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Effect of Salinity Stress on Anise (*Pimpinella anisum* L.) Seedling Characteristics under Hydroponic Conditions

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Abstract: This Crop yield depends upon various soil and environmental factors. Productivity can adversely be affected due to the fluctuations in any of these factors. Anise is a vital medicinal aromatic plant; provides valuable nutrition to human body. Present study was conducted under hydroponic conditions to evaluate the effect of different salinity levels (control, 3, 6, 9, 12 dS m^{-1}) on Anise growth and physiochemical attributes. Statistically analyzed that plant samples showed that there was significant reduction in root length (66%) shoot length (44%), shoot fresh weight (47%), root fresh (54%), shoot dry (68%), and root dry (79%) weights with increasing level of salinity. While, physiological parameters like Membrane Stability Index (28%), chlorophyll a (66%), chlorophyll b (55%) and carotenoids (42%) reduction was recorded as compare to the control treatment. While, there was significant increase in Na^+ concentration in shoots (60%), roots (87%) and K^+ concentration in shoots (44%) and root (66%) decrease with the increase in salinity. It was concluded that Anise is a sensitive crop against salinity at seedling growth stage. However, by increasing the salinity levels the growth and production of Anise significantly decreased but at lower salinity (1-3 dS m^{-1}), crop can survive and gave a reasonable yield.

Keywords: Anise, salinity stress, tolerance, hydroponic.

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1. Introduction

Anise *(Pimpinella anisum* L.*)*, is belongs to family Apiaceous is an annual vital spice and medicinal plant, and is considered as source of raw material for cosmetic, perfumery, pharmaceutics and food industries (Omidbaigi et al., 2003; Rocha and Fernandes, 2016; Ross, 2001; Samojlik et al., 2012; Tepe and Tepe, 2015). In recent years, it has gained more attraction and value due to antifungal, antimicrobial, insecticidal and antioxidative effect of the Anise (Tirapelli et al., 2007). The worldwide production of Anise essential oil is about 40 to 50 tons per annum. Anise seed also contains a significant quantity of γ-himachalene, anisaldehyde, cis-anethole and estragol (Ullah et al., 2014). Anise fruits (2-6%) and roots (0.05%) contains essential oil (Koul et al., 2008). Largest producers of anise oil including France, Poland, Russia, Spain and USA (Malhotra, 2012). Ground and dry Anise seed as whole and in its powder form is readily available in the spice market year around.

In aromatic and medicinal plants, growth, yield and essential oil production are subjected by numerous environmental factors, e.g. salinity stress (Aghaei and Komatsu, 2013; Akhtar et al., 2017; Penella et al., 2016). Anise is an essential medicinal spice (Lu et al., 2012; Tepe and Tepe, 2015) and its production is adversely affected by the salinity stress. The Anise production is not only depends upon the tissue sources but also may be incorporated with the salt-induced stress factors (Sangwan et al., 2001).

Salinity is among the main drastic threats for plant in the countries of semi-arid and arid regions, including Pakistan, which adversely affect the plants yield (Schleiff, 2008). Globally over 800 million ha land is affected by sodicity (434 million ha) or salt or salinity (397 million ha) (Bakht et al., 2011). Salt affected area in Pakistan is 10.01 million hectares and due to salinity crop yield losses are feared to reach at Rs. 880 Million (Behzad et al., 2014). The ground water quality of Bahawalpur and its adjacent areas is declining rapidly. A recent survey showed that 52.78% water of Bahawalpur is unfit while 34.37% water considered as fit for irrigation and remaining 12.85% is marginal fit waters for irrigation purposes as compared to standard values (Riaz et al., 2018). Among all these factors, soil salinity is a main limiting factor for plant growth, development and yields (Yihdego, 2017).

Salinity stress is a multifaceted mechanism that affects nearly every biochemical and physiological pathways in plants (Kibria et al., 2017; Nam et al., 2017; Negrão et al., 2017; Shen et al., 2018). Exchangeable salts cause toxic effects on growth of plant in salt affected soils are produced due to (a) water stress results due to low osmotic potential of soil (b) nutritional imbalance due to higher accumulation of toxic ions (c) specific ion effect (d) and any amalgamation of above mentioned factors (Ashraf and Harris, 2004). Osmotic potential of soil decreases due to high concentration of cationic metals and salts in soil solution which results in water stress and it create difficulty for plant in absorbing the water essential for normal growth. Under these circumstances leaf water potential also decreased and ultimately crop production decline (Ali and Yun et al., 2017; Riaz et al., 2018). Under salt stress germination is the most sensitive stage, salinity hinders seed germination as well as reduces the number of germinated seeds (Hannachi and Van Labeke, 2018; Houle et al., 2001; Mauromicale and Licandro, 2002). High degree of mortality of seeds is the principal cause of poor germination ultimately poor plant population results in low yield under high saline conditions (Pennings et al., 2005). Reduction in K^+ uptake is caused by high Na^+ ion concentration in soil solution and also caused chlorosis and necrosis on plant leaves (Gopal and Dube, 2003; Kere et al., 2016). Generally, reduction in leaf osmotic potential reduces the plants capability to tolerate salt stress either by accumulation of inorganic ions or by organic solutes synthesis (Hannachi and Van Labeke, 2018; Hasegawa et al., 2000).

Realizing the importance of aromatic plants and the severity of salt stress and high electrical conductivity of ground water in these areas, an attempt have been made to increase the understanding about the salinity effects on anise seedlings, physiological and ionic uptakes in the root and shoot.

2. Materials and Methodology

2.1. Experimental Site and Conditions

The experiment was conducted at rain-protected glass house of Department of Soil Science, University College of Agriculture and Environmental Sciences, The Islamia University of Bahawalpur, Pakistan. Treatments were arrangement in complete randomized design (CRD) conducted in trplicate.

The experiment was conducted during 2016. Seeds of Anise were collected from Department of Oilseed, Regional Agriculture Research Institute (RARI), Bahawalpur, Pakistan. The sterilized seeds of Anise was selected and sown in sand culture for obtaining uniform seedlings. After 25 days of sowing at two leaves stage, seedlings were transplanted into thermo pole sheet floating on half strength Hoagland solution culture in 15L iron tubs.

Table 1: Effect of salinity stress on growth parameters of Anise

Treatments	RL (cm)	SL (cm)	RFW (g)	SFW (g)	RDW (g)	SDW (g)
Control	42.33 a	50.24 a	5.20 a	9.32 a	0.29 a	1.10 a
T_1	38.10 a	45.5 b	4.31 b	8.72 a	0.25 b	0.96 ab
T_2	32.87 b	38.85 c	3.94 b	7.73 b	0.19 c	0.85 b
T_3	27.82 b	31.98 d	3.51 c	6.95 c	0.15 d	0.68 c
T_4	14.42 c	27.42 e	2.43 d	4.93 d	0.63 e	0.36 d
LSD	4.073	3.012	0.421	0.73	0.041	0.150

Columns sharing the same letter are non-significant at $p < 5$. Control :< 0.1 dS m^{-1} EC, T_1:3 dS m^{-1} EC, T_2:6 dS m^{-1} EC, T_3:9 dS m^{-1} EC, T_4:12 dS m^{-1} EC, RL: root length, SL: shoot length, RFW: root fresh weight, SFW: shoot fresh weight, RDW: root dry weight, SDW: shoot dry weight.

Table 2. Effect of salinity stress on physiological and biochemical attributes of Anise

Treatment	MSI	Chlorophyll a ($\mu g\ g^{-1}$)	Chlorophyll b ($\mu g\ g^{-1}$)	Carotenoids ($\mu g\ g^{-1}$)
Control	44.14 a	0.52 a	2.4 a	123.3 a
T_1	40.33 b	0.49 a	2.16 ab	110.0 ab
T_2	37.95 bc	0.44 b	1.82 b	100.3 bc
T_3	35.22 c	0.38 c	1.57 bc	87.0 cd
T_4	32.22 d	0.29 d	1.11 c	72.0 d
LSD	2.98	0.046	0.60	16.488

Columns sharing the same letter are non-significant at p < 5. Control :< 0.1 dS m^{-1} EC, T_1:3 dS m^{-1} EC, T_2:6 dS m^{-1} EC, T_3:9 dS m^{-1} EC, T_4:12 dS m^{-1} EC. MSI: membrane stability index.

Salinity was created by using different calculated doses of NaCl according to the treatments. Daily pH (7.0) of the medium was maintained. Aeration was given by bubbling air through aeration pump. The solution was changed after every seven days of period. Plants were exposed to Control = < 0.1 dS m^{-1} EC; T_1 = 3 dS m^{-1} EC; T_2 = 6 dS m^{-1} EC; T_3 = 9 dS m^{-1} EC;, T_4 = 12 dS m^{-1} EC.

2.2. Plant growth, physical and biochemical characteristics

The seedlings were collected after fifty days and subsequently thoroughly washed with double deionized water. To determine fresh and dry weights of plants and plant parts, 10 plants were randomly selected from each replication and well washed. These selected plants were separated into shoot and root for the determination their fresh and dry weights. After calculation of fresh weight, plant parts were oven dried at 65 °C till constant weight and dry weight was calculated. The remaining seedlings were grounded and further used for physical biochemical analysis including chlorophyll a and b, carotenoids and membrane stability index. Dried material (0.5 g) was digested in concentrated H_2SO_4 (2 ml) subsequently Ca^+, K^+ and Na^+ were determined with a flame photometer (Jenway, PFP7, Essex, UK).

2.3. Quality Control

All the chemicals used in this study were NIST traceable. Considering sensitivity and repeatability standard solutions were used in sample sequence after every 8 samples. The analytical precision and accuracy were accepted only when RSD values were below 5% for the REEs, according to the results of duplicate measurements of all samples.

2.4. Statistical Analysis

Collected data sets were statistically analyzed using analysis of variance (ANOA). Treatment means were compared by the least significant difference (LSD, 5%) (Steel et al., 1997). All data analyses were performed by using Statistix 8.0 (Analytical Software, 2003).

3. Results

3.1. Growth attributes

The data presented shows the impact of salinity stress on attributes of Anise (Table 1). The results showed that root and shoot length was significantly decreased as salinity increased in growth medium. Maximum lengths of both root and shoot of anise seedlings were recorded in control treatment, however gradually decreased with increasing level of salinity. Minimum shoot length (27.42 cm) and root length (14.42 cm) were observed at highest salinity level i.e. T_4 (12 dS m^{-1}). Root length under medium salinity levels (T_2:6 dS m^{-1} EC, T_3:9 dS m^{-1} EC) remained statistically similar with each other, but greater than the root length produced under T_4.

Table 3. Effect of salinity stress on ionic balance in shoots of Anise

Treatments	K^+ (ppm)	Ca^+ (ppm)	Na^+ (ppm)	Na^+/K^+	Na^+/Ca^{2+}
Control	886.5 a	232.7 a	125.8d	0.14 e	0.54 d
T_1	779.9 b	197.9 b	519.4 c	0.66 d	2.59 d
T_2	698.4c	156.2 c	946.1b	1.35 c	6.10 c
T_3	600.76 d	104.21 d	1036.7 ab	1.72 b	9.96 b
T_4	500.3e	54.5 e	1148.5 a	2.30 a	3.25 a
LSD	98	29	112	0.28	2.87

Columns sharing the same letter are non-significant at p < 5. Control :< 0.1 dS m^{-1} EC, T_1:3 dS m^{-1} EC, T_2:6 dS m^{-1} EC, T_3:9 dS m^{-1} EC, T_4:12 dS m^{-1} EC.

Table 4. Effect of salinity stress on ionic balance in roots of Anise

Treatments	K^+ (ppm)	Ca^+ (ppm)	Na^+ (ppm)	Na^+/K^+	Na^+/Ca^{2+}
Control	982.1a	192.2a	132.6 e	0.13 e	0.56 d
T_1	752.2 b	145.2 b	418.7 d	0.55 d	2.11 cd
T_2	628.6 c	116.0c	663.4 c	1.05 c	4.26 c
T_3	518.2 d	77.2 d	856.0b	1.65 b	8.22 b
T_4	437.1e	32.8e	1012.4a	2.33 a	18.90 a
LSD	104	24	103	0.25	4.33

Columns sharing the same letter are non-significant at p < 5. Control :< 0.1 dS m^{-1} EC, T_1:3 dS m^{-1} EC, T_2:6 dS m^{-1} EC, T_3:9 dS m^{-1} EC, T_4:12 dS m^{-1} EC,

Correspondingly, root fresh weights (RFW), root dry weights (RDW), results exhibited that their maximum values were produced under control treatment and showed decreasing trend with increasing level of salinity.

3.2. Physiological and Biochemical Parameters

The results regarding membrane stability index (MSI), carotenoid and chlorophyll (a and b) contents showed in Table 2. Our findings depicted that salinity stress significantly ($p \leq 0.05$) decreased the physiological parameters with increasing levels of salinity. Maximum decline in MSI (32.22), chlorophyll-a (0.29 µg g^{-1}), chlorophyll-b (1.11 µg g^{-1}) and carotenoid contents (72 µg g^{-1}) was observed at the treatment T_4 (12 dS m^{-1}) with respect to control and all other treatments. The declining trend was as follows: Control > T_1 > T_2 > T_3 >T_4.

3.3. Ionic Balance

The behavior of K^+ uptake in shoot and root of Anise are presented in Tables 3, 4. The data showed that at highest level (T_4:12 dS m^{-1}) of salinity there was minimum uptake of K^+ in both shoot and root. It was also observed that maximum K^+ was accumulated in shoot when compared to root at various treatment levels.

The increasing level of salinity the potassium and calcium concentration was significantly decreased in shoot, while sodium concentration, Na^+/K^+ and Na^+/Ca^{2+} was significantly increase with salinity (Table 3). The results highlighted that increasing level of salinity the potassium and calcium concentration was significantly decreased in root, while sodium concentration, Na^+/K^+ and Na^+/Ca^{2+} were significantly increase with salinity (Table 4).

4. Discussion

In present study the screening method is used to evaluate the tolerance of Anise against salinity levels at seedling and vegetative growth stage. The growth attributes i.e. plant height, fresh and dry weights (shoot and root), significantly ($p < 0.05$) decreased under salinity stress and this inhibitory effect was more on seedling and vegetative growth stage at 12 dS m^{-1} EC.. This decreased was due to the high salts concentration which may directly affect the morphological and physiological characteristics and hence the vegetative growth declined (Talat et al. 2013; Shabani et al., 2012).

Under salinity stress excessive uptake of toxic ions like Cl^- and Na^+, and inhibition of cell division lead to restricted plant growth. These ions disturb the osmotic potential of vacuoles and cause cytoplasmic dehydration. In addition, high salt concentration in root zone decreases water potential leading to low availability of water and on-set of osmotic stress (Chartzoulakis et al., 2002). Due to this salt-induced osmotic stress, cell expansion and growth is inhibited resulting in poor root and shoot development. The inhibition in growth is also attributed due to the disturbance in hormonal balance (Huez-Lopez et al., 2011; Khan et al., 2003).

The results showed that plant physiological attributes, i.e. membrane stability index carotenoids, chlorophyll (a and b) contents were negatively affected by the salinity stress. The reduction in these parameters is may be due to the degradation of chloroplasts and other photosynthetic pigments (Moradi and Ismail, 2007; Kafi, 2009). Salinity effects photosynthesis by reducing efficiency of different plant mechanisms including efficient water use (Sultana et al., 1999). Chlorophyll pigments are the principal components of photosynthesis. Under salt stress, the concentration of chlorophyll (a and b) and total chlorophyll significantly decreases. Reduction in these, results in inhibition of photosynthetic activity (Xinwen et al., 2008; Redondo-Gómez et al., 2011).

The chemical analysis of leaves and root revealed that under salinity stress, plants showed higher contents of toxic ions and low level of different essential nutrients. The results are parallel with the study of Khan et al. (2009) as they showed that under salinity stress, there was high concentration of Cl^- and Na^+ ions and decrease in the concentration of Ca^+, K^+ and Mg^{+2} was observed. Under salinity stress, due to higher concentration of salts plants tend to uptake excessive toxic ions which interferes the biochemistry of plant cells (Byrt et al., 2018; Munns and Tester, 2008).

The major toxic ions are Na^+ and Cl^- that are taken up by plant up to toxic level (Munns, 2005; Munns and Gilliham, 2015; Bhuiyan et al., 2017; Tetsuya and Sergey, 2018). Higher concentrations of these ions in soil result in the reduced uptake of water leading to osmotic stress (Mayak et al., 2004). Zhu (2007) also reported that due to similar ionic nature of Na^+ competes with K^+ and plant uptake excessive Na^+ instead of K^+, resulting in K^+ deficiency and toxicity of Na^+ in all plant parts. Decrease in K^+ uptake and increase in Na^+ uptake result in enhanced $Na^+\backslash K^+$ ratio. This $Na^+\backslash K^+$ ratio decrease the soluble sugars resulting in disruption of solute biochemistry in cells (Ibrahim et al., 2006). The Na^+ in high concentration inhibits the activity of many cellular enzymes. This inhibition is also dependent on how much potassium is present as higher ratio of Na^+/K^+ is the most damaging (Blumwald et al., 2000; Rahman et al., 2016).

5. Conclusion

It was concluded from present study that salinity stress adversely affected the development and growth by affecting height of plant, shoot and root dry and fresh weights, membrane stability index, chlorophyll 'a' and 'b' and carotenoid contents of Anise mainly due to higher concentration of toxic ions (Na^+) and deficiency of essential elements especially K^+ and Ca^{2+} that are mainly involved in osmoregulation. In order to reduce negative impact of salinity on agricultural productivity it is important to reduce its impact on germination and seedling growth. This study indicates that increasing in salinity level decreases the Anise production at seedling growth stage.

List of abbreviations: RDW, root dry weight; RL, root length; RFW, root fresh weight; SDW, shoot dry weight; SL, shoot length; SFW, shoot fresh weight.

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References

Aghaei, K., and S. Komatsu. 2013. Crop and medicinal plants proteomics in response to salt stress. Front. Plant Sci. 4:8.

Akhtar, M.F.U.Z., A. Hussain, F. Ahmad, M.A. Kharal, I. Khalid, M. Latif and M.U. Jamshaid. 2017. Screening of pepper (*Capsicum annuum* L.) genotypes against salinity stress. J. Environ. Agric. Sci. 11: 51-58.

Ali, A., D.-J. Yun. 2017. Salt stress tolerance; what do we learn from halophytes? J. Plant Biol. 60(5): 431-439.

Ashraf, M. and P. J. C. Harris. 2004. Potential biochemical indicators of salinity tolerance in plants. Plant Sci. 166: 3-16.

Bakht, J., M. Shafi, Y. Jamal. and H. Sher. 2011. Response of maize (*Zea mays* L.) to seed priming with NaCl and salinity stress. Span. J. Agric. Res. 9(1): 252-261.

Bhuiyan, M.S.I., A. Raman, D. Hodgkins, D. Mitchell and H.I. Nicol. 2017. Influence of high levels of Na^+ and $Cl^−$ on ion concentration, growth, and photosynthetic performance of three salt-tolerant plants. Flora. 228: 1-9.

Blumwald, E., G.S. Aharon, and M.P. Apse. 2000. Sodium transport in plant cells. Biochim. Biophys. Acta. 1465: 140-151.

Byrt, C.S., R. Munns, R.A. Burton, M. Gilliham and S. Wege. 2018. Root cell wall solutions for crop plants in saline soils. Plant Sci. 269: 47-55.

Chartzoulakis, K., M. Loupassaki, M. Bertaki and I. Androulakis. 2002. Effects of NaCl salinity on growth, ion content and CO_2 assimilation rate of six olive cultivars. Hortic. Sci. 96: 235-247.

Gopal, R. and B.K. Dube. 2003. Influence of variable potassium on barley metabolism. Ann. Agric. Res. 24: 73-77.

Greenwood, D.J. and D.A. Stone. 1998. Prediction and measurement of the decline in the critical-K, the maximum-K and total cation plant concentrations during growth of field vegetable crops. Ann. Bot. 82: 871-881.

Hannachi, S. and M.-C. Van Labeke. 2018. Salt stress affects germination, seedling growth and physiological responses differentially in eggplant cultivars (*Solanum melongena* L.). Sci. Hort. 228: 56-65.

Hasegawa, P.M., R.A. Bressan, J. K. Zhu, and H.J. Bohnert. 2000. Plant cellular and molecular response to high salinity. Ann. Rev. Plant Physiol. Plant Mol. Biol. 51: 463-499.

Houle, G., L. Morcelo, C.E. Reynolds and J. Siegel. 2001. The effect of salinity on different developmental stages of an endemic annual plant, *Aster laurentianus* (Asteraceae). Am. J. Bot. 88: 62-67.

Huez-López, M. A., A. L. Ulery, Z. Samani, G. Picchioni and R.P. Flynn. 2011. Response of chile pepper (*Capsicum annuum* L.) to salt stress and organic and inorganic nitrogen sources: I. growth and yield. Trop. Subtrop. Agroecosyst. 14: 137-147.

Ibrahim, M., A. A. Khan, S. K. Tiwari, M.A. Habeeb, M.N. Khaja and C.M. Habibullah. 2006. Antimicrobial activity of *Sapindus mukorossi* and *Rheum emodi* extracts against *H. pylori*: In vitro and in vivo studies. World J. Gastroenterol. 12: 7136-7142.

Kafi, M., 2009. The effects of salinity and light on photosynthesis, respiration and chlorophyll fluorescence in salt-tolerant and salt-sensitive wheat (*Triticum aestivum* L.) cultivars. J. Agric. Sci. Technol. 11: 535-547

Kere, G.M., Q. Guo and J. Chen. 2016. Growth and physiological responses of cucumber (*Cucumis sativus* L.) to sodium chloride stress under solid hydroponics. J. Environ. Agric. Sci. 6: 47-57.

Khan, M.A., R. Ansari, H. Ali, B. Gul, B.L. Nielsen. 2009. *Panicum turgidum*, a potentially sustainable cattle feed alternative to maize for saline areas. Agric. Ecosyst. Environ. 129: 542-546.

Khan, W., B. Prithviraj and D.L. Smith. 2003. Photosynthetic responses of corn and Soybean to foliar application of salicylates. J. Plant Physiol. 160: 485-492.

Kibria, M.G., M. Hossain, Y. Murata and M.A. Hoque. 2017. Antioxidant defense mechanisms of salinity tolerance in rice genotypes. Rice Sci. 24: 155-162.

Koul, O., S. Walia, and G.S. Dhaliwal. 2008. Essential oils as green pesticides: potential and constraints. Int. J. Bio. Pest. 4(1): 63-84.

Malhotra, S.K. 2012. Fennel and fennel seed. In: Handbook of Herbs and Spices (2nd Ed). p. 275-302.

Mauromicale, G. and P. Licandro. 2002. Salinity and temperature effects on germination, emergence and seedling growth of globe artichoke. Agronomie. 22: 443-450.

Mayak, S., T. Tirosh and B.R. Glick. 2004. Plant growth-promoting bacteria that confer resistance to water stress in tomatoes and peppers. Plant Sci. 166: 525-530.

Moradi, M. and A.M. Ismail. 2007. Responses of photosynthesis, chlorophyll fluorescence and ROS scavenging systems to salt stress, during seedling and reproductive stages of rice. Ann. Bot. 99: 1161-1173.

Munns, R. 1993. Physiological process limiting plant growth in saline soil-some dogmas and hypothesis. Plant Cell. Environ. 16:15-24.

Munns, R. 2005. Genes and salt tolerance: bringing them together. New Phytol. 167: 645-663.

Munns, R. and M. Gilliham. 2015. Salinity tolerance of crops – what is the cost? New Phytol. 208: 668-673.

Munns, R., and M. Tester. 2008. Mechanisms of salinity tolerance. Ann. Rev. Plant Biol. 59: 651-681.

Nam, K.-H., Y.-J. Kim, Y.S. Moon, I.-S. Pack and C.-G. Kim. 2017. Salinity affects metabolomic profiles of different trophic levels in a food chain. Sci. Total Environ. 599–600: 198-206.

Negrão, S., S.M. Schmöckel, M. Tester. 2017. Evaluating physiological responses of plants to salinity stress. Ann. Bot. 119(1): 1-11.

Omidbaigi, R., A., Hadjiakhoondi, and M. Saharkhiz. 2003. Changes in content and chemical composition of (*Pimpinella anisum*) oil at various harvest time. J. Essent. Oil Bearing Plants. 6: 46-50.

Penella, C., M. Landi, L. Guidi, S.G. Nebauer, E. Pellegrini, A.S. Bautista, D. Remorini, C. Nali, S. López-Galarza and A. Calatayud. 2016. Salt tolerant rootstock increases yield of pepper under salinity through maintenance of photosynthetic performance and sinks strength. J. Plant Physiol. 193: 1-11.

Pennings, S.C., M. Bestor-Grant and M.D. Bertness. 2005. Plant zonation in low-latitude salt marshes: disentangling the roles of flooding, salinity, and competition. J. Ecol. 93: 159-167.

Rahman, A., K. Nahar, M. Hasanuzzaman and M. Fujita. 2016. Calcium supplementation improves Na+/K+ ratio, antioxidant defense and glyoxalase systems in salt-stressed rice seedlings. Front. Plant Sci. 7:609.

Redondo-Go´mez, S., L. Andrades-Moreno, E. Mateos-Naranjo, R. Parra, J. Valera-Burgos and R. Aroca. 2011. Synergic effect of salinity and zinc stress on growth and photosynthetic responses of the cord grass, *Spartina densiflora*. J. Exp. Bot. 62: 5521-5530.

Riaz, U., Z. Abbas, Q. Zaman, M. Mubashir, M. Jabeen, S.A. Zulqadar, Z. Javeed, S. Rehman, M. Ashraf and J. Qamar. 2018. Evaluation of ground water quality for irrigation purposes and effect on crop yields: A GIS based study of Bahawalpur. Pakistan J. Agric. Res. 31: 29-36.

Rocha, L. and C.P. Fernandes. 2016. Chapter 22 - Aniseed (*Pimpinella anisum*, Apiaceae) Oils A2 - Preedy, Victor R. Essential Oils in Food Preservation, Flavor and Safety. Academic Press, San Diego, p. 209-213.

Ross, I.A. 2001. Medicinal plants of the world, Volume 3: Chemical constituents traditional and modern medicinal uses. 2nd ed. Human press, Totowa, New Jersey. p.363-374.

Samojlik, I., V. Mijatović, S. Petković, B. Škrbić and B. Božin. 2012. The influence of essential oil of aniseed (*Pimpinella anisum*, L.) on drug effects on the central nervous system. Fitoterapia. 83(8): 1466-1473.

Sangwan, N.S., A.H.A. Farooqi, F. Sabih and R.S. Sangwan. 2001. Regulation of essential oil production in plants. Plant Growth Reg. 34:3-21.

Schleiff, U. 2008. Analysis of water supply of plants under saline soil conditions and conclusions for research on crop salt tolerance. J. Agron. Crop Sci. 194: 1-8.

Shabani, A., A.R. Sepaskhah and A.A. Kamkar-Haghighi. 2012. Responses of agronomic components of rapeseed (*Brassica napus* L.) as influenced by deficit irrigation, water salinity and planting method. Int. J. Plant Prod. 7: 313-340.

Shen, Q., J. Yu, L. Fu, L. Wu, F. Dai, L. Jiang, D. Wu and G. Zhang. 2018. Ionomic, metabolomic and proteomic analyses reveal molecular mechanisms of root adaption to salt stress in Tibetan wild barley. Plant Physiol. Biochem. 123: 319-330.

Sultana, N., T. Ikeda and R. Itoh. 1999. Effect of NaCl salinity on photosynthesis and dry matter accumulation in developing rice grains. Environ. Exp. Bot. 42: 211-220.

Talat, A., K. Nawaz, K. Hussian and K.H. Bhatti. 2013. Foliar application of proline for salt tolerance of two wheat cultivars. World Appl. Sci. J. 22: 547-554.

Tepe, A.S. and B. Tepe. 2015. Traditional use, biological activity potential and toxicity of Pimpinella species. Indust. Crops Prod. 69: 153-166.

Terry, N. and L.J. Waldron. 1984. Salinity, photosynthesis, and leaf growth. California Agric. 38: 38-39.

Tetsuya, I. and S. Sergey. 2018. Control of xylem Na+ loading and transport to the shoot in rice and barley as a determinant of differential salinity stress tolerance. Physiol. Plant. doi: 10.1111/ppl.12758

Tirapelli, C.R., R.C. Andrade, O.A. de Cassano, A.F. de Souza, R.S. Ambrosio, B.F. Costa, and M.A. da Oliveria. 2007. Antispasmodic and relaxant effects of the hydrocoholic extract of *Pimpinella anisum* (Apiaceae) on rat anococcygeous smooth muscle. J. Ethnopharmacol. 110: 23-29.

Ullah, H., A. Mahmood and B. Honermeier 2014. Essential oil and composition of anise (*Pimpinella anisum* L.) with varying seed rates and row spacing. Pakistan J. Bot. 46(5): 1859-1864.

Xinwen, X., X. Hailiang, W. Yangling, W. Xiaojing, Q. Yongzh, and X. Bo. 2008. The effect of salt stress on the chlorophyll level of the main sand - binding plants in the shelterbelt along the Tarim Desert Highway. Chinese Sci. Bull. 53: 109-111.

Zhu, J.K. 2007. Plant Salt Stress: John Wiley and Sons, Ltd.