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Review paper

Cucumber and salinity

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Dedicated to the memory of Prof. Mohammad A. Suwwan

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Abstract

Salinity is becoming more expanded globally. Soil salinity imposes a great challenge for vegetable-crops production in arid and semiarid regions. Cucumber (*Cucumis sativus* L.) is the fourth most important vegetable crop worldwide. In this review, we discuss the complex network of effects, and the ways cucumber responds to salinity. Salt stress inhibits almost all growth phases and yield components of cucumber. Accumulation of Na^+ and/or Cl^- ions in cucumber tissues disturbs the absorption of other ions causing ionic imbalance which affect stomatal opening. Nevertheless, high levels of NaCl in soil inhibit water uptake in the root medium exposing cucumber to osmotic stress. Osmotic stress broadly interrupts metabolic pathways by altering enzymatic activity. Both, ionic and osmotic stresses induce ROS amassing in cucumber tissues. ROS directly constrain photosynthesis by decreasing levels of total chlorophyll and degrading PSII as well as corrupting thylakoid membranes. Ultimately, NaCl-induced stress inhibits cucumber seed germination, roots and shoots growth and development, fruit quality and yield production.

Keywords: Cucumber, Plant physiology, ROS, Soil salinity.
Abbreviations: ABA_ Abscisic acid, ADP_ Adenosine diphosphate, ATP_ Adenosine triphosphate, EC_ Electrical conductivity, ECe_ Electrical conductivity of the saturated paste extract, ESP_ Exchangeable sodium percentage, ETC_ Electron transport chain, NADH _Nicotinamide adenine dinucleotide, NOX_ NADPH oxidase, PS II_ Photosystem II, RCS_ Reactive carbonyl species, ROS_ Reactive oxygen species, Rubisco_ Ribose 1,5-diphosphate carboxylase/oxygenase, TCA cycle_ Tricarboxylic acid cycle, Krebs cycle

Introduction

Land degradation is a major global problem primarily resulted from soil erosion and salinity (Kingwell et al., 2008). Although occurring naturally, salinity is becoming more expanded as a result of anthropogenic activities such as intensive agriculture, misuse of agrochemicals, saline irrigation water, deforestations, and release of greenhouse gases (Smith et al., 2016). The effects of these activities are expected to exaggerate in the future due to dramatic climate change. Saline soils are widespread in arid and semiarid regions of the world, where annual precipitation is insufficient to leach salts out of the upper soil level (Li et al., 2016). Moreover, high evapotranspiration and low-quality irrigation water participated in the expansion of saline soils in these areas (Farooq et al., 2015; Beithou et al., 2022). The spread of saline soils is increasing with time and it was estimated that 23% of cultivated lands are saline (Shahid et al., 2018).

In saline soils, the major cationic electrolytes are sodium, calcium, magnesium, and potassium, while the anionic electrolytes are chloride, sulfate, bicarbonate, and carbonate (Rengasamy, 2016). Soil salinization includes saline, alkaline and saline– alkaline soils considered as raised salt concentration, elevated pH and high sodium concentration, respectively. Main soil salt types are sodium chloride (NaCl), sodium sulfate (Na_2SO_4) and sodium carbonate (Na_2CO_3). NaCl is the most dominant salt in saline soil and is mainly associated with clay particles (Rengasamy, 2010). Saline soil, by definition, has a salt concentration of more than 0.25 % and an electrical conductivity (EC) over 4 dS m^{-1}, an exchangeable sodium percentage (ESP) <15% and a pH < 8.5 in its saturation paste (Shrivastava and Kumar, 2015; Seifi et al., 2020). This salinity level negatively impacts crop growth and productivity and thus reduces economic revenue and profitability of agricultural lands (Ammari et al., 2013; Qadir et al., 2014; Abdulfatah et al., 2021b).

Soil salinity impose a great challenge for vegetable-crops production in arid and semiarid regions (Machado and Serralheiro, 2017). Cucumber (*Cucumis sativus* L.) belongs to the gourd family (Cucurbitaceae) and is the fourth most important vegetable crop worldwide. Cucumber can be consumed as pickles (fermented) or fresh in salads and appetizers (Sotiroudis et al., 2010). Growth and economic yield of this vegetable crop are severely affected by salinity and drought conditions prevailing in arid and semiarid regions (Trajkova et al., 2006; Abu-Romman, 2010; Abu-Romman and Suwwan, 2012). It is reported that cucumber tolerate an ECe of about 2.5 dSm-1 where its yield diminished by 13% with each unit of ECe increase above the threshold value (Abu-Zinada 2015).

The present review aims at discussing the effects of salinity stress on cucumber growth and development.

Effects of salinity on cucumber plants

Salinity exhibits different effects on crop plants such as specific ionic effects, osmotic stress, and mineral deficiencies (Adem et al., 2014). These conditions impair plant growth, development and reproduction. Photosynthesis is the major primary process affected by salinity, accompanied with limited CO_2 diffusion to the leaf and reduced stomatal conductance (Liu et al., 2017; Pan et al., 2020). Such effects on photosynthesis caused over-reduction of the electron transport chain, causing burst production of reactive oxygen species (ROS). These highly reactive ROS exacerbate normal cell metabolism by oxidative damages of major macromolecules (Choudhary et al., 2020). Increased ROS levels in plant cell resulted in lipid peroxidation in organellar membranes (Montillet et al., 2004). Membrane lipid peroxidation leads to the formation of reactive carbonyl species (RCS) including acrolein, hexenal, malondialdehyde, and nonenal. RCS act in downstream of ROS and are cytotoxic due to their ability to modify proteins (Al-Momany and Abu-Romman, 2016).

Plants cope with the effects of ROS by developing efficient enzymatic and non-enzymatic antioxidant defense systems. Antioxidant enzymes include superoxide dismutase, catalase, ascorbate peroxidase, glutathione reductase, dehydroascorbate reductase, and monodehydroascorbate reductase (Abu-Romman, 2019; Kapoor et al., 2019; Abdulfatah et al., 2021a; Al-Faris et al., 2022). On the other hand, nonenzymatic antioxidants include ascorbate, glutathione, tocopherols, and carotenoids (Ahmad et al., 2009).

Cucumber is sensitive to salinity and is more sensitive to Na^+ compared to Cl^- where Na^+ ion is the main cause of ion-specific toxicity and damages (Zhu et al., 2008; Chen et al., 2020). Salt stress inhibits almost all growth phases and yield components of cucumber. Understanding the physiological and molecular impacts of salinity on growth, development and yield of cucumber will improve management practices employed to increase profitability of cucumber cultivation in saline areas.

Germination and seedling emergence

Seed germination is the most sensitive stage to NaCl-induced salinity stress (Ibrahim, 2016). Generally, salt stress delays germination process of cucumber seeds and reduces the total germination percentages (Marium et al., 2019; Din et al., 2020). Abdel-Farid et al. (2020) reported that concentrations of 25 mM and 50 mM of salt delayed the seeds germination as the emergence of radicle was noticed only in the third day under 25 mM and in the seventh day under 50 mM, while it was emerged in the first day in control seeds. They also showed that cucumber germination percentage was significantly reduced only when treating seeds with high concentration of salt (200 mM), while lowest concentrations were not significantly effective when comparing with untreated control (Abdel-Farid et al., 2020). However, Variation in germination speed was recorded among different cucumber varieties (Marium et al., 2019). Salinity affects the germination process by altering water imbibition by seeds due to lower osmotic potential (Khan and Weber, 2007), this changes the activities of enzymes essential for nucleic acid and protein metabolism (Gomes-Filho et al., 2008; Dantas et al., 2015). In addition, salinity induced osmotic potential disturbs hormonal balance, and reduces the utilization of seed reserves (Khan and Rizvi, 1994; Othman et al., 2006).

Root growth

Root system plays an important role in sensing salt stress signals. Salt stress suppressed primary root elongation, lateral root formation and gravitational growth, which effects overall root growth and development (Galvan-Ampudia and Testerink, 2011). Salt stress significantly decreased roots dry weight, surface area, volume and tip number of strawberry (Fan et al., 2011). Increasing salinity decreased radicle elongation of germinated cucumber seeds (Mahdy et al., 2020). NaCl treatment decreased cucumber's root growth (Din et al., 2020; Miao et al., 2020), and both fresh and dry weight of cucumber roots (Khan et al., 2013; Usanmaz et al., 2019). Root system is in direct contact with salt and this may negatively affect enzymes activity and cell division in root tips which reduce root length (Abdel-Farid et al. 2020). On the other hand, It has been argued that salt-tolerant plants decrease water potential in leaves by reducing their root hydraulic conductance, thereby control the delivery of salt-containing water to the shoot (Gama et al., 2009; Vysotskaya et al., 2010). Supplementary phosphorus was reported to ameliorate the inhibitory effects of NaCl on cucumber root growth (Abu-Romman et al., 2013).

Shoot growth

In many plant species, salinity decreases water uptake, thus cause a discernible reduction in vegetative growth, shoot length, leaf area and leaf number, fresh weight and dry matter accumulation (Hwang and Chen, 2001; Kaya et al., 2001; Ali et al., 2004). In cucurbits it is well documented that vegetative growth responded negatively to increased salinity (Abu-Romman et al., 2014; Erdinc et al., 2021). Salinity reduces the number of leaves in cucumber plant (Khan et al., 2013). Reduction in number of leaves is a common attribute of plants growing under salt stress due to the reduction in turgor potential that is essential for cell elongation in plants and reduced turgor pressure (Munns 2002; Ashraf and Harris, 2004; Iqbal and Ashraf, 2005). A recognizable indication of salinity stress is a reduction in shoot growth, which, in turn, can change the allocation of biomass between roots and shoots (Negrão et al., 2017). Decline in overall growth and stem elongation of cucumber plants under NaCl treatment was reported, where the reduction was linearly increased with salt concentration (Khan et al., 2013; Abdel-Farid et al., 2020).

Under salinity stress, injury of transpiring leaves due to entering of salt to transpiration steam may consequently affect plant growth (Heidari et al., 2012). Salinity caused leakage of solute and increased membrane permeability of cucumber leaf tissue (Alpaslan and Gunes, 2001), this signify membrane injury, which affected by the formation of ROS (Montillet et al., 2004; Choudhary et al., 2020). In addition, NaCl treatment causes osmotic changes in leaf tissues which ultimately effect CO_2 concentration and stomatal closure (Liu et al., 2017; Pan et al., 2020). Interestingly, the effect of salt treatments was reported to be more pronounced on root dry weight than shoot dry weight in cucumber (Khan et al., 2013). This phenomenon might be explained by the fact that higher water loss occurs at roots during salinity stress when comparing with water loss from shoots (Khan et al., 2013). However, cell division and cell elongation in all of the vegetative parts and roots in plants are directly affected by the salinity (Lauchli and Epstein; 1990).

Water relations

Maintain water content in tissues at optimal levels, is rather challenging for a plant subjected to salinity in order to sustain their normal functions. Loss of water from plant tissues has dramatic effects on cell expansion and division, stomatal opening, and some hormonal abnormality such as abscisic acid (ABA) (Hsiao and Xu, 2000). At low or moderate salt concentration (higher soil water potential), plants adjust osmotically (accumulate solutes) and maintain a potential gradient for the influx of water (Romero-Aranda et al., 2001). On the other hand, at very low soil water potentials, this condition interferes with plant's ability to extract water from the soil and maintain turgor. In cucumber, it has been shown that the water potential decreases linearly with increasing salinity levels (Khan et al., 2013).

Osmotic stress is the first stress experienced when a plant is subjected to salinity. One of the primary responses of plant is osmotic adjustment, which can occur through either accumulating high levels of inorganic ions (cations or anions) in cells vacuoles, or accumulating compatible organic solutes (such as glycine betaine, proline and polyols) in the cytoplasm (Almansouri et al., 2000; Abu-Romman 2010; dos Reis et al., 2012; Zhu et al., 2020). Published studies showed controversy records about proline accumulated levels in NaCl treated cucumber plants. One study reported that cucumber plants subjected to salinity stress either showed a decrease in proline content or the content was not significantly affected (Khan et al., 2013). While another study informed that salt stress greatly increased the content of proline in cucumber (Zhu et al., 2020). This may be ascribed to the accumulation of another osmoregulatory compound other than, or, in combination with proline under salinity stress (Mittler 2006; Kasim and Dowidar, 2006). However, the association between accumulating higher levels of compatible solutes and NaCl induced salinity tolerance in plants remains to be shown. For barley, at least, it appears that less compatible solutes accumulated in more salt-tolerant varieties when comparing with sensitive varieties (Chen et al., 2007).

Plant response to osmotic stress is complex network of retorts ultimately leads to the formation of ROS (Montillet et al., 2004; Choudhary et al., 2020). ROS are highly reactive and may cause cellular damage through oxidation of lipids, proteins, and nucleic acids (Gupta and Huang, 2014; Isayenkov and Maathius, 2019; Choudhary et al., 2020). ROS produced as signalling moiety to activate salinity defence system and regulate numerous physiological and transcriptional processes (Miller et al., 2010). Studies on plants have linked the increase in ROS with salinization such as $O_2^{\bullet-}$, OH, $^1O_2$, and H_2O_2 (Miller et al., 2010; Nxele et al., 2017; Choudhary et al., 2020). Excess sodium caused the ROS over-production and cell membrane injury in cucumber plant (Jiang et al., 2019). However, plants possess almost all of the components that mediate ROS homeostasis and redox signaling including NOX-like proteins, superoxide dismutase, catalase, peroxidase, iron uptake/storage regulating mechanisms, and a network of thio- and glutaredoxins (Mittler 2017; Abu-Romman, 2019; Kapoor et al., 2019).

Stomatal conductance

The stomatal opening is imperative for plant physiological metabolism. Stomata plays an important role in balancing CO_2 assimilation and water loss in plants (Hetherington and Woodward, 2003; Hedrich and Shabala, 2018). Thus, stomatal response to environmental stimuli has a great impact on water fluxes, especially when talking about salinity stress (Lawson and Vialet-Chabrand, 2019).

Several studies reported the negative impact of NaCl on stomatal conductance in cucumber plant (Suping et al., 2006; Chen et al., 2020; Ma et al., 2020). Stomatal conductance was sensitive to Na^+ concentration but insensitive to Cl^- in the cucumber leaf (Chen et al., 2020). At the early stage of salt stress, stomatal closure is the main challenging factor to the plant. In pea plants, NaCl-induced salt stress decreased stomatal conductance, but after 24 h post-treatments, parameters were recovered to control values (Hernández and Almansa, 2002). Following stomatal closure, the internal reduction of CO_2 decreases, which decrease the activity of ribose 1,5-diphosphate carboxylase/oxygenase (Rubisco) enzyme and reduces the CO_2 fixation (Sudhir et al., 2005; Chaves et al., 2009; Yildiztugay et al., 2020). This in turn destroy the photosynthetic system, and the chloroplast structure/function or thylakoid at the later stage of salt stress (Chen et al., 2020; Sudhir et al., 2005; Demetriou et al., 2007; Shu et al., 2012). As a result, photosynthetic rate inhibited and carbohydrate metabolism becomes destroyed, thus reducing dry matter accumulation (Chaves et al., 2009; Jurczyk et al., 2016). These effects were reported in cucumber as mentioned before.

Ion effects

Salts have dual effects on plants: osmotic and ionic. Ion accumulation and ion transport are complex processes associated with a variety of physiological phenomena, such as transpiration, the ability to avoid/enhance ion entering the shoots (Moualeu-Ngangue et al., 2016; Fricke 2020; Munns et al., 2020; Rubio et al., 2020). At high concentrations, even non-toxic salts such as Na_2SO_3 become toxic, disrupting the normal physiological processes (İbrahimova et al., 2021). Excessive accumulation of ions like Na^+ and Cl^- in cells has a toxic effect on the plant. Na^+ ions are preferentially accumulated in supporting tissues or in the vacuole (Davenport et al., 2005; James et al., 2011), while other ions recirculated from shoot to roots via the phloem (Berthomieu et al., 2003; Peuke 2010). In cucumber, Na^+ and Cl^- concentration in leaves of cucumber were increased under salt stress, while Ca^{++} as well as K^+/Na^+ ratio in leaves of plants were significantly decreased (James et al., 2011; Usanmaz and Abak, 2019).

Toxicity

Na^+ and Cl^- ions accumulation in tissues is one of the most destructive effects of NaCl-induced salinity on plants (Maathuis et al., 2014). In most species, Na^+ accumulates to toxic levels before Cl^- does (Miao et al., 2020). Na^+ accumulation to toxic levels can perturb the plant's ability to control assimilation of other ions, especially of K^+ and Ca^{2+}, resulting in ion imbalances of K^+, Ca^{2+} and Mg^{2+} (Keutgen and Pawelzik 2009). In addition, many of the deleterious effects of Na^+ are related to the structural/functional integrity of membranes (Kurth et al. 1986). Decrease in Ca^{2+} and Mg^{2+} content of leaves upon salinity stress increases membrane stability and decreased chlorophyll content (Parida et al. 2004).

In order to tolerate salinity, plants need to reduce Na^+ in their shoots, while maintain K^+ homeostasis. Also, ion recirculation from young leaves to old leaves is an important way for protecting young leaves from ion toxicity (Berthomieu et al., 2003; Munns and Tester, 2008). Cucumber has a high leaf turnover rate and the accumulation of salt to a toxic level takes 15-20 days (Chen et al., 2020). Under NaCl salinity, when compared to old leaves, young cucumber leaves accumulate less Cl^- but similar Na^+, indicating that cucumber plant is able to recirculate Cl^- but not Na^+, from young to old leaves (Chen et al., 2020). However, there are still no convincing data showing the mechanism of Cl^- specific toxicity and the tissue tolerance of Cl^- in cucumber since Na^+ and Cl^- concentrations are very well correlated under NaCl salinity (Savvas et al., 2005; Teakle and Tyerman, 2010; Chen et al., 2018). High Cl^- concentration reduced the photosynthetic capacity due to nonstomatal effects and chlorophyll degradation (Tavakkoli et al., 2011). Thus, Cl^- toxicity significantly contributes to plant growth and yield reduction under salinity (Colla et al., 2012; Colla et al., 2013). Furthermore, Cl^- induced salinity reduces Cd sorption in soils by forming soluble Cd^{2+} complexes and increase Cd uptake in plants (Weggler et al., 2004). Though, it was shown that, in cucumber leaves, photosynthesis is better correlated with Na^+ concentration than with Cl^- (Drew et al., 1990).

Nutrition imbalance

Salinity stress does not only affect morphological performance of plants such as seeds germination, seedlings growth and fresh and dry weights, but also it affects nutrient availability, competitive uptake, transport, or distribution within the plant (Rogers et al., 2003; Hu and Schmidhalter, 2005; Zhu et al., 2004). Furthermore, the presence of excessive soluble salts in the soil competes with the uptake and metabolism of mineral nutrient that are essential to cucumber (Chen et al., 2020). Increased salt uptake induces specific ion toxicities like that of high Na^+, Cl^-, or sulfate (SO_4^{2-}) that decrease the uptake of essential nutrients like phosphorus (P), potassium (K^+), nitrogen (N), and calcium (Ca^{2+}; Zhu 2001; Abu-Romman and Suwwan, 2018).

High concentrations of Na^+ reduced K^+ and Ca^{2+} uptake and reduced photosynthesis mainly by reducing stomatal conductance (Parida et al., 2004; Keutgen and Pawelzik, 2009). Mg^{2+} concentration was decrease in leaf but not much affected in stems and roots (Khan et al., 2000). Salinity could reduce nitrogen accumulation in plants as well. This phenomenon is explained by the possible interaction between Na^+ and NH_4^+ and/or between Cl^- and NO_3^- that ultimately reduce the growth and yield of the crop (Rozeff 1995). The reduction in NO_3^- uptake is associated with Cl^- antagonism or reduced water uptake under saline conditions (Bar et al., 1997; LeaCox and Syvertsen, 1993). Nevertheless, the availability of phosphorous is also reduced in saline soil (Mahmood et al., 2013). Hence, it is noteworthy that phosphate concentration in agronomic crops decreases as salinity increases (Qadir and Schubert, 2002).

Plants under salinity stress showed different growth and metabolomic responses. This metabolomics alteration (positive or negative) under salinity stress is controlled by many factors including plant species, developmental stages, magnitude and duration of stress itself. Secondary metabolites like polyphenolics, flavonoids, saponins, anthocyanins and tannins were altered in plants subjected to salinity stress (Hussain et al., 2013; Singh et al., 2015; Abdel-Farid et al., 2020). Flavonoids content was increased in cucumber under the highest level of salinity stress, whereas saponins content was increased under low and moderate levels of salinity (Abdel-Farid et al., 2020). Furthermore, total antioxidant capacity, which is correlated with the content of secondary metabolites, was also increased in cucumber under low level of salinity (Abdel-Farid et al., 2020).

Non-structural carbohydrates are mainly involved as osmotic regulators in plant cell responses to stress (Keunen et al., 2013). Carbohydrates and protein contents are found to vary in plants under salinity stress (Somayeh et al., 2012; Jamil and Rha, 2013). Yuan et al. (2015) found that the accumulation of starch in salt-stressed leaves is not only related to the impediment of photosynthetic product transport, but is also related to decreases in starch hydrolase activity levels. TCA cycle which is an important indicator of life activity, was significantly inhibited in cucumber seedling upon subjecting to salinity (Li et al., 2015). Correspondingly, treating cucumber seedlings with 80 $mmol \cdot L^{-1}$ NaCl for seven days resulted in significant reduction of hexokinase, phosphofructokinase, pyruvate kinase, isocitrate dehydrogenase, succinate dehydrogenase and malate dehydrogenase activities (Li et al., 2020). The dramatic decrease causes reduction in levels of pyruvate, citrate, NADH, ADP and ATP contents in leaves (Li et al., 2020).

Photosynthetic pigments and photosynthesis

Photosynthesis is a vital characteristic of plants. Photosynthesis also inhibited when high concentrations of Na^+ and/or Cl^- are accumulated in chloroplasts (Zhang et al., 2008). Photosynthesis could be more restricted under low rather than high salinity due to the stronger ion toxicity (Drew et al., 1990). The decrease in chlorophyll content under salt stress is a commonly reported phenomenon, related to chloroplast membrane deterioration and pigment-protein complex oxidation or chlorophyll stability disrupted (Zhang et al., 2008; Mane et al., 2010). All of these effects were ascribable by ROS formation in response to salinity stress (Montillet et al., 2004).

To understand the impact of salinity on photosynthetic responses, many studies quantify the amount of chlorophyll

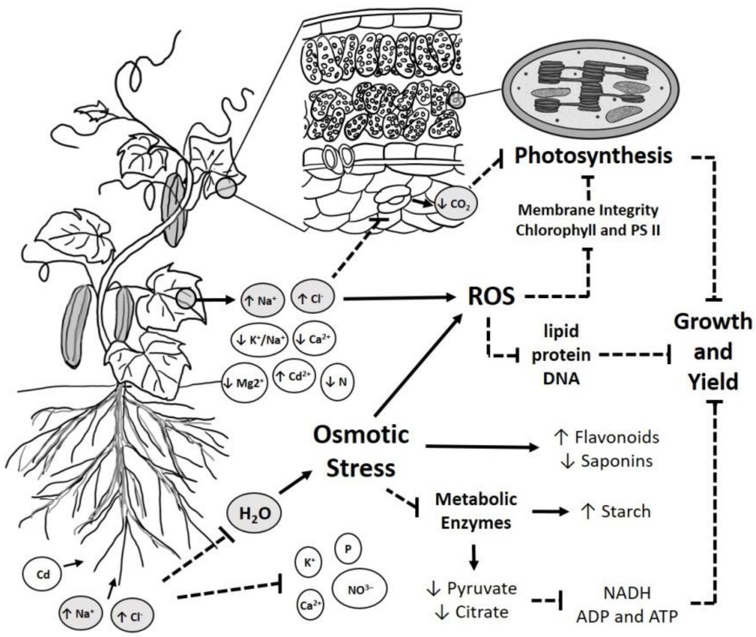

Fig. 1. Salinity effects on cucumber plant as recorded in published data.

in leaf which is used as a sensitive indicator of the cellular metabolic state (Chutipaijit et al., 2011). Decreased levels of total chlorophyll, chlorophyll a, chlorophyll b, carotenoids, and xanthophylls as well as the intensity of chlorophyll fluorescence under NaCl-induced salinity, were stated in published data (Furtana and Tipirdamaz, 2010; Amirjani 2011; Chutipaijit et al., 2011; Saha et al., 2010). Chlorophyll a and chlorophyll b were reduced in cucumber seedlings subjected to salinity (Khan et al., 2013; Garcia-Sanchez et al., 2002; Furtana and Tipirdamaz, 2010). Khan et al. (2013) showed that total leaf chlorophyll contents significantly decreased with an increasing NaCl levels. The decrease in total chlorophyll contents was 12, 21, and 30 % at 2 and 3, and 5 dS m^{-1} of salt stress, respectively, compared to control non-treated plants, with 16 % loss of the intensity of chlorophyll fluorescence (Khan et al., 2013). In concordance with these findings, formation of proteolytic enzymes such as chlorophyllase, which can induce the reduction of chlorophyll content in cucumber under salinity stress (Zhao et al., 2007). Conversely, one of the studies reported that the content of chlorophyll a and b was increased in cucumber that is subjected to the highest levels of salinity stress (Abdel-Farid et al., 2020).

Salt stress reduced chlorophyll content, affects photosynthetic electron transport chain (ETC), and inhibits Photosystem II (PS II) activity as a consequence of the accumulation of Na^+ and/or Cl^- in chloroplasts (Zhao et al., 2007). PS II is a relatively sensitive component of the photosynthetic system (Allakhverdiev et al., 2000). A substantial reduction of PS II efficiency, ETC, and assimilation rate of CO_2 under salinization has been discerned (Piotr and Grazyna, 2005). Fv/Fm is an established indicator of the photo-inhibition or the biotic/abiotic stress damage to the PS II (Calatayud and Barreno, 2004). The value for Fv/Fm was significantly reduced in the cucumber plants under salinity concentrations of 50 and 100 mM (Furtana and Tipirdamaz, 2010), signifying the damage to PS II system.

Yield and fruit quality

The most countable effect of salt stress in agriculture is the yield of crops. The above mentioned effects of salt stress on plants ultimately lead to reduction of cucumber yield. Salinity causes huge reductions in the cultivated land and crop yield (Yamaguchi and Blumwald, 2005). Salt stress seriously inhibits plant growth and yield mainly through ionic stress, osmotic stress and the utmost effect of oxidative stress (Inal and Gunes, 2008; Al-Momany and Abu-Romman, 2016; Faghih et al., 2017).

Reduction in growth and yield of cucumber in response to salinization is well established; fruit yield decreases by 13% with each unit increase of electrical conductivity above 2.5 dS m^{-1} (Chen et al., 2018). NaCl treatment impairs plant growth mainly by inhibiting photosynthetic ability and diminishing root growth (Ma et al., 2020). Numbers of pods per plant, seeds per pod, and seed weight were negatively correlated with salinity levels in several plants (Parihar et al., 2015). Increased N uptake under saline conditions reduces the growth and yield of the crop (Rozeff 1995). Moreover, Cl^- toxicity contributes to yield reduction under salinity as well (Colla et al., 2012; Colla et al., 2013).

Salinity stress affects cucumber plants at all levels of growth, from seeds to yield and beyond. The complex network of effects, and the ways cucumber respond to this kind of stress are illustrated in Fig. 1. It is rather hard to interpret salinity stress effects on plants. An effective way to unravel that complex networked of multi-folded impression of salts on plant; is to study effects of ions (*i.e.* Na^+ or Cl^-) individually rather than in combination like in mixed salts experiments. Furthermore, studies at components levels (*i.e.* protein) might give a better insight on salinity effects at molecular level. Thus, influence our understanding of salinization on whole plant and on various growth parameters (*i.e.* vegetation and yield). At the end, effects of saline conditions must be tested in the field.

Conflict of Interest
The authors declare no conflict of interest.

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