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Impact of saline water irrigation plus potassium sulphate application on growth and yield potential of pepper plants

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ABSTRACT

The aim of this research was to investigate the impact of different saline water irrigation levels plus potassium sulphate (K_2SO_4) application on growth and yield potential of pepper plants. The treatments consisted of three saline water irrigation levels (2.5, 4 and 6 dS m^{-1}) and tab water as control. Each treatment was supplemented with different levels of K_2SO_4 at (zero, 2 and 4 gm K_2SO_4 per plant), except for the control. Plant observations were collected to evaluate plant length, fruit number per plant, fruit yield per plant, stem water potential, plant transpiration, photosynthetic rate and dry matter of shoots and roots. Results of this study indicated that K_2SO_4 application played a positive impact on alleviating salinity stress and improving plant growth parameters mainly under saline water irrigation levels of 2.5 and 4 dS m^{-1} plus 2 gm K_2SO_4 compared to saline water irrigation treatments which were not supplemented with K_2SO_4.

Key words: Greenhouse, Photosynthetic rate, Salinity stress, Transpiration, Water potential.

INTRODUCTION

Salinity is one of the major stresses in arid and semi-arid regions, causing adverse effects on physiological, biochemical and molecular levels, limiting crop productivity (Chaitanya *et al.*, 2014; Yadav *et al*. 2011; Tester and Davenport, 2003; Munns 2002). Generally, salinity adversely affects seed germination and plant growth, which may be attributed to non-availability of water and disturbance in nutrients uptake causing deficiency and ion toxicity to plants (Kusvuran 2015). Most of the salt stresses in nature are due to Na^+ salts, particularly NaCl (Demiral 2005). The increase in the concentration of NaCl decreases the ionic concentration of Mg, Ca and K (Han and Li, 2014). Salt stress can disturb growth and photosynthetic processes by causing changes in the accumulation of Na^+, Cl^- and nutrients, and disturbance in water and osmotic potential.

High concentration of salts causes hyper osmotic stress and ion imbalance that produce secondary effects on plants growth. Several scientists summarized that; salinity decreased the root and shoot growth and total dry biomass of the plants (Ebrahimi *et al.*, 2012; Zhu 2001). The reduction of plant growth is actually depends on the severity and levels of salinity (Kausar *et al.*, 2012).

Leaf water potential has often been used as an indicator of plant physiological status under stressed conditions (Katerji *et al.*, 2003). The reduction in leaf water potential induces stomatal closure, which prevents the transport of water vapor and CO_2 and thus photosynthesis and transpiration decrease. Thus, leaf water potential can be used to develop appropriate irrigation management to improve crop production in saline conditions. However, determining the specific stomatal behavior for each plant type is required to understand the relationship between leaf water potential and plant photosynthesis and transpiration.

Photosynthesis inhibition has been suggested to be responsible for growth reduction of salt-stressed plants. Several studies have shown that the photosynthetic rate of pepper is reduced by salinity stress (Melo *et al.*, 2017; Serrano *et al.*, 2017). This reduction in photosynthetic rate could be ascribed to Na and Cl accumulation in the leaves under salt stress (toxic effect), and also to the decrease in stomata conductance due to the osmotic stress (Serrano *et al.*, 2017).

Potassium is a macronutrient element which is required in higher concentration for the growth of plants. It plays an important role in the activation of enzyme, stomata opening and closing, improves the efficiency of photosynthesis and use of water (Ross 2001). Application of potassium to plant under saline conditions enhances the growth of plants and inhibited the detrimental effect of salinity stress (Safaa *et al.*, 2013). Furthermore, it helps to maintain the osmotic adjustment more than Na^+ and Cl^- in the plant under saline conditions (Kausar *et al.*, 2014).

Arid and semi-arid regions of Palestine are more vulnerable to salinity risk, which is found to be a serious

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threat to agriculture affecting both growth as well as the yield. Reclamation of salt affected lands by the common practices such as leaching and drainage are expensive and impracticable; particularly in the Palestinian territories which faces water crises and scarcity. Taking into account the importance of potassium nutrient under salinity stress conditions, the present study was conducted to investigate the impact of different doses of potassium sulphate application in alleviating the detrimental effect of water salinity on the growth performance and yield production of pepper plants under different saline water irrigation levels.

MATERIALS AND METHODS

A field study was conducted at the experimental farm of Palestine Technical University Kadoorie, Tulkarm, West Bank, Palestine. Tulkarm area is recognized by its moderate climate, with average yearly precipitation varies between 530-630 mm.

The aim of this research was to investigate the impact of potassium sulphate (K_2SO_4) in alleviating salinity stress of pepper plants irrigated with different saline water levels under greenhouse condition. Pepper seedlings were cultivated in plastic pots filled with loamy soil from the first of March 2017 until the end of August 2017. The physiochemical properties of the soil are given in (Table 1). The experiment was designed by using complete randomized design with five replicate per each treatment. Compound fertilizer N-P-K was applied during the growing period based on the nutrient requirements of the crop as given in (Table 2). Data were analyzed using excel stat program. Three saline irrigation water treatments (2.5, 4 and 6 dS m^{-1}) were applied after three weeks of transplanting. K_2SO_4 was applied with each saline water treatment, at the soil surface before each irrigation event at a rate of (Zero, 2 and 4 gm K_2SO_4 per plant). Tab water was applied without K_2SO_4 application as control. Saline irrigation water was prepared using tab water mixed with sodium chloride (NaCl).

Table 1: Physiochemical properties of the soil at initial condition.

Parameters	Unit	Values
Sand	(%)	45
Silt	(%)	30
Clay	(%)	25
Texture		**Loamy soil**
$CaCO_3$	(%)	20.33
Ca	(meq/l)	3.26
Mg	(meq/l)	7.24
Na	(meq/l)	4.25
P_2O_5	(ppm)	12.46
NO_3	(ppm)	4.66
ECe	(dS/m)	0.13
pH		7.46

Plant length, fruit number per plant, fruit weight per plant, total yield, dry weight of shoots and roots were measured during the growing period. Midday stem water potential was measured. Two fully expanded leaves per plant located on branches near the main trunk were selected and covered with aluminum foil for about two hours between 12:00 and 14:00 before excision. The selected leaves were collected and water potential was measured using a pressure bomb chamber (SKPM 1400). A portable photosynthesis unit (LCi Photosynthesis System) was used to monitor leaf net photosynthetic and transpiration rates; using mature leaves that fully exposed to light. The measurements were taken in the morning between 9:00 and 11:00, when midday heat stress was absent.

RESULTS AND DISCUSSION

Plant length: The results of this study indicated that the plant irrigated with tab water had the highest plant length compared to that irrigated with different saline irrigation levels as shown in (Fig 1). Also, plant length was reduced under different saline irrigation levels and the major plant inhibition observed under 6 dS m^{-1}. Similar investigations were also reported by a number of investigators (Ali *et al.*, 1999; Rahil *et al.*, 2013). Moreover, the plant irrigated with 2.5, 4 and 6 dS m^{-1} plus 2 gm K_2SO_4 recorded higher plant length than that irrigated with the same saline water level without K_2SO_4 application. Abida and Munazza (2014) found that, application of potassium sulphate significantly enhanced shoot length of two wheat cultivars under saline condition.

Yield production: Results of this study indicated that the plant irrigated with tab water produced higher yield production compared to saline water irrigation treatments as shown in (Fig 2). The results also showed that the treatments irrigated with saline water 2.5 dS m^{-1} plus 2 gm K_2SO_4 produced a total yield close to the treatment irrigated with tab water. Moreover, all saline irrigation treatments supplemented with 2 gm K_2SO_4 produced higher production than that supplemented with zero and 4 gm K_2SO_4. It is obvious from the results of this study that, K_2SO_4 application under saline irrigation played a positive impact on reducing salinity stress and increasing the yield production of pepper

Table 2: Nutrient requirement of pepper plants cultivated inside greenhouse.

Growth stages	Nutrient requirement (gm^{-1} du^{-1} day^{-1})		
	N	P_2O_5	K_2O
Transplanting - first fruit set	50-100	50-100	50-100
First fruit set - harvesting	200-480	150-400	100-250
Harvesting – end of growing season	250-600	250-500	200-250

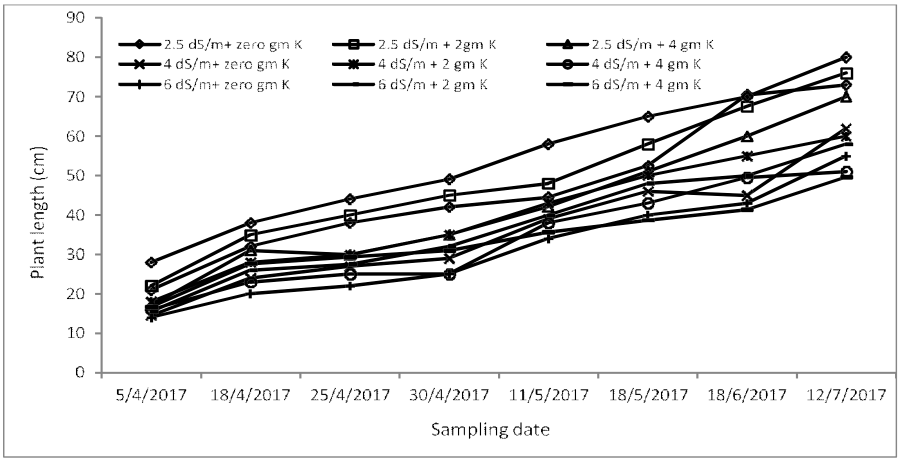

Fig 1: Plants length under different levels of saline irrigation plus K_2SO_4 application.

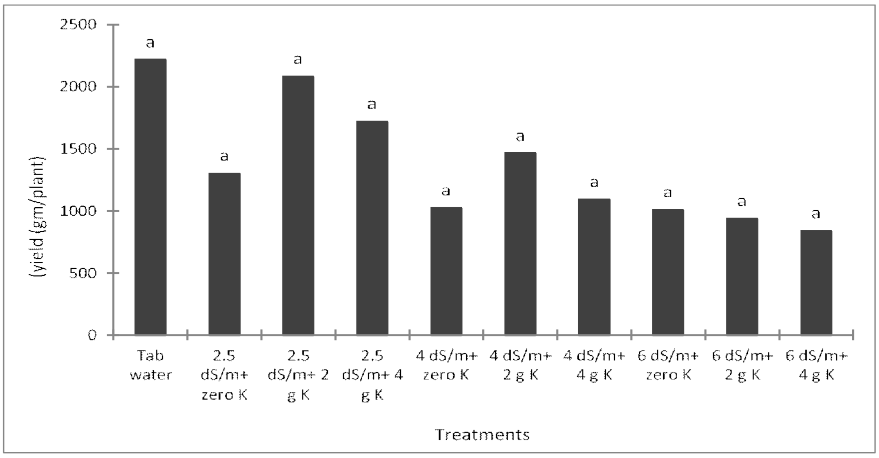

Fig 2: Fruit yield of pepper plants under different saline irrigation levels plus K_2SO_4 application.

plants mainly under saline water level up to 4 dS m^{-1}. Also, the yield production of treatments irrigated with saline water level of 6 dS m^{-1} indicated the lowest yield production compared to the other treatments. Pardossi *et al.* (1999) found that the increased in salinity generally reduced the yield production of vegetables, but it improved their quality, as observed in plants grown both in soil and soilless culture media.

Fruit number per plants: Results of this study indicated that the application of K_2SO_4 played a positive impact in increasing the fruit number of pepper plant mainly in saline irrigation treatment of 2.5 dS m^{-1} plus 2 gm K_2SO_4 as shown in (Fig 3). Also 2 gm of K_2SO_4 inhibited the salinity stress mainly under low saline irrigation levels of 2.5 and 4 dS m^{-1} compared to saline water level of 6 dS m^{-1}. The statistical analysis showed that there was no significant difference in fruit number between control and plant irrigated with saline water levels of 2.5 and 4 dS m^{-1} at all levels of K_2SO_4 application; while there was a significant difference between control and treatments irrigated with saline water level of 6 dS m^{-1}.

Plant dry matter: The results of this study indicated that the highest dry weight of shoots and roots was observed for the treatments irrigated with tab water as shown in (Fig 4). Khorshid *et al.* (2018) found that the effect of salinity on shoot dry weight was higher than root dry weight. Results also showed that all treatments irrigated with saline water plus 2 gm K_2SO_4 per plant indicated higher dry weight for both shoots and roots, than that supplemented with zero and 4 gm K_2SO_4. This can be explained by the positive impact of K_2SO_4 application in reducing salinity stress and in improving vegetative growth of the plant. Moreover, the results indicated that K_2SO_4 application under high salinity level (6 dS m^{-1}) played a quit less impact in reducing salinity stress mainly under higher dose of K_2SO_4 (4 gm per plant). Hamayun *et al.* (2014) found that, the application of potassium nitrate enhanced shoot length, fresh and dry shoot weight, fresh and dry root weight and alleviated the detrimental effect of NaCl on soybean growth parameters. Statistical analysis indicated that there was a significant difference in shoot dry weight between control and plant irrigated with all saline water levels. Statistical analysis also indicated that there was no significant difference in root dry weight between control and treatment irrigated with saline water level of 2.5 dS m-1, whereas there was a significant difference in root dry weight between control and treatments irrigated with saline water level of 4 and 6 dS m-1 at all level of K_2SO_4 application.

Stem water potential: Results presented in Fig 5 showed that increased water salinity level decreased the stem water potential of pepper plant. The values detected showed an inverse relationship between salt stress and osmotic potential for the sap of pepper leaves. The results registered by many researches in this field corresponded to the results we obtained (Stoeva and Kaymakanova, 2008; Gama *et al.*, 2009). Azuma *et al.* (2010) observed that, the total potential in the leaves of pepper plant at 21 days, were equal to -0.7, -1.05 and -1.29 MPa under saline irrigation water of zero, 5 and 10 dS m-1 of NaCl. Statistical analysis indicated that

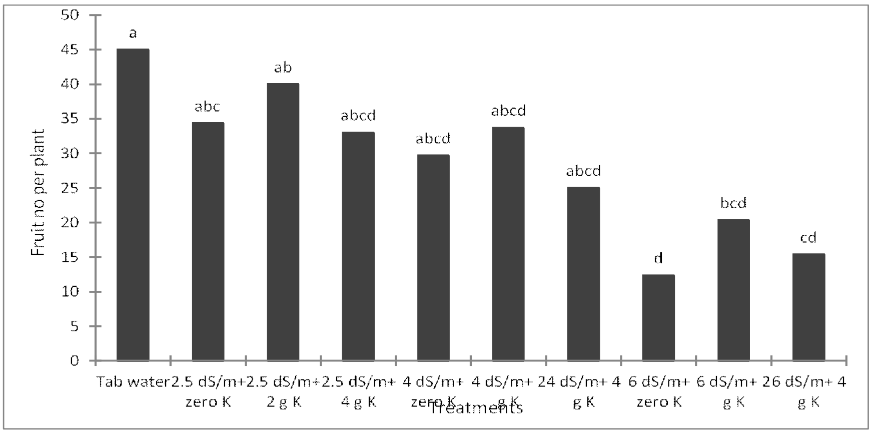

Fig 3: Fruit number of pepper plants under different saline irrigation levels plus K_2SO_4 application.

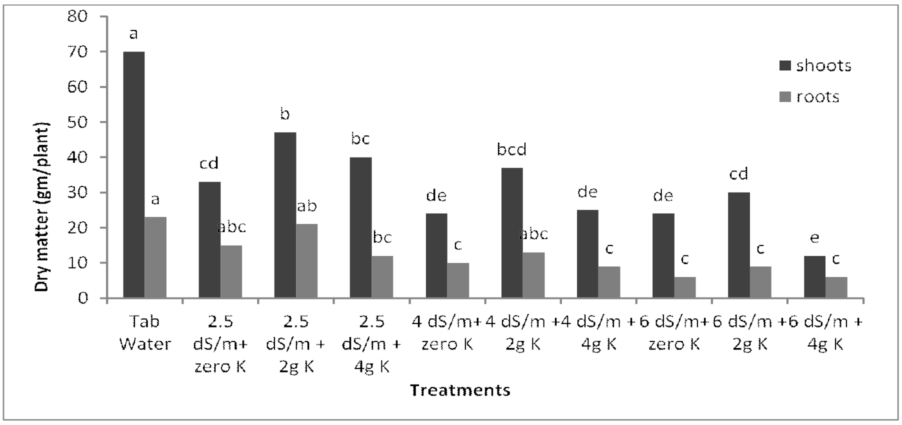

Fig 4: Shoot and root dry weight of pepper plants under different saline irrigation level plus K_2SO_4 application.

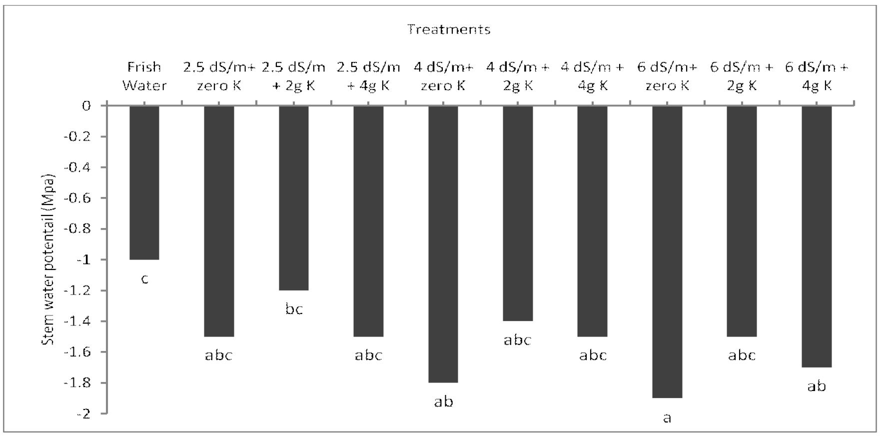

Fig 5: Stem water potential of pepper plants under different saline irrigation levels plus K_2SO_4 application.

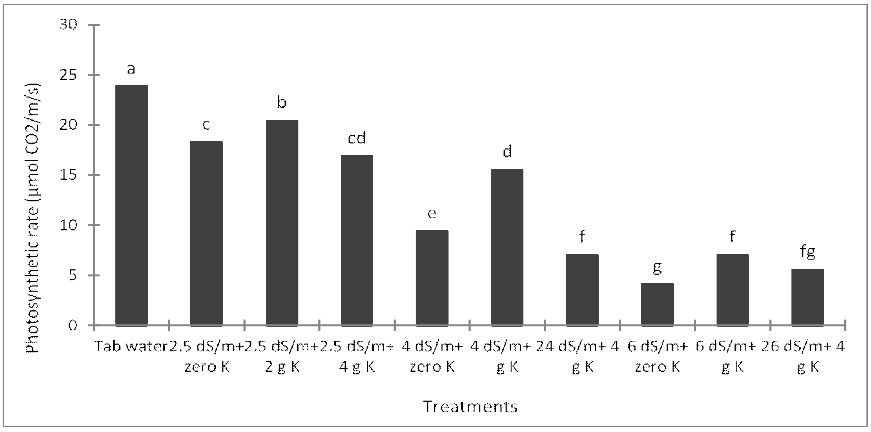

Fig 6: Photosynthetic rate of pepper plant under different saline irrigation level plus K_2SO_4 application.

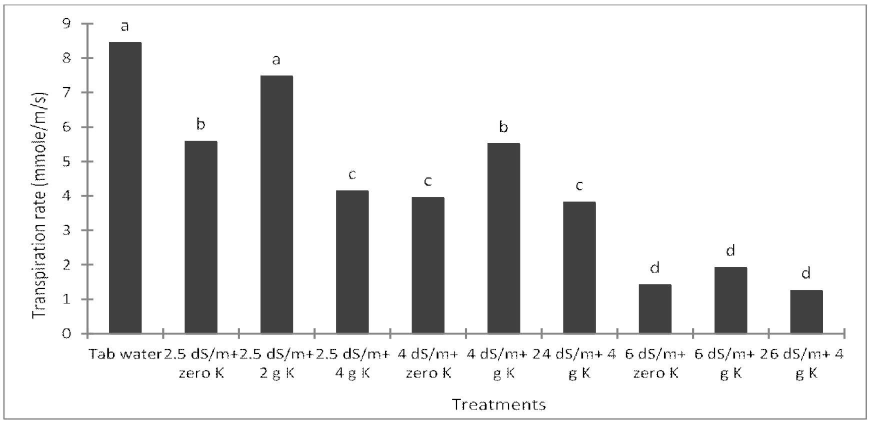

Fig 7: Transpiration rate of pepper plants under different saline irrigation levels plus K_2SO_4 application.

there was no significant difference in stem water potential between control and treatments irrigated with saline water levels of 2.5 and 4 dS m^{-1} mainly at 2 and 4 gm of K_2SO_4 while there was a significant difference between control and treatments irrigated with saline water levels of 6 dS m^{-1} at zero and 4 gm of K_2SO_4.

Photosynthetic parameters: Results of this study indicated that the photosynthetic rate and transpiration of pepper plant were higher for treatments irrigated with fresh water compared with saline irrigation treatments as presented in (Fig 6 and 7); respectively. This may be explained by the reduction of stomatal conductance as a result of salinity stress. Serrano *et al*. (2017) confirmed that salt stress markedly reduced photosynthetic rate and transpiration in pepper plant. Melo *et al.* (2017) observed that the reduction in transpiration under salinity stress has been attributed to stomatal closure as the first defence mechanism of the plants under osmotic stress. Furthermore, the photosynthetic rate of plant irrigated with saline water plus potassium application was higher than that under saline irrigation without potassium application. This approved that potassium application played a positive impact in improving plant photosynthesis by maintaining the osmotic adjustment of plant under salinity stress. In a field investigation, Akram *et al.* (2009) observed an improvement in growth of sunflower due to the foliar spray of K_2SO_4 and KNO_3 at 1.25% under saline concentration of 150 mM NaCl. Statistical analysis indicated that there was a significant difference in photosynthetic rate and transpiration rate between control and treatments irrigated with all levels of saline irrigation water.

CONCLUSION

The results of this study indicated that, saline water irrigation supplemented with K_2SO_4 enhanced the total yield production, plant length, root and shoot dry weight as compared to saline irrigation treatments without K_2SO_4 application, and its application played a positive impact and alleviated the detrimental effect of salinity stress. Also, saline irrigation supplemented with 2 gm K_2SO_4 improved plant growth parameters compared to that supplemented with 4 gm K_2SO_4 mainly at salinity levels of 2 and 4 dS m^{-1}. K_2SO_4 application had a beneficial effect on improving the stem water potential, photosynthetic and transpiration rates of pepper plants mainly under low saline water level.

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