EFFECT OF POTASSIUM SILICATE AS A FOLIAR FERTILIZER ON DROUGHT TOLERANCE OF *PINUS ROXBURGHII SARG* SEEDLINGS

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ABSTRACT: *This study was conducted at the nursery of Timber trees and Forestry Department, Horticulture research Station at El-Kanater El-Khayria, Qalyubia Governorate, Egypt, during the seasons of 2012 and 2013.To study the response of Pinus roxburghii Sarg seedling (one year old) to different irrigation periods (4, 6 and 8 days), affected by potassium silicate at 5 ,10 and 15 ml/l as a foliar spray.*

The results indicated that, irrigation plants at 8 days periods,height growth, stem diameter and biomass fresh and dry weight greatly diminished and these parameters increased due to 4 days irrigation periods.On the other hand, the longest roots correlated with deficit soil moisture content. Total chlorophyll increased in the plants grown under 4 days irrigation period and decreased with 8 days irrigation period.Whereas,total carbohydrate increased at irrigating every 8 days period and the opposite occurred at 4 days.Potassium needles content decreased as soil moisture content decreased, meanwhile, proline content increased in the plants grown under drought stress condition (8 days irrigation).

Foliar spray with potassium silicate at rate of 10 or 15ml/l on the plants grown under 8 days irrigation period promoted height, stem diameter growth and biomass fresh and dry weight more than those untreated by potassium silicate and irrigated at 4 days interval. High level of potassium silicate spray combined with water stress 8 days irrigation interval resulted in greatly longest roots compared to those irrigated at 4 days and not spray with potassium silicate fertilizer.

Total chlorophyll and total carbohydrate increased due to spray potassium silicate at rate of 10 or 15 ml/l combined with those irrigated every 6 or 8 days rather than control.

Spraying potassium silicate at 10 or 15 ml/l resulted in progressive values in needles potassium and proline content and its absence caused a reduction in both of them.

Therefore it could be recommended that spraying the needles of Pinus roxburghii with potassium silicate at rate of 10 or 15 ml/l and irrigated every 6 or 8 days as water stress ameliorated most of growth parameters better than those irrigated every 4 days and untreated with potassium silicate, meaning that, it can be used less water in irrigating the plants with spraying potassium silicate.

Key words: *Potassium silicate–pinus roxburghii–water intervals-water periods.*

INTRODUCTION

Pinus is a genus of family Pinaceae which is a most important family, embracing about 300 different species, varieties and cultivars. The large order (Pinal) contains many trees which have great economic importance, as the forest pines of the world furnish most of man's requirements in softwood timber and wood pulp besides various oils. It is often used in furniture in boat buildings, constrictions and for other purposes where is resistance to decay is advantageous, also for carving pattern - making, hobby work. This is because of its natural durability and it is less expensive than hardwoods Walker*et al*., (1993). It is one of most exotic wood species producing good timbers which are very important for wood industries El-Morshedy, *et al*., (2001).

Potassium is considered as one of the most essential for growth and development of every living plant. It plays a major role in many physiological and biochemical process

Nassar *et al*., (2001) and Sakran*,* (2008). Potassium is a univalent cation with hydrated ionic radius of (0.331 nm) and is an essential macro element in plant nutrition. It is taken up in a large quantity and highly mobile in plants. Young roots and fleshy fruits are rich in K^+. In plant cells, the highest concentration (in the range of 130–150 mM) is in the cytosol, whereas vacuolar K^+ concentration ranges from (20–100 mM) and reflects the K^+ supply Fernando *et al*., (1992). Potassium decreases the water potential and makes the water uptake possible. Xylem parenchyma cells extrude K^+ into xylem vessels where it decreases water potential and attracts the water there which helps to create the root pressure. Potassium may accumulate in vacuoles at high concentration where it not only represents K^+ storage but also functions as an indispensible osmotic. In most cells, the volume of vacuole is relatively large and its turgor is essential for the tissue turgor. The osmotic function is nonspecific as several organic and inorganic osmotic may regulate it in plants. Nonetheless, is the predominant osmotic in this regard which is transported at sufficient rates to the fast-growing tissues Mengel, (2007).

Silicon (Si) is the second most abundant element in the earth's crust and is also abundant in most soils Marschner, (1995) and Datnoff *et al*., (2001). It is readily taken up by plants and is often present in relatively high concentrations in plant tissues Epstein, (2005). Silicon concentrations in plant tissues sometimes even exceed the concentrations of Nitrogen and Potassium

Furthermore, Sakran*,* (2008) cleared that, irrigation the plants at 7 days period since they were exposed to water stress the increment height growth rate,stem diameter, biomass production and shoot/roots ratio and these parameters exceeded due to subjected the plants under non water stress 3 days irrigation period, on the other hand the lowest, roots correlated with deficit soil moisture content.

Therefor the aim of present study is the effect of Potassium silicate as a foliar fertilizer on drought tolerance of *Pinus roxboghii Sarg* seedlings irrigated at different irrigation periods which grown in sandy loam soil as a new reclaimed soil.

MATERIALS AND METHODS

This study was carried out at the experimental area of Horticulture Research Station at El-Kanater El-Khayria during two successive seasons of 2012 and 2013, to study the effect of Potassium silicate on drought tolerance of *Pinus roxburghii Sarg* seedlings irrigated at different irrigation periods grown in sandy loam soil transported from Belbiese desert in El-Sharkia Governorate.

Plant materials:

On the first of February 2012 and 2013 one year old a uniform seedlings of *Pinus roxborghii* (15 cm height and 0.6 cm diameter at soil surface) were transplanted individually into plastic bags 20 cm diameter and 30 cm depth filled with 8 kg of sandy loam soil.

The seedlings were placed in shade area and after one month from transplanting the seedlings were subjected outdoors to sunny area above sheets of thick polyethylene to prevent penetrate the growing roots into soil outer bags.

Physical and chemical properties of soil:

The physical analysis of the used soil was done according to the Pipette method as described by Black (1965), the chemical analysis of the used soil was performed before the experiment using the method described by Piper (1947) as shown in Table (1).

Layout of experiment:

The bags distributed randomly in three replicates to ensure that all replicates are subjected under the same conditions, each replicate included 48 plant.

Table (1): Physical and chemical properties of the used soil.

Practical size distribution (%):								Cations (meq/L)				Anions (Meq/L)					
Coarse sand	Fine sand	Silt	Clay	**Soil texture**	pH soil: water susp., 1:2.5	F.c. 1/3 bar %	EC, dSm-1 soil: water ext., 1:2.5	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	Available K (mg/kg)	Available P (mg/kg)
22.10%	35.30%	25.10 %	17.50 %	Sandy loam	7.75	16%	3.53	1.20	0.70	3.10	0.26	-	1.3	2.4	1.56	13.5	7.1

E.C. = Electrical conductivity. F.C. = Field capacity.
Meq/L – Milie equivalent per liter.

- Chemical fertilization:

On March 2012 and 2013 after one month from transplanting, seedlings were fertilized by 5 gm ammonium sulphate (20.6 % N), whereas potassium silicate(15 % K_2O + 30 SiO_2) was sprayed 3 times in April, June and August by three different levels of5,10 and15 ml/l using Trayton B as adhesive substance (1ml/l).

Calcium superphosphate fertilizer (15.5 % P_2O_5) was mixed with the soil in one time before planting at (6 gm./bag).

Potassium silicate (K_2SiO_3) 15 % K_2O + 30 % SiO_2, liquid from Estrna Industries Company in Egypt.

The seedlings were irrigated up to field capacity after that the seedlings were divided into three treatments of water irrigation periods regime namely (4, 6 and 8 days) represented, non-water stress, medium and stressed soil moisture content respectively.

Vegetative growth measurements:-

1- Growth height (cm.).
2- Stem diameter (cm.)
3- Root length (cm.)
4- Biomass fresh weight (g.).
5- Biomass dry weight (g.).

Chemical analysis:

1- Total chlorophyll mg/g. f.w. was determined in needles according to method described by Saric*et al.,* (1967).
2- Total carbohydrate % in stem was determined as percentage described by Dubasit*et al*., (1956).
3- Potassium was determined using Atomic Absorption Spectrophotometer "Perkin Elmer 3300" Chapman and Pratt (1961).
4- Proline mg/100g.f. w. determined as described by Bates *et al*., (1973).

- Statistical analysis:

The experiment was arranged in a randomized complete blocks design and the obtained data were subjected to analysis of variance and significant differences among means were determine according to Snedecor and Cochran (1980). In addition significant differences among treatments were distinguished according to the Duncan multiple rangetest Duncan (1955).

RESULTS AND DISCUSSION

Vegetative growth.

Height growth (cm.)

Data presented in Table (2) cleared that, height growth was more affected by different irrigation periods where a steady increases exhibited with those irrigated every 4 days and had the superior values of 25.43 and 24.70 cm.Whereas the seedlings irrigated every 6 days gave the same values approximately in average of 24.62 and 24.03 cm while at 8 days irrigation period, height growth had significantly the inferior in average of 23.49 and 23.50 cm. in both seasons respectively, compared to those of 4 days irrigation. The differences between 4 and 6 days irrigation periods were insignificant in first and second seasons. Regardless the effect of potassium silicate spray, it means that, seedlings of *Pinus roxburghii* grew higher in non-water stress (4 day) and medium stress (6 day) compared with the stressed soil moisture content(8 days) irrigation period.

Table (2): Effect of potassium silicate as a foliar spray on seedling height, stem diameter and root length (cm.) of *Pinus roxbourghii* seedlings irrigated at different irrigation periods during 2012 and 2013 seasons.

Characters	Height growth (cm.)				Stem diameter (cm.)				Root length (cm.)			
Treatments	Irrigation periods			Mean	Irrigation periods			Mean	Irrigation periods			Mean
	4 day	6 days	8 days		4 day	6 days	8 days		4 day	6 days	8 days	
	1st season											
T_0	22.79e	22.04f	21.93fg	22.25D	1.55g	1.70d	1.16i	1.47D	11.98f	13.54e	16.89c	14.14D
T_1	24.27d	23.80e	22.53ef	23.53C	1.84cd	1.77de	1.68f	1.76C	12.41ef	15.03d	20.08b	15.84C
T_2	26.87b	25.77bc	24.61cd	25.75B	1.86bc	1.85cd	1.76e	1.82B	12.85ef	15.31d	23.87a	17.34B
T_3	27.80a	26.88b	24.90c	26.53A	1.95a	1.93ab	1.88a-c	1.92A	13.35e	16.50c	24.55a	18.13A
Mean	25.43A	24.62AB	23.49C		1.80A	1.81A	1.62B		12.65C	15.09B	21.35A	
	2st season											
T_0	23.01ef	22.08g	22.00gh	22.36C	1.75c	1.48d	1.23e	1.49B	12.96e	14.99c	15.62bc	14.52B
T_1	23.91e	23.40ef	22.83f	23.38B	1.90b	1.87bc	1.83bc	1.86A	13.21e	15.00c	16.36a	14.86A
T_2	25.75bc	25.50bc	24.30d	25.18A	1.93ab	1.93ab	1.85bc	1.90A	13.46e	15.54bc	15.80ab	14.93A
T_3	26.12a	25.12bc	24.86cd	25.37A	1.82bc	2.02a	1.91ab	1.92A	14.07d	15.08c	16.38a	15.18A
Mean	24.70A	24.03A	23.50C		1.85A	1.82A	1.70B		13.43C	15.15B	16.04A	

T_1= Potassium silicate 5 ml/l. T_2= Potassium silicate 10ml/l. T_3= Potassium silicate 15ml/l.

Regarding the effect of potassium silicate as foliar spray, it can be concluded from data in Table (2) that, rate of 5, 10 or 15ml/l significantly increased height growth in both seasons compared to control.In addition using potassium silicate at 15 ml/l gave significantly the highest values of seedling height growth(26.53cm) compared to those sprayed with rate of 10 ml/l (25.75cm) in the first season while the rate of 10 and15 ml/l significantly increased height growth as compared to control and 5ml/l however the differences were insignificant in between.

The interaction between the irrigation periods and potassium silicate spray, it might be concluded that plants treated with 15 ml/l potassium silicate combined with those irrigated every 4 days period in the first and second season significantly increased seedlings height growth as compared to all the other interactions.The least values appeared with the seedlings irrigated every 8 day and un-sprayed with potassium silicate. It can be noticed also that the seedling irrigated at 8 days interval and sprayed by potassium silicate at level of 15ml/l produced the highest values more than those irrigated at 4 days and did not spray by potassium silicate fertilizer.

Stem diameter (cm.).

Data presented in Table (2) showed that , irrigation seedlings every 4 and 6 days significantly increased stem diameter (1.80 and 1.81 cm) and (1.85 and 1.82 cm) as compared to 8 days irrigation period (1.62 and 1.70 cm) respectively in two seasons. However , the differences were insignificant in between and the values were closely similar in two seasons.

The data indicated that, foliar spray with potassium silicate at the concentration of 5, 10, and 15 ml/l significantly increased stem diameter compared to control in an ascending order in the first season. While the differences among 5, 10 or 15 ml/l potassium silicate wee insignificant in the second season, although they were significant exceeded than control.

The interaction between the irrigation periods and Potassium silicate spray, indicated that , the thickest stem 1.95 cm appeared with those irrigated every 4 days combined with sprayed by potassium silicate at level of 15 m/l, it also noticed that irrigating the plants every 8 days and sprayed by potassium silicate at any level induced significantly the thickest diameter better than those irrigated at 4 days interval and did not spray (control) .

Root length (cm.).

Data presented in Table (2) revealed that, root length significantly increased in an ascending order as irrigation periods were 4,6 and 8 days irrigation periods in two seasons. Which the values were (12.65, 15.09 and 21.35 cm) and (13.43, 15.15 and 16.04 cm) in two seasons respectively.

In this respect the effect of potassium silicate spray at rate of 10 or 15 ml/l induced significantly the maximum root length in average of 17.34 and 18.13 cm respectively, followed by spraying at 5 ml/l which gave main value of 15.84 cm while the control produced the shortest roots in average value 14.14 cm. The differences among the treatments were significantly in the first season, meanwhile in the second season the seedlings sprayed with 5, 10 or 15 ml/l potassium silicate pronounced the highest value compared to control even so the differences among them were not significant.

As for the interaction between the different of irrigation periods and rates of potassium silicate spray, the results illustrated in Table (2) that, root length of the plants irrigated at 8 days intervals combined with sprayed at rate of 10 or 15ml/l produced the longest root length than others. The differences between 10 or 15 ml/l spray potassium silicate were not significantly in the first season.The result have been taken the same trend approximately in second one.

Biomass fresh weight (g.).

Data of Table (3) obviously cleared that, biomass fresh weight affected by different water irrigation periods since the plants subjected under water stress and irrigated every 8 days had the inferior values of 124.4 and 121.5 g. while, those subjected under non-water stress irrigated every 4 days had the superior values of 135.3 and 148.2 g. respectively, followed by those irrigated every 6 days period in which the fresh weight of biomass was intermediate 130.28 and 133.10gm. However, the differences between 4 and 6 days periods were not significant in two seasons.

As for the effect of potassium silicate as foliar fertilizer, the obtained results obviously cleared that, the plants which sprayed with potassium silicate at rate of 10 ml/l produced the highest biomass fresh weight 141.50gm. compared with the others, however there were no significant differences between 10 of 15 ml/l in the first season, on the other hand the concentration of 15 ml/l produced the heaviest biomass fresh weight compared to others in the second one.

Regarding the interaction between water irrigation periods and potassium silicate spray, it might be demonstrated that,seedlings treated with 10 ml/l potassium silicate combined with those irrigated by 4 days exhibited significant the heaviest biomass fresh weight (149.2 g) in the first season, whereas in the second one the seedlings irrigated at 4 days period and sprayed by potassium silicate at rate of 15 or 10 ml/l revealed excessive values to the maximum of (153.7 and 150.6 g) respectively,and the differences were insignificant in between. It means that the plants subjected under drought stress which irrigated at 8 days period and didn`t receive potassium silicate spray had the slightest biomass fresh weight 107.6gm while,those irrigated at 4 days interval and sprayed with potassium silicate 10 or 15 ml/l had the heaviest biomass fresh weight in two seasons as well as the plants irrigated every 8 days and treated with 15ml/l potassium silicate resulted record more biomass fresh weight than those irrigated at 4 days and did not received potassium silicate.

Table (3): Effect of potassium silicate as a foliar spray on biomass fresh weight and dry weight (gm.) of *Pinus roxbourghii* seedlings irrigated at different irrigation periods during 2012 and 2013 seasons.

Characters	Biomass fresh weight (gm)				Biomass dry weight (gm)			
Treatments	Irrigation periods			Mean	Irrigation periods			Mean
	4 day	6 days	8 days		4 day	6 days	8 days	
1st season								
T_0	127.4d	115.0f	107.6g	116.7C	58.40d	54.43e	51.78f	54.87C
T_1	123.3de	122.8de	119.2ef	121.8B	60.88c	59.91cd	55.04e	58.61B
T_2	149.2a	142.2b	133.2c	141.5A	65.69a	63.32c	60.67c	63.23A
T_3	141.2b	141.1b	137.3bc	139.9A	64.00b	64.02b	61.04c	63.02A
Mean	135.3A	130.28AB	124.4C		62.24A	60.42AB	57.13C	
2nd season								
T_0	142.9b	118.7e	119.9de	127.2C	65.78d	58.68f	53.07g	59.18C
T_1	145.6b	119.7de	119.8de	128.3C	70.37bc	63.04e	61.93e	65.11B
T_2	150.6a	142.4b	120.5de	137.8AB	73.46a	70.28c	71.21bc	71.65A
T_3	153.7a	151.7a	126.1c	143.8A	72.11ab	70.77bc	70.03c	70.97A
Mean	148.2A	133.1AB	121.5B		70.43A	6569B	64.06C	

T_1= Potassium silicate 5 ml/l/l. T_2= Potassium silicate 10 ml/l/l. T_3= Potassium silicate 15 ml/l.

Biomass dry weight (g.).

Data presented in Table (3) showed that the highest biomass dry weight revealed with the seedling irrigated 4 or 6 days intervals while those exposed to water stress 8 days irrigation period gave significantly the lowest one compared to the two others, these facts revealed in two seasons.

Regarding the effect of potassium silicate spray it can be noticed from data existed in Table (3) that, rate of 10 or 15 ml/l obviously cleared the highest values in biomass dry weight, however the differences were not significant in between, in addition rate of 5 ml/l recorded the lowest one compared to the two others in spite of it gave the best value than those of control.These results were confirmed in first and second season.

As for the interaction between the different irrigation periods and rates of potassium silicate spray, it can be concluded from the results illustrated in Table (3) that, biomass dry weight of the seedlings irrigated at 4 or 6 days interval combined with those sprayed by 10 or 15 ml/l potassium silicate were higher than others.

The aforementioned results showed that, irrigating the seedlings at water stress resulted in markedly reduction in height growth; stem diameter, biomass fress and dry weight, while the opposite occurred when plants were subjected under nun-water stress in accordance with the findings of Sakran, (2008). On *Eucalyptus gomphocephala* and *Swietenia mahogany* and Shvalva *et al* (2005). On *Eucalyptus globules*, mean while the longest roots correlated with the deficit soil moisture content, in agreement with the finding of shehata, (2002). On *khaya senegalensis* also Moroni *et al* (2003). On *Ecalyptus globules* where they reported that root length were greater in drought than those irrigated soil. Also the herein obtained result. It can be concluded that , potassium silicate fertilizer sprayed on seedings exposed to water stress enhanced seedling height , stem diameter , root length and biomass fresh and dry weight . There results were similarly with those obtained by Ahmed *et al* (2011) on sorghum plants and Lu and Cao(2001). On melon , who reported that spray of potassium silicate on plants resulted in increased all vegetative growth parameters , may be due to silicon and potassium promotes plant growth and has unique role in conferring tolerance in plants to various abiotic and biotic stress Laing *et al*., (2007).

It is worthily to notice also that spraying the plants with potassium silicate at the rate of 15 or 10 cm./l and irrigated every 8 days represented water stress resulted in ameliorated vegetative growth better than those irrigated every 4 days represented wet or no water stress but did not fertilizer with potassium silicate. It means that the plants subjected under stressed water and sprayed with 10 or 15 ml/l increased resistance of drought stress.

Total chlorophyll (mg/gm.f.w.):

The results of Table (4) showed that, total chlorophyll significantly increased with irrigation at 4 days periods more than those irrigated at 6 or 8 days in first season,while those irrigated at 4 or 6 days interval produced excessive values more than those of 8 days.

As for the effect of spray by potassium silicate, it can be noticed that all the used rates significantly increased total chlorophyll compared to control. However, there are no significant differences between rates 10 or 15 ml/l in the first season.While, in the second one the differences among all treatments were not significant. The results obviously cleared that, the seedlings irrigated with 4 days period combined with those sprayed with 10 or 15ml/l potassium silicate produced the highest value of total chlorophyll.

These results were in harmony with those obtained by Soad (2005) on Jojoba seedlings and Azza *et al*., (2006) on *Taxodium distichwm*. Also Abd-Elaziz (2000) on *Azadirachta indica* where they found that, all different fertilization treatments considerably increased total cholorophyll content , also Dunisch *et al* (2002) showed that , the net phot synthesis of *swietenia macrophlla* and *Cedrela odorata* strongly depends on high water and potassium content of the plants .

Total carbohydrate (%):

The resulted in Table (4) illustrated that, total carbohydrate in stem influenced by different irrigation periods in which it significantly increased with 8 days period comparable with the two others in both season,

In this respect the seedlings sprayed with 10 or 15 ml/l potassium silicate pronounced the highest values even so the differences were not significant in between followed by those sprayed with 5 ml/l whereas the control produced the lowest total carbohydrate in the first season, on the other hand potassium silicate spray at rate of 15 ml/l recorded significantly the highest total carbohydrate compared to the others in the second one.

In addition the interaction between different irrigation periods and potassium silicate spray ,total carbohydrate produced the highest values with those irrigated by 8 days periods combined with sprayed by potassium silicate at rate of 15 ml/l.13.20% and 12.45% in two season respectively.

Table (4): Effect of potassium silicate as a foliar spray on total chlorophyll (mg/gm.f.w.) and total carbohydrate % of *Pinus roxbourghii* seedlings irrigated at different irrigation periods during 2012 and 2013 seasons.

Characters	Total chlorophyll (mg/gm f. w.)				Total carbohydrate %			
Treatments	Irrigation periods			Mean	Irrigation periods			Mean
	4 day	6 days	8 days		4 day	6 days	8 days	
1st season								
T_0	1.613cd	1.593d	1.080f	1.429C	10.18e	10.06e	10.18e	10.14C
T_1	1.693a-c	1.587d	1.510e	1.597B	11.31d	11.40d	11.74c	11.49B
T_2	1.737a	1.707ab	1.653a-d	1.699A	12.31b	11.95c	12.36b	12.21A
T_3	1.730a	1.715ab	1.640b-d	1.695A	11.84c	11.93c	13.20a	12.32A
Mean	1.693A	1.650AB	1.471C		11.41B	11.34B	11.87A	
2nd season								
T_0	1.717ab	1.710a-c	1.653cd	1.693A	10.05g	10.71f	10.62f	10.46D
T_1	1.740a	1.673b-d	1.620d	1.678A	11.38e	11.80c	11.90c	11.69C
T_2	1.703a-c	1.730ab	1.657cd	1.697A	11.65d	11.81c	11.96c	11.81B
T_3	1.717ab	1.720ab	1.633d	1.690A	12.23b	12.47a	12.45a	12.38A
Mean	1.719A	1.708A	1.641B		11.33B	11.70AB	11.73A	

T_1= Potassium silicate 5 ml/l. T_2= Potassium silicate 10 ml/l. T_3= Potassium silicate 15 ml/l.

From the obtained previous results, it can be concluded that, drought stress condition resulted in rising up total carbohydrate in stem and the opposite was occurred in non-water stress. These results were agreement with Shehata (1992) and El-Tantawy *et al* . (1993a) on *Eucalyptus comaldulensis* all of them declared that, total carbohydrate increased in stem of seedling subjected to reduction of water supply, also Shehata *et al*; (1999) on three pinus species in which confirmed that NPK ferhlization resulted in abundance in total sugars, may be due to potassium is known to be linked with carbohydrate metabolism and sugar translocation .

Potassium %

Data presented in Table (5) showed that, potassium % in needles exceeded significantly in the seedlings irrigated at 4 or 6 days more than that of 8 days, the values of k % obtained from 4 days interval were similar to those of 6 days interval approximately in which the mean values were 0.645 and 0.635 % respectively, while mean value was 0.598 % in the seedling irrigated at 8 days.

In the second season, the results have taken the same trend but the values were different where they were 0.644, 0.603 and 0.566 % in the seedlings irrigated at 4, 6 and 8 days interval respectively. The differences among the three irrigation periods were significant.

Table (5): Effect of potassium silicate as a foliar spray on potassium (%) and proline content (mg/100 g.) of *Pinus roxbourghii* seedlings irrigated at different irrigation periods during 2012 and 2013 seasons.

Characters	Potassium %				Proline content (mg./100g.)			
Treatments	Irrigation periods			Mean	Irrigation periods			Mean
	4 day	6 days	8 days		4 day	6 days	8 days	
1st season								
T_0	0.557de	0.557de	0.533e	0.549C	1.07c	1.14bc	1.21b	1.14C
T_1	0.647b	0.617bc	0.583c-e	0.616B	1.17b	1.17b	1.19b	1.18B
T_2	0.650b	0.647b	0.610b-d	0.636B	1.23b	1.42a	1.43a	1.36A
T_3	0.727a	0.720a	0.667b	0.704A	1.35a	1.41a	1.48a	1.41A
Mean	0.645A	0.635A	0.598B		1.21B	1.29A	1.33A	
2nd season								
T_0	0.567f	0.520h	0.463i	0.517D	1.10f	1.14d-f	1.15d-f	1.13C
T_1	0.653bc	0.607e	0.550g	0.603C	1.12ef	1.16de	1.19d	1.16C
T_2	0.663b	0.643cd	0.617e	0.641B	1.15d-f	1.24c	1.32b	1.24B
T_3	0.693a	0.640cd	0.633d	0.656A	1.17de	1.36ab	1.40a	1.31A
Mean	0.644A	0.603B	0.566C		1.14C	1.23B	1.27A	

T_1= Potassium silicate 5ml/l. T_2= Potassium silicate 10 ml/l. T_3= Potassium silicate 15 ml/l.

Regarding the effect of potassium silicate spray on potassium % content, data in Table (5) demonstrated that spraying with potassium silicate at rate of 15 ml/l in the first season produced significantly the highest value in average of 0.704%, compared to the others, and the lowest values of 0.549 % appeared with those did not spray with potassium silicate , while the seedlings which are sprayed at rate of 5 or 10 ml/l resulted in the intermediate in average value of 0.616 and 0.636 % respectively, however the differences between 5 or 10 ml/l potassium silicate were not significant.

In the second season, the result have been taken the same trend approximately, meanwhile spraying at 15 ml/l induced significantly the maximum values in average of 0.656 % followed by 10 or 5 ml/l spray potassium silicate which gave the mean values of 0.641 and 0.603 %, respectively, while control produced the minimum value in average of 0.517 %. and the differences among the rates of potassium silicate spray were significant.

Concerning the interaction between different irrigation periods and potassium silicate spraying it can be resulted from Table (5) plants treated with 15 ml/l potassium silicate combined with 4 or 6 days irrigation period produced the highest values of potassium % compared with others in both seasons.

These results were agreement with the findings of El-Tantawy *et al* (1993a) on *Eucalyptus conaldulensis* and Shehata, (2002) on *Khaya senegalensis* who observed that, Potassium% in stem were stimulated gradually by increasing wate supply while low level of soil moisture reduced it , also Abd-Elaziz (2000) and Sayed (2001) on *Khaya senegalensis* observed that , the high Potassium level, in NPK fertilization gave the highest potassium content in the leaves.

Proline (mg/100 g.)

As shown in Table (5) proline content in needles of *Pinus roxburghii* increased in average value of 1.33 and 1.27 mg/100 gm fresh weight when the seedlings exposed to drought stress in which they were irrigated every 8 days and the seedling irrigated every 4 days interval represented non-water stress proline content in needles noticeable reduced to minimum values of 1.21 and 1.14mg/100gm.f.w, on the other hand exposing the seedlings to medium water stress 6 days irrigation period, proline content was the intermediate, meanwhile the values were 1.29 and 1.23 mg/100 gm. f. w. in both seasons respectively. The differences between 6 or 8 days intervals were insignificant in the first season, whereas in the second one the differences among three treatments of irrigation periods were significant.

As for the effect of potassium silicate as a foliar spary it can be observed from data of Table (5) that, proline content in needles of *Pinus roxburghii* had progressive values, in response of spraying the seedlings with rates (5, 10 and 15 ml/l) of potassium silicate in which it raised up at 10 or 15 ml/l potassium silicate in average value of 1.36 and 1.41 and in absence of potassium silicate spraying proline content suppressed to minimum value of 1.14 mg/100 gm. f. w. in the first season, while in the second season the obtained results have taken the same line to those obtained from first one where the proline content increased to maximum values of 1.24 and 1.31 mg/100 gm f. w. due to spraying the plants with high rates of potassium silicate 10 or 15 ml/l respectively.

In this respect the effect of interaction between different irrigation periods and rates of potassium silicate, it is evident from the herein obtained results that, proline content attained to maximum values 1.48 and 1.40 mg/100 gm f. w. in seedlings, exposed to drought stress conditions 8 days irrigation period and sprayed with high rate of potassium silicate in rates of 15 ml/l and reduced to minimum values of 1.07 and 1.10 mg/100 gm f. w. corresponding with exposing the plants to non-water stress 4 days interval and did not spray with potassium silicate in both seasons.

The former results illustrated that leaves Proline content increased clearly with drought stress conditions causing high osmotic pressure in plant cells consequently associated in drought tolerance ., In accordance with the findings of Shvaleva *et al* (2005) on *Eucalyptus globules* and Azza *et al.* (2006) on *Taxodium disticum*. Who observed increases in concentration of Proline with drought stress.

The above mentioned results obviously cleared that subjecting the plants to water stress conditions and fertilization with high levels of potassium silicate resulted in increases in leaves Prolin content that was associated in drought tolerance.

As a recommendation, in abound water or water deficit conditions, application of Potassium silicate is favorable for *Pinus roxburghii* seedlings growth.

Conclusions

From the aforementioned results it could be recommended that spraying the needles of *Pinus roxbourghii* seedling with potassium silicate at rate of 10 or 15 ml/l and irrigated every 6 or 8 days represented water stress resulted in ameliorated most of parameters growth better than those irrigated every 4 days represented no water stress but did not receive potassium silicate, it is beneficial in reducing irrigation water.

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تأثير الرش بسليكات البوتاسيوم على تحمل شتلات الصنوبر للجفاف

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الملخص العربى

أجريت هذه الدراسة فى مشتل الأشجار الخشبية والغابات بمحطة بحوث البساتين بالقناطر الخيرية – محافظة القليوبية، مصر خلال موسمين متتاليين 2012 و2013 لدراسة تأثير التسميد الورقى بسليكات البوتاسيوم على تحمل شتلات الصنوبر "*Pinus roxburghii* " عمر سنة النامى فى تربة مستصلحة (رمليه طمييه) ورويت على فترات رى مختلفة كل 4، 6، 8 أيام .

حيث أضيف تركيز ثابت من النتروجين (سلفات النشادر 20.6) 5 جم/ شتلة وكذلك الفوسفور (سوبر فوسفات اللكالسيوم 15.5 %) 6 جم/شتلة بينما أضيف البوتاسيوم (سليكات البوتاسيوم 15 % K_2O + 30 % SiO_2) بثلاث تركيزات هى 5، 10، 15 ملى لتر/لتر رشاً على الأوراق.

وفيما يلى ملخص لأهم النتائج:

1- نقص النمو الطولي والقطري للشتلات وكذلك الكتلة الحيوية الطازجة والجافة نتيجة تعرض الشتلات للجفاف عندما رويت كل 8 أيام بينما زادت هذه القياسات عند الرى كل 4 أيام.

2- زاد طول الجذر فى النباتات المعرضة للجفاف والتي رويت كل 8 أيام.

3- زاد الكلوروفيل الكلى فى الشتلات التى لم تعرض للجفاف حيث رويت كل 4 أيام وكذلك النامية تحت ظروف الرطوبة المتوسطة المروية كل 6 أيام بينما قلت عند تعرض الشتلات للجفاف والتى رويت كل 8 أيام فى حين زادت الكربوهيدرات الكلية فى السقان عند تعرض النباتات للجفاف أكثر من المروية كل 4 ايام بينما النباتات التى رويت كل 6 أيام أظهرت نتائج متوسطة.

4- زاد البوتاسيوم فى أوراق الشتلات التى رويت كل أربعة أيام يليه النباتات التى رويت كل 6 أيام فى حين قل عند الرى كل 8 أيام، وعلى العكس زاد البرولين فى الشتلات التى تعرضت للجفاف .

5- أدى الرش بسليكات البوتاسيوم بتركيز 10 أو 15 ملى لتر/لتر إلى زيادة في النمو الطولي والقطري تحت ظروف الجفاف حيث رويت كل 8 أيام أكثر من التى لم يتم رشها رغم نموها فى مستوى رطوبة مرتفعة حيث رويت كل 4 أيام.

6- رش النباتات بسليكات البوتاسيوم المعرضة للجفاف (المروية كل 8 أيام) أدى إلى زيادة فى طول الجذر.

7- زادت الكتلة الحيوية الطازجة والجافة للشتلات التى عرضت لظروف الجفاف وتم رشها بسليكات البوتاسيوم بتركيز 10 أو 15 سم/لتر مقارنة بالنباتات التى لم تتعرض للإجهاد المائى ورويت كل 4 أيام أى أن الرش بسليكات البوتاسيوم يفيد فى ظروف تعرض الشتلات للجفاف.

8- زادت النسبة المئوية للبوتاسيوم وكذلك البرولين فى الأوراق عند الرش بسليكات البوتاسيوم بمعدل 10 أو 15 ملى لتر/لتر تحت ظروف الإجهاد المائى وأن عدم الرش يؤدى إلى نقص كل منهما.

ومن النتائج السابقة يمكن التوصية برش المجموع الخضرى لشتلات الصنوبر باستخدام سليكات البوتاسيوم بمعدل 10 أو 15 ملى لتر/لتر مع ريها كل 6 أو 8 أيام حيث أن ذلك يفيد فى تحمل الشتلات لظروف الجفاف وزيادة معظم قياسات النمو وتقليل مياه الرى.