative biomass allocation for *T. aphylla* seedling

Figure 1 shows the relative distribution of the biomass components for the individuals of *Tamarix aphylla* seedlings as affected by the three water regime. It can be seen that the percentage of the dry stem has increased as the irrigation period increased, where it was 54.49, 58.41 and 59.92% for irrigation period 1, 2 and 5 weeks, respectively. The same trend was obtained for the dry root, where it was 22.96, 24.74 and 26.75% for the same period, respectively. In the current study, the root/shoot weight ratio increase from 0.298-0.365 as irrigation period increase from one to five weeks. Increasing the percentage of the dry root biomass resulted in a higher root/shoot weight ratio under drought (Li *et al*., 2009; Guang-Cheng *et al*., 2010), which represents one of the most adaptive mechanisms in plants tolerance to water stress. However, the percentage of the dry foliage (leaf weight ratio) decreased as irrigation period increased, where it is 20.55, 16.75 and 13.32% for the same order. Reduced growth and leaf shedding as a result of drought stress are well known phenomena (Kozlowsky and Pallardy, 1997). These results are in agreement with those obtained by Aref and El-Juhany (2005) and Rao *et al*. (2008). This result may be attributed to the reduced development and expansion of new leaves and/or increased leaf loss compared to seedlings under irrigated conditions (Engelbrecht and Kursar, 2003).

Effect of irrigation periods and water quality on the specific gravity of wood: The analysis of variance Table 6 indicates that the effect of IP on the specific gravity of wood was significant. However, the effect of WQ and the interaction IP*WQ were not significant. Table 7 shows that the mean values of the Specific Gravity of wood (SG) were decreased as the irrigation period increased. Increasing IP from one to two weeks significantly decreases the SG of wood from 0.659-0.619, while increasing the IP to five weeks decreases the SG without any significant differences between the seedlings irrigated every two and five weeks (0.619 and 0.607, respectively). It can be seen that there is a slight effect of drought on the SG of wood, where the percentage change in the SG is about 1.94% from one to five weeks. The basic information regarding the effect of sewage effluent irrigation on wood properties is very limited. However, similar results on the effect of sewage effluent irrigation had been obtained from previous studies by Hassan (1996) who concluded that sewage water irrigation had slight effect on specific gravity of *Leucaena leucocephala* seedlings after two years of treatment and finding of Szopa *et al*. (1977) when they studying white oak, Kayal (1996) on five Egyptian tree species and Kayad *et al*. (2005) on chinaberry.

Table 7: Mean values of specific gravity, fiber length and chlorophyll content of *T. aphylla*

			Chlorophyll (μmol L^{-1})		
Irrigation period	Basic SG	Fiber length (mm)	A	B	AB
Weekly	0.659^{A}	0.491^{A}	3.43^{A}	1.77^{A}	4.11^{A}
Two weeks	0.619^{B}	0.539^{A}	2.79^{B}	1.35^{B}	3.23^{B}
Five weeks	0.607^{B}	0.525^{A}	2.21^{C}	1.14^{B}	2.60^{C}

Mean values of 6 samples except for fiber length 100 measures, Means with the same letters in a column are not significantly different at 0.05 level of probability according to Duncan's multiple range test

Effect of irrigation period and water quality on the fiber length of *T. aphylla* wood: The statistical analysis of the data in Table 6 reveals no significant effects of either irrigation periods or water quality however, the interaction between them is significant. Table 8 shows that the fiber length for the seedlings irrigated with PTW has the lower value (0.518 mm) compared with the value recorded by the seedlings irrigated with WW (0.531 mm) and there is no significant difference between the two means according to Duncan's multiple range test. This result is in agreement with Kayad *et al*. (2005) on *Melia azedarach* but in disagreement with Hassan (1996) who concluded chlorophyll content was obtained with PTW irrigation for the total chlorophyll content (3.52 μmol L^{-1}) as well as chlorophyll A (3.0 μmol L^{-1}) and chlorophyll B (1.54 μmol L^{-1}). The enhancement of chlorophyll that irrigation with high concentration of sewage water markedly decreased the fiber length of *Acacia saligna*. On the other hand, no trend was obtained for the effect of irrigation periods on the fiber length of *T. aphylla* and this effect was not significant Table 8. Similar trends were obtained for the interaction between IP and WQ but the interaction was significant (Table 9).

Effect of water quality on the chlorophyll content of *T. aphylla* leaves: The chlorophylls are virtually essential pigments for the conversion of light energy to stored chemical energy. The amount of solar radiation absorbed by a leaf is a function of the photosynthetic pigment content, thus, chlorophyll content can directly determine photosynthetic potential and primary production (Filella *et al*., 1995). In addition, chlorophyll gives an indirect estimation of the nutrient status because much of leaf nitrogen is incorporated in chlorophyll (Moran *et al*., 2000). Furthermore, leaf chlorophyll content is closely related to plant stress (Merzlyak *et al*., 1999). The analysis of variance (Table 6) showed that the effects of irrigation period and water quality on the chlorophyll content of the seedlings of *T. aphylla* were highly significant. On the other hand, the interaction WQ*IP was significant except for the chlorophyll A content.

The analysis of variance Table 6 reveals that WQ had significant effects on leaves chlorophyll contents. Data in Table 8 showed that seedlings irrigated by PTW enhanced the chlorophyll content of leaves. The higher resulted from PTW irrigation may be due to the increase of nutrients in the occupancy root zone, which have a great important role in biochemical processes moreover Mg ion that participate in chlorophyll structure (Ali, 2005).

Regarding with the significant interaction of PI*WQ except for chlorophyll A (Table 9), similar trend like those obtained for the effect of irrigation periods was recorded with irrigation by either well water or PTW. The chlorophyll contents were decreased as irrigation periods increased from one to five weeks.

Effect of irrigation periods on the chlorophyll content of *T. aphylla* leaves: Irrigation periods significantly affected the chlorophyll contents of *T. aphylla* leaves (Table 6). The mean values of chlorophyll contents as affected by irrigation period are presented in Table 7. It can be noted that the content of chlorophyll decreased with increasing the irrigation periods from one to five weeks. The content of chlorophyll A significantly decreased from 3.43- 2.21 μmol L^{-1} as irrigation period increased from one to five weeks without any significant differences. In the same order, the content of chlorophyll B and total chlorophyll decreased significantly from 1.77-1.14 μmol L^{-1} and from 4.11-2.60 μmol L^{-1}, respectively. These results are in agreement with the finding of Alvarez *et al*. (2009) and Liu *et al*. (2011).

Effect of water quality on the chemical constituents of wood: Table 10 shows the analysis of variance for the chemical constituents of *Tamarix* wood. The results indicated that the differences in the chemical composition of wood among irrigation periods, WQ and the interaction between them were highly significant except water quality and the interaction of the extractive content were not significant.

Table 8: Effect of water quality on specific gravity, fiber length and chlorophyll of *T. aphylla*

Water quality	Basic SG	Fiber length (mm)	Chlorophyll (μmol L^{-1}) A	B	AB
Well water	0.642^{A}	0.531^{A}	2.62^{B}	1.30^{B}	3.12^{B}
Primary T. wastewater	0.615^{A}	0.518^{A}	3.00^{A}	1.54^{A}	3.52^{A}

Mean values of 9 samples except for fiber length 150 measures, Means with the same letters in a column are not significantly different at 0.05 level of probability according to Duncan's multiple range test

Table 9: Effect the interaction between irrigation period and water quality on *T. aphylla*

Water quality	Irrigation period	Basic SG	Fiber length (mm)	Chlorophyll (μmol L^{-1}) A	B	AB
MW	1	0.650	0.541	3.18	1.59	4.02
	2	0.648	0.535	2.65	1.21	3.11
	5	0.626	0.519	2.03	1.09	2.22
PTW	1	0.668	0.491	3.68	1.94	4.21
	2	0.589	0.539	2.93	1.49	3.36
	5	0.587	0.525	2.39	1.19	2.99

Mean values of 3 samples except for fiber length is an average of 50 measures

Table 10: Analysis of variance of the wood chemical constituents of *T. aphylla*

Source of variation	df	Extractive	Cellulose	Hemicellulose variation	Lignin	Ash
Block	2	0.41	0.12	0.21	0.58	0.005
Irrigation period (IP)	2	11.18**	10.66**	20.02**	4.07**	0.311**
Error (a)	4	0.15	0.24	0.21	0.14	0.016
Water quality (WQ)	1	0.52^{NS}	5.37**	1.32*	0.35^{NS}	0.375**
WQ*IP	2	0.13^{NS}	0.88*	2.16**	1.46*	0.092*
Error (b)	6	0.23	0.16	0.14	0.09	0.016

*,**Significant at 0.05 and 0.01 level of probability, respectively; NS: Not significant

The data in Table 11 indicates that the irrigation of the seedlings with PTW increased significantly the cellulose and ash contents of *T. aphylla* wood as compared to those seedlings irrigated with WW. However, hemicelluloses content was decreased when seedlings irrigated by PTW. On the other hand, irrigation with PTW did not significantly affect the extractive and lignin contents of wood. Although, the differences between the two types of water quality used for irrigation on the chemical composition of wood were highly significant, the percentage of change between PTW and WW as a percentage to the later were quite low (less than <10%) and these differences could be considered as natural and random error (Table 11). The change percentage in the chemical composition of wood ranged from 2.27% for hemicellulose content to 5.46% for ash content. These results are in agreement with Abdel-Aal *et al.* (2008) on *Casuarina cunninghamiana*. They reported that sewage irrigated trees contained significantly higher alpha cellulose and ash contents. They attributed these results to the increase in latewood compared to early wood or thicker fiber walls especially in S2 layer. The decrease of hemicelluloses content and increase of cellulose content of *Tamarix aphylla* wood with irrigation the seedlings by PTW may be due to the increase of available nutrients of seedlings irrigated with PTW which increase the photosynthesis rate and the seedling tend to create the long polymer i.e., cellulose than the short polymer i.e., hemicelulose (Al-Mefarrej *et al*., 2011).

Effect of irrigation period on the chemical constituents of wood: The analysis of variance in Table 10 indicated that the effect of IP on all the chemical composition of wood was highly significant. The mean values of the chemical composition of *Tamarix* wood as affected by IP are presented in Table 12. In general, it can be seen that increase the IP from one to two week did not significantly decrease the extractive and hemicelluloses contents. However, increasing the period to five weeks significantly decrease the three chemical components. The data in Table 12 indicated that there are two trends can be obtained. The lignin and ash contents of wood increased with increasing the irrigation period from one to five weeks, while the extractive, cellulose and hemicelluloses contents were decreased. The decrease of hemicelluloses and cellulose contents of wood with increasing the irrigation periods may be caused by the seedlings tend to synthesis the long polymer i.e., cellulose due to the decreased the hemicellulose content, which resulted from decreased photosynthesis. Rao *et al.* (2008) reported that the rate of net photosynthetic were decreased in very high drought stress compared to control in *Albizia lebbek*, *Dalbergia sissoo* and *Leucaena leucocephala*.

Anatomically, it can be seen from Fig. 2 that drought stress influenced the wood anatomy of *T. aphylla* wood

Table 11: Effect of water quality on the chemical compositions of *T. aphylla* wood

	Percentage of				
Water quality	Extractive	Cellulose	Hemicellulose	Lignin	Ash
Municipal water (MW)	25.70	41.71^{B}	24.38^{A}	33.25	5.31^{B}
Primary treated wastewater	26.04	42.80^{A}	23.84^{B}	33.69	5.60^{A}
Percentage change of MW	NS	2.55	-2.27	NS	5.46

Means with the same letters in the column are not significantly different at 0.05 level of probability according to Duncan's multiple range test

Table 12: Chemical composition of *Tamarix* wood as affected by irrigation periods

Irrigation period	Extractive	Cellulose	Hemicellulose	Lignin	Ash
Weekly	26.89^{A}	43.74^{A}	25.44^{A}	32.71^{B}	5.25^{B}
Two weeks	26.39^{A}	41.84^{B}	24.86^{A}	33.80^{A}	5.41^{B}
Five weeks	24.32^{B}	41.17^{B}	22.03^{B}	33.89^{A}	5.70^{A}

Mean values of 6 samples, means with the same letters in the column are not significantly different at 0.05 level of probability according to Duncan's multiple range test

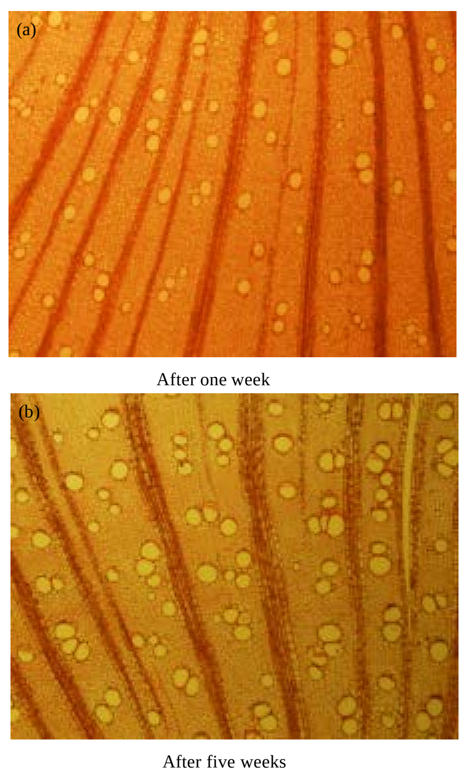

Fig. 2: Cross-section of *T. aphylla* wood as affected by irrigation periods

by increasing the percentage of vessels and the vessels tended to be in groups in the radial direction. This result needs more attention in the future.

CONCLUSION

Results obtained from the current study have shown significant enhance in the growth and biomass production of the *T. aphylla* seedlings under irrigation with Primary Treated Wastewater (PTW) over six months as compared with Well Water (WW). However, the specific gravity and fiber length as well as extractives and lignin content of wood were not affected. Irrigation of the seedlings with PTW significantly increased the cellulose and ash contents but decreased hemicellulose content of *T. aphylla* wood as compared to those seedlings irrigated with WW. PTW had slight effect on the properties of wood, which means that the produced wood did not differ much than the wood irrigated with WW. Results indicated that all the growth parameters and biomass production have decreased significantly as the irrigation period increased from one to five weeks for the seedlings irrigated by either WW or PTW. Chemically, the data indicated that two trends were obtained. The lignin and ash contents of wood were increased with increasing the irrigation period from one to five weeks, while the extractive, cellulose and hemicelluloses contents were decreased. As mentioned above, we advice to use primary treated wastewater in cultivating forest trees to encourage the growth and to solve the problems of terminating excess sewage and diminishing water supply. More studies are needed in this field for a longer experiment to assure the effects of PTW on the wood properties especially chemical constituents of wood.

ACKNOWLEDGMENTS

With sincere respect and gratitude, we would like to express deep thanks to Deanship of Scientific Research (SABIC), King Saud University and Agriculture Research Center, College of Food and Agriculture Sciences for the financial support, sponsoring and encouragement.

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