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Castor Bean Plants Response to Phosphorus Sources under Irrigation by Diluted Seawater

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Abstract: A greenhouse experiment was conducted in The National Research Centre at Dokki, Giza, Egypt to evaluate the growth, macro and micro-nutrients concentration of castor bean shoots as affected by phosphorus fertilizer under salt stress. Two sources of phosphorus fertilizer (phosphoric acid P_1 and monopotassium phosphate P_2) in rate of 200 ppm were sprayed and distilled water used as a control. Castor bean plants were irrigated by diluted seawater in rate of 20 % seawater and tape water as a control. A negative relationship was detected between salt stress and growth characters. Irrigation castor bean plants with 20% diluted seawater decreased plant height, green leaves number, leaves area and dry weight of root, stem, leaves and whole plant compared to plants that of irrigated regularly with tape water. The data indicated that plant height and number of green leaves were the lesser affected growth character with salt treatment, however, the area of green leaves was the greatest growth character affected with salt subjection. Meanwhile, root, stem, leaves and whole plant dry weight were approximately responded similarly. Number or area of leaves showed that its higher values when plants received P_1 more than plants received P_2 or distilled water. This was true for plants irrigated regularly by tape water or saline water. Plant height under tape water irrigation showed the same response but under salt stress the longest plants was shown by spraying P_2. Also root, stem, leaves and whole plant dry weight and shoot/root ratio responded similarly to number and area of leaves. Irrigation castor bean with 20% diluted seawater led to reduce the uptake of all determined nutrients in this work. Spraying of P_1 or P_2 increased the uptake of mineral elements except for Ca and K. Application of P_1 source encourage the uptake of all elements more than P_2 application except P uptake which the reverse was true. The effects of treatments on photosynthetic pigments were included.
Keywords: Castor bean (*Raciness communes* L) - Salt stress - Phosphorus fertilizers – Growth - Photosynthetic pigments - Mineral status.

Introduction

Castor bean (*Ricinuss communis* L.) is one of the most important cash crops grown under diverse climatic conditions in the world. It has a low demand for irrigation and nutrition, high seed oil content, and good yielding ability[1]. It was mainly used for manufacturing industrial surfactants, coatings, greases, fungicidal surfactants, and pharmaceutical and cosmetic products. Castor bean grows well in semiarid and arid regions, areas that often have low to medium soil saline concentrations[2].

Many new cultivated soils suffer from lack of fresh water, so, using of nontraditional water such as saline well water, drainage water and diluted seawater is necessary. Use of diluted seawater caused many adverse effects on physiological processes in plants[3,4, and 5]. Irrespective of the harmful effect of seawater on plant growth, it must be using of diluted seawater in irrigation. The need for more researches describe the suitable dilution of seawater without harmful effect on plant growth is become urgently[6].

Salinity adversely affected growth, metabolic processes, oil quantity and quality and yield of castor bean plants are described by [7and 8]. Leaf photosynthetic capacity depends on physiological characteristics such as chlorophyll contents, Rubisco activity and photosystem efficiency[9]. It has been reported that chlorophyll content decreases in salt susceptible plants such as tomato and pea[10], but that chlorophyll content increased in salt tolerant plants such as pearl millet and mustard[11]. Living with salinity by different managements is considering an important practice to sustaining agricultural production[12].

Phosphorus is an essential nutrient for plants, animals and humans. It is one of the 20 most abundant elements in the solar system, and the 11th most abundant in the earth's crust. Phosphorus is also a key component in some agrochemicals, such as phosphoric acid (H_3PO_3). Thus, there are two types of P closely associated with crop production. While growers are familiar with P-containing fertilizers, the abundance of terms, apparently similar such as phosphoric acid, may create some confusion as to the actual content and efficacy of these products [13]. Phosphorus is considered one from the major limiting factors in crop growth, development and finally economic yield [14, 15 and 16] in order to its effect on different metabolic processes such as : photosynthesis [16], nucleic acid synthesis [17] assimilation and transport of nitrate [18] and energy transport [19 and 20]. [21] reported that the unbalanced fertilization affected the development and seed production of castor bean, and the best response of the plants was observed at levels of 200 kg N/ ha; 150 kg P_2O_5/ha and 150 kg K_2O /ha. [22] showed the effect of phosphorus deficiency on root and shoots growth of castor bean plants and the different responses of varieties to P deficiency. [20] noticed that high root to shoot dry weight ratio can be considered is an adaptive strategy of P-deficient plants grown in substrate low in phosphors supply. Assimilation and transport of nitrate and phosphate were affected by phosphorus deficiency in castor bean plants[18]. The responses of plants to different sources of phosphorus were studied by many authors: [3, 23 and 24]. Phosphorus application used for increasing tolerance of plants to salt stress was studied by [25, 26 and 27].

Therefore, this work designed to investigate the effect of two phosphorus sources on growth, chlorophyll, carotenoids and mineral content of castor bean plant which irrigated with diluted seawater.

Materials and Methods

A greenhouse experiment was conducted in The National Research Centre at Dokki, Giza, Egypt, to evaluate growth, chlorophyll, carotenoids and concentration of macro and micro-nutrients in leaves of castor bean plants (*Ricinus communis* L.) as affected by two sources of P under salinity stress. Two sources of phosphorus fertilizer (phosphoric acid P_1 and monopotassium phosphate P_2) in rate of 200 ppm were sprayed and distilled water (DW) used as a control.

Castor bean plants were thinned to leave three plants / pot, irrigated by diluted seawater (DSW) in rate of 20 % seawater and tape water (TW) as a control. Soil sample was taken from Kerdasa region, Giza governorate, air-dried, crushed, sieved to pass through 2mm sieve. Some physical and chemical characteristics of the investigated soil were determined [28] and shown in Table (1). Foliar application treatments were applied at two successive times 60 and 90 days after sowing. The irrigation with saline water was started at 45 days from sowing. Some chemical properties of used seawater were as follow: pH 8.4, EC (dSm^{-1}) 50, cations and anions Ca, Mg, K, Na, HCO_3, Cl and SO_4 as 0.42, 1.31, 0.43, 11.02, 0.12, 19.88 and 2.74 g/L, respectively. At 180 day from sowing, plants leaves were picked cleaned, dried in electric oven at 70°C, and ground in stainless steel mill. Dry powder was digested and analyzed N, P, K, Ca, Mg, Na, Fe, Zn, Mn and Cu [29]. The relations between measured nutrients were calculated. Analysis of variance (ANOVA) and least significant difference (LSD) at 0.05 probability level was computed [30].

Table (1): Some physical and chemical properties of the investigated soil

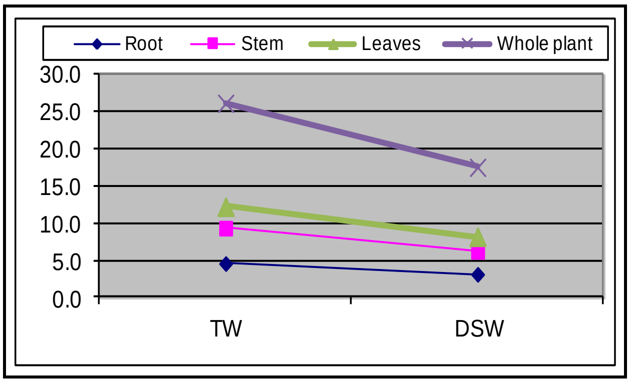
Characteristics	Values
Chemical properties	
pH (1 : 2.5 soil : water ratio)	8.01
EC (1:5 soil : water ratio) dSm^{-1}	1.10
Soluble cations (me/L):	
Calcium	3.50
Magnesium	1.90
Potassium	0.92
Sodium	4.88
Soluble anions (me/L):	
Carbonate	-
Bicarbonate	1.30
Chloride	6.20
Sulphate	3.70
Physical properties (%):	
Organic matter	1.10
Calcium carbonate	2.70
Sand	20.4
Silt	29.5
Clay	50.1
Textural class	Clayey

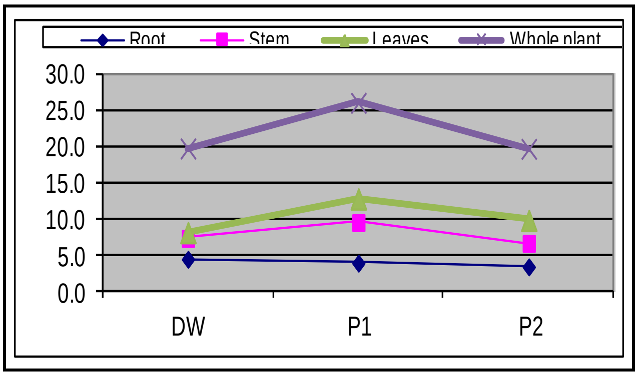
Results and Discussion

Effect of diluted seawater, phosphorus sources and the interaction between them on growth parameters, photosynthetic pigments, mineral status and its relations are presented as follow:

Growth parameters

A negative relationship was detected between salt stress and growth characters. Irrigation castor bean plants with diluted seawater decreased plant height, green leaves number, leaves area and root, stem, leaves and whole plant dry weight by 12.52, 11.22, 57.66, 31.66, 33.48, 33.03 and 32.96 % compare to plants irrigated with tape water. These data indicated that plant height and number of green leaves were the lesser affected growth character with salt treatment; however, the green leaves area was the greatest growth character affected with salt subjection (Fig.1 and Table 2). Salinity adversely affects seedling growth and some relevant metabolic processes of glycophytic plants [8 and 27]. Salt treatment induced decreases in leaf water potential at a germination [31]. Salinity could seriously change the photosynthetic carbon metabolize, leaf chlorophyll content as well as photosynthetic efficiency[32 and 33]. Carbohydrates are accumulated in plant tissues under saline stress and these substances are suspected of contributing to osmotic adjustment and chlorophyll content [34 and 35]. These results are close agreement with those obtained by [36] whereas reported that the reduction in plant height and dry weight of faba bean referring to salinity stress effect.





W= Water source, TW=Tape water, DSW=Diluted seawater, P=Phosphorus source, DW=distilled water, P_1=Phosphoric acid, P_2=Mono potassium phosphate

Fig. (1): Castor bean growth as affected by DSW and P sources treatment

Table (2): The growth parameters as affected by the interaction between DSW and P sources.

W Source	P source	Plant Height(cm)	Leaves No	Leaves Area (cm^2)	Dry weight (g)				
					Root	Stem	Leaves	Whole plant	S/R
TW	DW	79.0	9.6	1148	5.29	10.07	12.81	28.17	4.33
	P_1	82.7	10.7	1184	5.02	12.70	13.23	30.95	5.17
	P_2	78.0	9.0	1155	3.43	5.27	10.64	19.34	4.64
DSW	DW	68.0	6.7	225	3.48	4.49	3.36	11.33	2.26
	P_1	66.7	10.7	660	2.68	6.24	12.29	21.21	6.91
	P_2	75.0	8.7	590	3.23	7.92	8.91	20.06	5.21
Mean	TW	79.9	9.8	1162	4.58	9.35	12.23	26.15	4.71
	DSW	69.9	8.7	492	3.13	6.22	8.19	17.53	4.79
Mean	DW	73.5	8.1	687	4.39	7.28	8.09	19.75	3.29
	P_1	74.7	10.7	922	3.85	9.47	12.76	26.08	6.04
	P_2	76.5	8.9	873	3.33	6.60	9.78	19.70	4.92
$LSD_{5\%}$	W	6.08	N.S	550	1.79	2.85	5.44	N.S	-
	P	N.S	N.S	N.S	N.S	N.S	3.84	6.95	-
	W x P	4.3	N.S	N.S	N.S	N.S	5.43	N.S	-

W= Water source, TW=Tape water, DSW=Diluted seawater, P=Phosphorus source, DW=distilled water, P_1 =Phosphoric acid, P_2=Mono potassium phosphate, S/R=Shoot/Root

All the growth parameters enhanced with P foliar addition than distilled water except root weight. The plants received P_1 represent higher leaves numbers or area, root, stem, leaves, whole plant dry weight and shoot/root ratio more than plants received P_2 or distilled water. This was true for plants irrigated by both of tape water or saline water. This may be due to that, the plant takes its requirement through leaves. The different effects of different phosphorus sources on plants growth were studded by [13]. There is one exception, plant height under tape water irrigation showed the same response but under salt stress the longest plants was shown by spraying P_2. [37] concluded that mineral nutrition significantly affects on the dynamics of leaf surface formation and extent leaf area, which is reflected in the sum total of leaf surface, the photosynthetic potential and net of photosynthesis. Of all macro metabolic elements, the greatest influence on development of plants in general and their leaf surface is exerted by nitrogen, those enhanced by phosphorus and to lesser extent by potassium.

Photosynthetic pigments

The anti-salt mechanism of plants has been extensively studied, and the shape development, photosynthesis, and carbon metabolization of plants under salt stress have been investigated by [38, 39 and 40]. Chlorophyll is the main coloragent responsible for photosynthesis. Under adverse circumstances, the chlorophyll level is a good indicator of the photosynthesis function. Chlorophyll level of trees decreases with aggravated salt stress [39] due to enzymatic chlorophyll degradation [40]. Nevertheless, the increase in chlorophyll content has been thought to be due to the accumulation of NaCl in the chloroplast [41].

The content of chlorophyll-*a* and *b*, total chlorophyll (*a*+*b*) and carotenoids decreased with saline treatments (Table 3). Leaf photosynthetic capacity depends on physiological characteristics such as chlorophyll contents, Rubisco activity and photo-system efficiency [9]. Chlorophyll content decreases in salt susceptible plants such as tomato and pea [10], but that chlorophyll content increased in salt tolerant plants such as in pearl millet and mustard plants [11]. It is clearly that Chl.a, Chl.b. and carotenoids concentrations were not affected significantly with water source. Both of Chl.b and carotenoids affected significantly by P source.

Table (3): Effect of two phosphorus sources and salt stress on photosynthetic pigments of castor bean plants.

W source	P source	Chl.a	Chl.b	Carotenoids	Chla+b	Chla:Chlb	(Chla+b)/Carotenoids
TW	DW	10.13	4.82	4.48	14.95	2.10	3.34
	P_1	10.16	4	8.57	14.16	2.54	1.65
	P_2	11.04	3.49	4.3	14.53	3.16	3.38
DSW	DW	9.84	4.97	4.19	14.81	1.98	3.53
	P_1	9.75	4.53	4.27	14.28	2.15	3.34
	P_2	9.6	3.68	4.4	13.28	2.61	3.02
Mean	TW	10.4	4.1	5.8	14.55	2.55	2.52
	DSW	9.7	4.4	4.3	14.12	2.21	3.29
Mean	DW	10.0	4.9	4.3	14.88	2.04	3.43
	P_1	10.0	4.3	6.4	14.22	2.33	2.21
	P_2	10.3	3.6	4.4	13.91	2.88	3.20
$LSD_{5\%}$	W	N.S	N.S	N.S	-	-	-
	P	N.S	0.66	1.12	-	-	-
	W x P	N.S	N.S	1.59	-	-	-

W= Water source, TW=Tape water, DSW=Diluted seawater, P=Phosphorus source, DW=distilled water, P_1 =Phosphoric acid, P_2=Mono potassium phosphate

As for effect of the interaction between the studied factors on photosynthetic pigments it can be observed that, Chl.a. and Chl.b. were slightly affected with the interaction between water and P sources without significant difference. Chl.a:Chl.b ratio, however Chl.a+Chl.b concentration was not affected by salinity stress. On reverse, Chl.b concentration and Chl.a+Chl.b: carotenoids ratio was slightly decreased. Chlorophyll b concentration was decreased by salt stress [27].

[42] found out that saline stress slows down the production of photosynthetic pigments. [43] highlighted that saline stress induces degradation of β-carotene, which causes a decrease in the content of carotenoids that are integrated constituents of thylakoid membranes and act in absorption and light transfer to chlorophyll; besides, they protect chlorophyll from photooxidation[44 and 45]. Thus, degradation in carotenoid synthesis may imply degradation of chlorophylls[45]. The degradation of the photosynthetic apparatus may have contributed to the reduction in the content of photosynthetic pigments. In studies performed with *Salvinia molesta* subjected to 50, 100 and 200 mM of NaCl[46], the decrease in carotenoids content and chlorophyll were also observed. Due to this event, the capability of *Salvinia auriculata* to colonize saline environment is probably reduced as well[47]. In contrast, [48] concluded that salt stress induced an increase in the chlorophyll content, which could be due to an increase in the number of chloroplasts in stressed leaves.

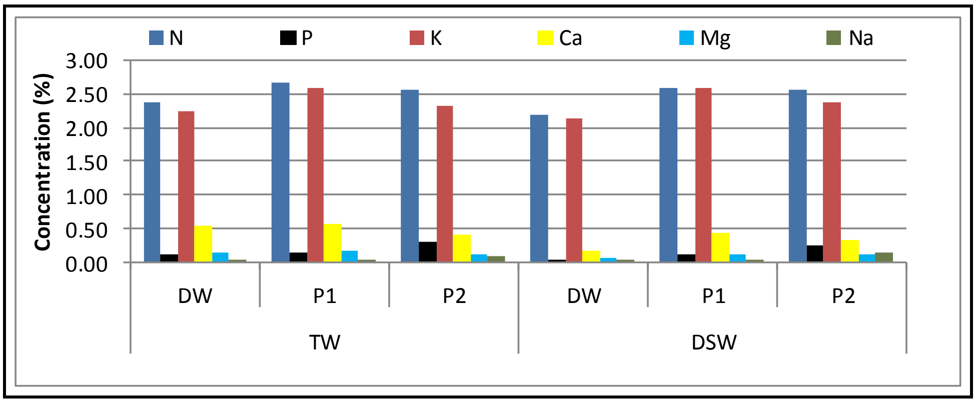
Many authors have established that chlorophyll and carotenoid synthesis in dependent upon mineral nutrition ([49 and 50]). The concentration of this element in green leaves is related to chlorophyll content, and therefore indirectly to one of the basic plant physiological process, photosynthesis[51, 52 and 53]. [54] reported that phosphorus has influence on stability of molecule chlorophyll in plants, especially with advent of unfavorable weather conditions in fall. Phosphorus is primarily used to enhance root production. Strong roots are important to the plants because the roots are responsible for the intake of water and nutrients for the plant. A poor root system leads to an unhealthy plant and minimal bean production.

Mineral status

Macro, micro nutrients concentration and its relations as affected by diluted seawater, P sources and the interaction between them are illustrated in Figures number 2, 3, 4 and 5.

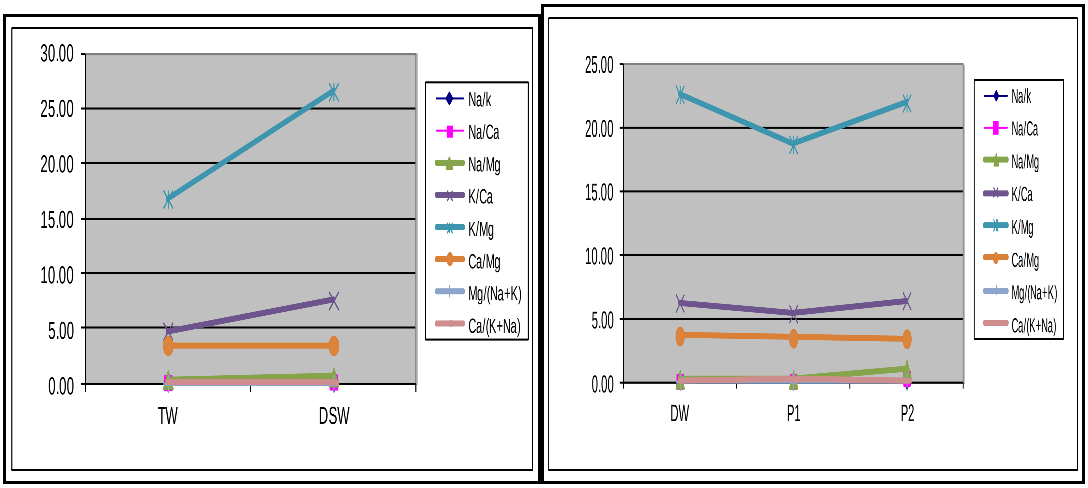
Irrigation castor bean with diluted seawater led to lowering the concentrations of all determined nutrients except Na and Cu, it seemed to be without effect. The depressions were amounted by 3.54, 23.52, 3.67, 35.71 and 38.0% for N, P, K, Mg and Ca, respectively. The depression percentages were 30.77, 30.99 and 17.22 % for Fe, Mn and Zn compared to the irrigation with tap water. The decrease percentage values of Fe and Mn seemed to be similar, this confirm that both of them very closed in their functions in physiological process into plant cells. [26] mentioned that Na and Cl concentrations often exceed those of most macronutrients by one or two orders of magnitude, and by even more in the case of micronutrients. Therefore, high concentrations of Na and Cl in the soil solution may depress nutrient-ion activities and produce extreme ratios of Na, Ca, Na/K, Ca/Mg and Cl/NO_3. As a result, the plant becomes susceptible to osmotic and specific-ion injury as well as to nutritional disorders that may result in reduced yield or quality. [55] found that sodium accumulation in plant was negatively related with nitrogen, phosphorus, copper, zinc, manganese and iron. [56]demonstrated that salinity lowered the uptake of most nutrients in sorghum plants and attributed this phenomenon to the depression in dry mass caused by salt stress more than that resulting from effect of salts on nutrients concentrations. Concentration and uptake of N, P, K, Na and Ca were decreased by salt stress, Na/K ratio increased as salt concentration increased but Ca: (Na+K) showed the opposite response [27].

Spraying of P_1 source encourages the concentration of all elements more than P_2 application except P concentration whereas the reverse was true. The leaf Fe, Zn, Mn and Cu concentrations were also increased with foliar application of both P sources than control. However, the leaf Fe and Mn concentrations were influenced by P_1 than P_2. The opposite was true as for Zn and Cu whereas increased with P_2 than P_1. Phosphorus fertilization increased the mobility of minerals in xylem-phloem of trees[57]. The application of phosphorus fertilizer can result in considerable enhancement of crop growth. However, the excessive amount of phosphorus could cause iron deficiency in the leaves due to the precipitation of ferric phosphate in the apoplast of the root [58] also Zn deficiency [59]. If phosphorus availability is scarce in the soil, it can cause severe P deficiency in plants [20] diminishing aerial plant growth by reducing the leaf photosynthetic activity [60].



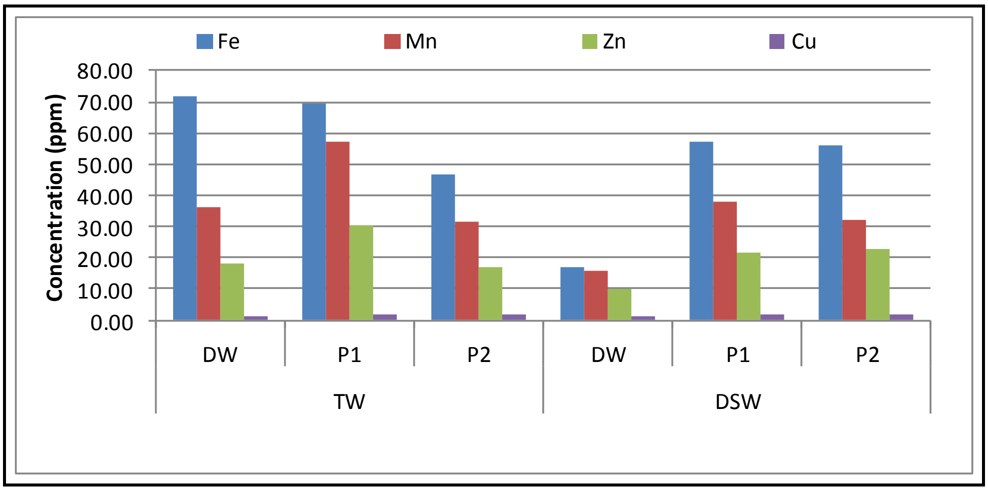
W= Water source, TW=Tape water, DSW=Diluted seawater, P=Phosphorus source, DW=distilled water, P_1 =Phosphoric acid, P_2=Mono potassium phosphate

Fig. (2): Macro-nutrients concentration as affected by DSW and P sources treatment.



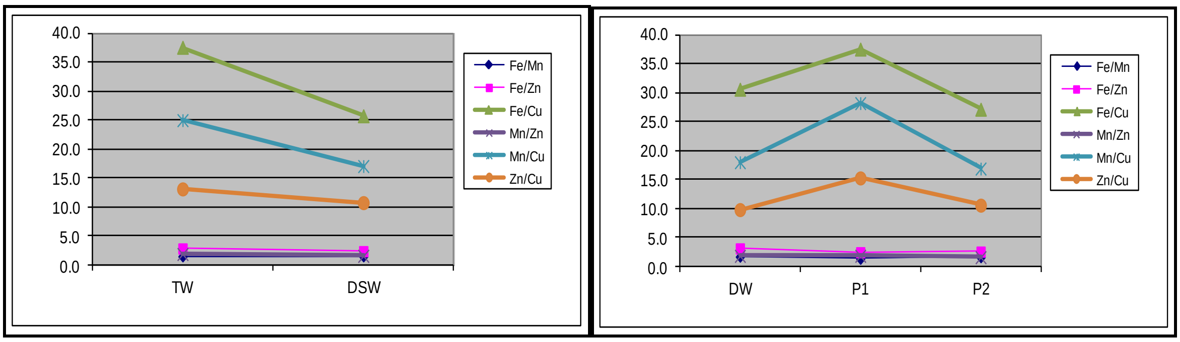
W= Water source, TW=Tape water, DSW=Diluted seawater, P=Phosphorus source, DW=distilled water, P_1 =Phosphoric acid, P_2=Mono potassium phosphate

Fig. (3): Macro-nutrient relations as affected by DSW and P sources treatments.



W= Water source, TW=Tape water, DSW=Diluted seawater, P=Phosphorus source, DW=distilled water, P_1 =Phosphoric acid, P_2=Mono potassium phosphate

Fig. (4): Micro-nutrients concentration as affected by DSW and P sources treatment.



W= Water source, TW=Tape water, DSW=Diluted seawater, P=Phosphorus source, DW=distilled water, P_1 =Phosphoric acid, P_2=Mono potassium phosphate

Fig. (5) Micro-nutrient relations as affected by DSW and P sources treatments

The increase percentage of nutrients concentration compared to control emphasized that, both of P_1 and P_2 increased all elements concentrations measured in leaves of castor bean but P_1 more effective than P_2. Nitrogen, P, K, Ca, Mg, Na, Fe, Mn, Zn and Cu increased by 1.19 and 1.17, 2.79 and 6.49, 1.21 and 1.12, 2.40 and 1.91, 2.29 and 2.29, 1.93 and 8.53, 3.40 and 3.34, 2.40 and 2.04, 2.13 and 2.28 and 1.06 and 1.33 time with application of P_1 and P_2, respectively. The highest effect was in Na and P concentration under P_2 treatment and the lowest in Cu and K concentrations. Foliar levels of mineral nutrients and irrigation particularly important in the adaptation of peach cultivation to different growth condition [61]. Nutrient imbalances can result in salt-stressed plants in various ways. Imbalances may result from the effect of salinity on nutrient availability, competitive uptake, transport or partitioning within the plant or may be caused by physiological inactivation of a given nutrient resulting in an increase in the plant's internal requirement for that essential element [62]. Additions of P increased crop salt-tolerance over a fairly wide range of salinity (10±100 mM NaCl [25]. Salinity decreases the concentration of P in plant tissue [63], but the results of some studies indicate salinity either increased or had no effect on P uptake. [55] stated that more over the successful establishment of tree plantation requires proper monitoring of nutrient status of the stand under saline lands, especially during early establishment. Reliance on visual symptoms of nutrient disorders means that some sever nutrient stress situation exist, as a result of which productivity is already adversely affected [64].

It can be concluded that micronutrients relations take the same trend of growth and opposite trend of macronutrient ratios. K/Mg, K/Ca and Ca/Mg are the highest ratios affected by water and phosphorus sources. The micronutrient ratios decreased in the order of Fe/Cu, Mn/Cu and Zn/Cu as affected by both of salinity and P source.

[35] reported that there were non-significant differences between the two salt species for leaf area, K^+ and Na^+ contents and K^+/Na^+ ratio. A significant increase in osmotic pressure and Na^+ content in sap was observed with increasing Na^+ concentrations whereas in leaf area, K^+ contents of sap and K^+ /Na^+ ratio decreased with increasing Na^+ concentrations.

Conclusion

This study confirms that P is one of the important nutrients that decrease the adverse effect of salinity or increase the alleviating to stress condition, therefore, especial care have paid to it. Also, P problem in soil led to accumulate huge amount of useless P fertilizers, so it can be recommended that the pest source and application method is spraying phosphoric acid especially under salinity stress.

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