

Ameliorative Effects of Potassium on the Salinity Stress in Plants: A Review

S. A. A. El Sayed^{1*}, F. A. Hellal¹, Nadia Gad El-Rab¹ and R. M. Zewainy¹

¹Department of Plant Nutrition, National Research Centre, Dokki, El-Behouth St., 12622, Cairo, Egypt.

Authors' contributions

This work was carried out in collaboration among all authors. All authors managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Salt stress is one of the major abiotic stresses decreasing crop production, particularly in dry and semi-arid regions. Reclamation of salt-damaged soil is important as it is sweeping cultivable land day by day. Potassium is an essential element for plant development which is an extremely active ion in the soil system. Potassium is second to nitrogen in plant tissue levels ranging from 1 to 3% by weight. As a cation, potassium is highly mobile in plant and moderately mobile in the soil system. The essentiality of potassium is identified with its multiple roles in plants. Among these are the maintenance of cell turgor pressure and cell lengthening, osmoregulation, leaf and stomata movements, enzyme activation, phloem solute transport, cation/anion balancing, control of membrane polarization, cytoplasmic pH regulation, chloroplast structure and functioning, protein and starch synthesis, and energy preservation across membranes. As almost all of these processes are directly associated to plant adaptation to the inhospitable environment. It could be concluded that potassium uptake, transportation, and homeostasis play important role in conferring salt tolerance in plants.

Keywords: *Environmental stress; salt stress; potassium; plant growth; yield production, proline content.*

*Corresponding author: Email: Elsayed.saied1993@yahoo.com;

1. INTRODUCTION

Salt stress is an agro-ecological issue restricting plant development and improvement in arid and semi-arid areas of the world and turns into the issue of genuine concern [1]. Salinity problem exacerbated by the transformation of agricultural land, expanding rivalry amongst yields and vitality plant species, and a necessity to increment worldwide sustenance provide by around 70% to address the year of 2050 difficulty of sustaining 9.3 billion populations [2]. High salinity may influence most of all aspects of plant physiology and metabolism and cause both hyperionic and hyperosmotic stresses, which prompt plant demise. Salinity prompts a development of sodium and chloride ion concentration in the cytosol, which can be eventually unfavorable to the cell. Higher concentrations of sodium particles (over 100 mM) are harmful to cell metabolism and can restrain the action of numerous fundamental enzymes, cell division and extension, membrane disruption, and osmotic imbalance, which at last prompt growth inhibition [3].

Potassium utilization slowly mitigated the destructive impacts of salt stress on plants. The vitality of potassium is identified with its different parts in plants [4]. Among of these, cell turgor pressure and cell prolongation, leaf and stomata developments, enzyme activation, phloem solute transport, cation/anion adjusting, control of layer polarization, cytoplasmic pH direction, chloroplast structure and working, protein and starch synthesis and energy protection across the membrane, etc. Majority of these procedures are directly engaged with plant adjustment to salt stress resistance in plants. Changes in potassium ions due to the effect of salt stress can disturb the osmotic balance, the capacity of stomata, and the capacity of a few chemicals. Saltiness causes specific stresses resulting in a modified potassium/sodium proportion. The external sodium can adversely affect intracellular potassium influx [5]. This review article planned to comprehend the essential role of potassium in alleviating the salt stress on the advancement and development of the plant.

2. THE SALINE SOIL IN EGYPT

The total land area of Egypt is a hundred million ha (Mha). The total cultivated area is 3.36 Mha. Majority of salt-affected soils are located in the Northern-Central part of the Nile Delta and on its Eastern and Western sides. Other areas are

found in Wadi El-Natroun, El-Kebeir, The Oases, many parts of the Nile Delta and Valley and El-Fayoum province. About 0.9 Mha suffer from salinization in cultivated irrigated areas: 60% of the Northern Delta region, 20% of the Southern Delta and Middle region and 20% of the Upper region. In Egypt, all the farming areas are under irrigation system. Farming is of prime significance for the employment of the Egyptian population. However, degradation of soils through salinity and alkalinity has been a noteworthy agricultural problem. The high evapotranspiration rate and high groundwater level causes saltiness advancement particularly in the northern part of the Nile Delta [6]. Egypt experiences the ill effects of saltiness, wherein the electrical conductivity of the extract from saturated soil is more than 4 dS m^{-1} . Most of the salt-affected lands exist in Lower Delta. In fact, the present circumstance is not kidding and undermines agricultural sustainability, as well as the entire environmental system [7].

3. ADVERSE EFFECT OF SALINITY STRESS

3.1 Plant Growth

Salinity inhibition of plant development is the consequence of osmotic and ionic impacts and the different plant species have created a distinctive mechanism to adapt to these impacts. The reduction of cell osmotic potential by net solute accumulation has been viewed as an essential component of salt tolerance in plants. This decrease in osmotic potential in salt-stressed plants could be a consequence of inorganic ions (Na^+ , Cl^- and K^+) and good organic solute (carbohydrates, amino acids, and proline) accumulations. An excess amount of salt in cultivated soils retards the growth, as far as possible financial yield and even lead plants to death. There are a few focuses at which salt transport is controlled. These are (i) specific take-up from the soil solution, (ii) stacking of xylem, (iii) expulsion of salt from the xylem in the upper parts of the plant, (iv) loading of the phloem and (v) discharge through salt organs or bladders [8]. Farid [9,10] studied the effect of salt stress on germination and seedling growth of ten barley cultivars. Results indicated that increased salinity caused a significant reduction in percentage of germination and seed germination rates. Increasing salt levels caused a significant reduction in root and shoot length at the seedling stage. In this study Giza 126, Giza 130, Giza 135, Giza 2000 have got higher germination

growth component indicating their tolerance to salinity stress in sandy soil. Barley cultivars grown under salt stress classified into barley cultivars Giza 126, Giza 127 and Giza 2000 as highly tolerance and barley cultivar Giza 129, Giza 123 and Giza 127 as moderately tolerance and the rest is sensitive.

The tuber and leaves essentially influenced by salty water and distinctive levels of compost and their interactions, under saline water irrigation system, leaves or tubers weights marginally diminished with increasing saline water up to 4000 ppm. In addition, significant augmentations were seen when Table beet plants were subjected to the high a level of salinization (6000 and 8000 ppm) as indicated by [11]. Root and shoot development of the maize plants was depressed by salinity stress and NaCl essentially diminished shoot and root dry mass of maize plants as shown by [12]. Sodium chloride caused increasing Na, Cl, P, Zn and Mn contents of root and shoot. Applied NaCl diminished N, Ca and Fe contents of the shoot, increased N, Ca and Fe concentrations of the root. Sodium, Cl, N, P, Ca, Fe, Zn and Mn accumulated in root as per applied NaCl. The salt impacts disturb intracellular ion homeostasis, membrane work and metabolic movement. As auxiliary impacts, salt-initiated osmotic pressure diminishes root epidermal cell division and extension rates, decreasing essential root development, in the long run bringing about hindrance of development and decreasing of crop productivity [13]. Reduction dry weight of the plant, leaf relative water content and photosynthetic pigments as affected by salt stress as demonstrated by [14]. The substance of total phenolic was expanded by 64%, in the plants after salt treatment. The exogenous use of salicylic acid significantly reduced the development hindrance of plants caused by NaCl and was joined by higher leaf relative water contents, photosynthetic pigments and lower total phenolic.

3.2 Nutrient Imbalance

High concentration of sodium and chloride ions in soil solution lessened the take-up of potassium ions which eventually caused potassium inadequacy in plants. Potassium inadequacy brings about chlorosis and afterward necrosis in plant leaves [15]. Salinity decreases nutrient accessibility and also transport to the developing regions of the plant, along these lines influencing the quality of both vegetative and regenerative

organs. For instance, higher concentrations of sodium in soil diminished the calcium activity in the outer medium which likewise brings about low availability of calcium in *Celosia argentea* [16]. Salt stress causes an unevenness in sodium ions homeostasis, which is kept up by activity of different pumps, ions, calcium sensors, and its downstream connecting partners, which at last outcomes in the efflux of abundance sodium ions. Certain channels demonstrate greater selectivity to potassium over sodium. These incorporate the potassium internal correcting channel, which mediates the influx of potassium upon plasma membranes hyperpolarization and selectivity accumulates potassium over sodium ions [17].

Osmotic pressure administrative molecules in plants as compared with classifications of yeast signal components. Vertical sections show sort of confirmation for the participation of gene in plant stress signaling. Salinity forces negative consequences for plant development through low osmotic capability of soil solution and nutritional imbalance [18]. Ionic imbalance happens in the cells because of higher accumulation of sodium and chloride and decreases the uptake of other mineral supplements, for example, potassium, calcium and Mn^{2+} [19]. Alarger amount, saltiness restrains the content of potassium and calcium in the leaves and roots of *Brassica napus* (canola) cultivars [20]. High sodium: potassium proportion unfavorably influences metabolic processes in plants [21]. The interactions between salts and mineral nutrient supplements result in impressive nutrient instability [22].

3.3 Osmotic Pressure

The unfavorable impact of saltiness as osmotic stress at the cell level is all around reported in several comprehensive reviews [18]. Be that as it may, the degree of development hindrance because of salt-initiated osmotic pressure relies upon the sort of plant tissue and content of salts shows in developing medium. The salt stress prompted osmotic pressure is the significant reason of development decrease at introductory stage of salt stress, while at later stages accumulation of sodium happens in leaves and lessens plant development [23]. The distinctive examinations uncovered that development of the cells is essentially connected with turgor potential and diminishment in turgor pressure is one of the real reasons for the hindrance of plant development under saline conditions, e.g., *Shepherdia argentea* [24].

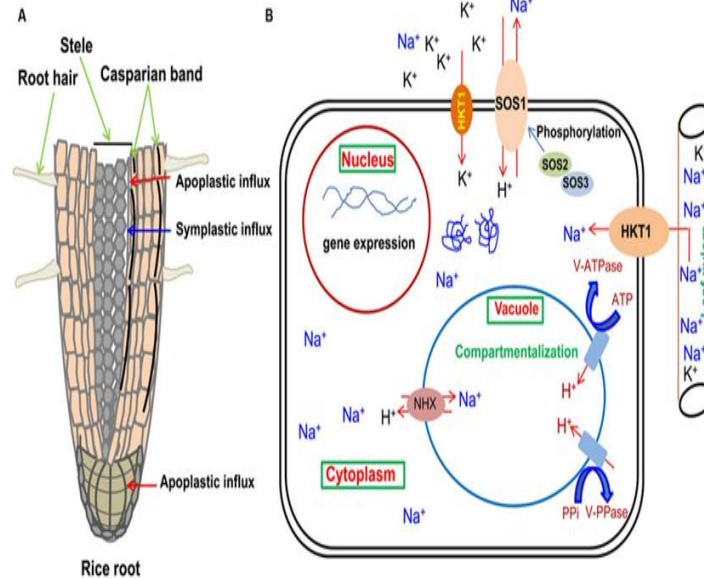


Fig. 1. Graphic elucidate of flow Na⁺ in roots, its sequestration pathways and essential defensive instruments as intervened by the transporters introduce on plasma membrane and tonoplast of the cell [25]

Cell ion homeostasis is kept up by the ion pumps like symporters, antiporters, and transporter proteins introduce on the membranes. In cereals, sodium avoidance systems were proposed to be made out of a few transporters exhibit on cell layer like hydrogen pump ATPases, sodium/hydrogen anti-porter and the high uptake of potassium ion. The increment in the level of salt induces the sodium/ hydrogen antiporter activity however it opens up more in saltiness tolerant varieties than saltiness susceptible ones. The sodium/ hydrogen exchange in vacuole is resolved through two separate proton pumps, i.e. vacuolar hydrogen ATPase and vacuolar hydrogen translocating pyrophosphatase. Control in the levels of the vacuolar transporter (NHX1) leads to enhance saltiness resistance in rice shown in Fig. 1 as indicated by [25].

4. THE POTASSIUM CYCLE IN THE SOIL PLANT SYSTEM

There are four sources of potassium in the soil. The greatest soil part of potassium, 90 to 98%, is the soil minerals, similar to, feldspar and mica. The second soil potassium source is the non replaceable potassium, 1 to 10%, and is connected with the 2: 1 clay minerals. The noncompatible potassium source goes about as a save source of potassium in the soil. The third soil potassium source, 1 to 2%, is known as the compatible or expeditiously open potassium and

is found on the cation exchange destinations or in the soil solution [26]. The use of potassium supplements in synthetic manures is immediately settled to the insolubilized forms, particularly in salt-affected soil, and this is the explanation behind the low availability of potassium. Late investigations have demonstrated that utilization of bio-fertilizer joined with 25% of chemical fertilizer gives great outcomes for plant development in the long term [27].

5. POTASSIUM SIGNIFICANCE IN MITIGATING SALT STRESS

5.1 Photosynthesis

Utilization of potassium essentially enhanced photosynthetic parameters [28]. The extension of potassium to a saline culture solution has been found to expand potassium content in plant tissue that relates to a decrease in sodium content, with a further augmentation in plant improvement and salt tolerance. Extended proof demonstrates that it isn't the total amount of sodium in essence that effects salt resistance, yet rather the cytosolic potassium/ sodium proportion that decides plant salt tolerance [5]. Potassium inadequacy basically extended the negative effects that were impelled by salt in the photosynthesis of barley and was joined by an extension in salt affectability. Practically identical results were found by [29].

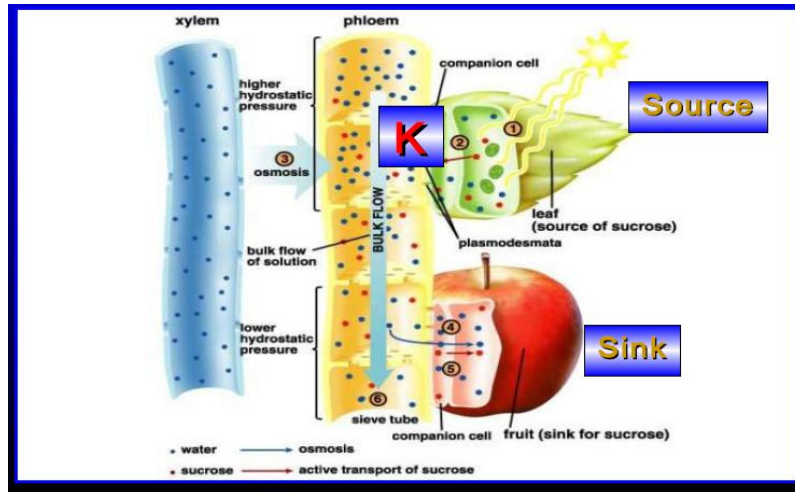


Fig. 2. Potassium plays a critical role in phloem transport

Potassium plays an important role in many of the physiological processes of crops [30,31]. Several authors demonstrate that mild potassium deficiency depresses assimilate translocation without influencing on the photosynthesis at the source or metabolism at the sink. Potassium is the major cation in the phloem and stimulates sugar loading into the phloem sap. This has been speculated that AKT2-like channels participate in this procedure by regulating sucrose/H⁺ symporters via the membrane potential of phloem cellular material as presented in Fig. 2 [30,31].

Potassium is transported in into the cell for that the electrochemical potential in the cytosol is lower than in the external solution. With the import of the positive charge, the electrochemical potential builds (diminishing of the negative charge of the cytosol) lastly accomplish that of the external medium, balance is achieved, and there is no further driving force for the uptake of potassium [32].

5.2 Enzymes Activity

Potassium is essential for enzyme activation, protein blend and osmoregulation, invigorating photosynthesis and keeping up cell turgor pressure. Elevated amounts of sodium can displace calcium from root membranes, changing their respectability and in this manner influencing the selectivity for potassium take-up [33]. The high content of sodium and chloride ions in soil solution decreased the take-up of potassium ions which at last caused potassium insufficiency in plants. Potassium insufficiency brings about

chlorosis and afterward necrosis in plant leaves. Support of required potassium level in a plant cell under saline conditions relies on particular take-up of potassium, cell compartmentation of sodium and potassium and distribution in the leaf tissues [34]. Potassium nitrate application lightens salinity impact in winter wheat by improving exercises of antioxidant enzymes [35]. Accumulation of sodium and debilitation of potassium nutrition is really normal for salt-stressed plants. Consequently, potassium: sodium proportion in plants is viewed as a valuable manual toevaluating salt tolerance [36]. This demonstrates sodium salinity other than diminishing the uptake of potassium rate additionally interferes to a great extent in potassium translocation from root to shoot, which brings about a lower potassium shoot content and higher potassium root content.

5.3 Stomatal Activity

Stomatal conductance and transpiration diminished with saltiness as indicated by [37]. Transpiration and stomatal conductance are straightforwardly associated with photosynthesis, diminish in transpiration and stomatal conductance brings about the decline in CO₂ absorption and photosynthesis. During a salt stress, the plant needs to close their stomata because of water loss. When all is said in done, estimation of stomatal protection gives a strong correlation with deciding the level of stress in plants [38]. Plants depend on potassium to deal with the opening and closing of stomata. The pores through which leaves exchange carbon dioxide, water vapor and oxygen with the

atmosphere. Exactly when the water supply is short, potassium is coordinated out of the guard cells. The pores close solidly to check loss of water and point of confinement drought stress to the plant [39].

Potassium application mitigates the undesirable impacts of salinity through its role in stomatal control, osmoregulation, charge adjust, protein synthesis and homeostasis [40]. As well as balanced potassium: sodium ratio is essential for the proper adjustment of opening and close of stomatal, enzymes activation, protein synthesis, cell osmoregulation, oxidants metabolism, as well as turgor maintenance and photosynthesis [41]. Potassium plays a major role in turgor changes in the guard cells during stomata movement. The transport of K^+ across the plasma membrane and tonoplast causes the turgor changes of guard cells. Stomata open when guard cells accumulate potassium, which lowers the cells' water potential and causes them to take up water by osmosis. The cells become turgid [42].

5.4 Abscisic Acid

Abscisic acid (ABA) is an important phytohormone that plays a key role in plant signaling system which helps the plant to perform function normally under water stress conditions [43].

Abscisic acid ABA causes an alkalization of the guard cell cytosol which directly enhances K^+ out channel activity and down-regulates the transient R-type anion channels. The sustained efflux of both anions and K^+ from guard cells via anion and K^+ out channels contributes to loss of guard cell turgor, which leads to stomatal closing (Fig. 3) [44].

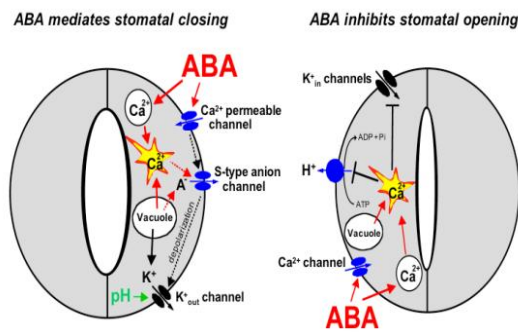


Fig. 3. A model for roles of ion channels in ABA signaling [43]

The phytohormone abscisic acid (ABA) manages many pressure related procedures in plants. In this setting ABA intercedes the responsiveness of plants to salt stress. In response to water pressure, ABA incites stomatal closure by actuating calcium, potassium and anion channels in guard cells.

Potassium supply influences germinability, ABA contents and embryo ABA sensitivity in developing seeds of Sorghum as indicated by [45]. The potassium influenced the ABA level in developing bell pepper seeds and the sprouting of seeds in the maturing bell peppers was correlated with potassium nutrition and potassium content of the leaves and fruit as investigated by [46].

Abscisic acid assumes a focal part in root-to-shoot and cell motioning in drought pressure and in the control of growth and stomatal conductance [47]. In any case, estimations of abscisic acid in developing zones of barley and maize leaves in saline soil don't bolster a basic Abscisic acid control theory. Abscisic acid deficient mutants in maize and tomato generally have the same leaf growth rates as wild-type in drying soil and saline soil [48].

Application of abscisic acid and proline alone as well as in combination improved all growth characteristics by improving proline, total soluble carbohydrates, photosynthetic pigments, peroxidase (POD) and catalase (CAT). Results show the effective utilization of abscisic acid and proline together on reestablishing the modified physiological process initiated by water stress [49].

5.5 Proline Content

Proline, which increments proportionately faster than other amino acids in plants under water stress, has been suggested as an assessing parameter for irrigation scheduling and for selection of drought-resistant cultivars of different species. Potassium uptake as an index for screening cultivars on drought resistance was reported by [50]. The improved action of H⁺/ATPase proton pumping movement would outfit plasma membrane Na⁺/H⁺ antiporter with the main impetus to oust Na⁺ out of the cytoplasm. The NHX-type antiporter i.e. Na⁺/H⁺ situated in tonoplast have been accounted for to expand salt-tolerance in numerous plant species by driving Na⁺ amassing in the vacuole. The diverse ion pumps/ channels as appeared in Fig. 4 [51].

Proline amassing in saltstressed on plants is an essential defense response to keep up the osmotic pressure in a cell. A few reports demonstrate a critical role of proline in osmotic alteration, protecting cell structure and its function in plants in salt tolerant and sensitive different varieties of many crops [38]. Proline has a role in cell osmotic modification, membrane adjustment and detoxification of injurious ions in plants presented to salt stress is generally detailed by [52]. Proline has been appeared to rummage free radicals and ROS. Up-control of the segments of antioxidant defense system offered by proline secures plant against NaCl-incited oxidative harm. In refined tobacco cells, proline stifles cell passing and improves salt tolerance by expanding the activity of enzymes and/or expression of genes involved in the antioxidant defense systems [53].

5.6 Leaf Water Potential

Salt stress caused a great lessening in growth such as leaf area, fresh and leaves dry weight. These changes were related to a diminishing in relative water content and potassium content [54].

Salinity stressed adversely the relative water contents and water retaining capacity but plant water relation in Mungbean plant has been improved significantly by application of the higher amount of potassium [55]. Stomatal closure attributed to drought was somewhat short-circuited by potassium hardship. Stomatal conductance of droughted and potassium denied plants was higher than plants that were just drought stressed [56]. Under depress of potassium in sunflower, ethylene plays a role in modulating stomatal conductance under drought, which may be an adaptive response that incrementing the transport of potassium from roots to leaves [57]. Significantly, potassium isn't just a fundamental macronutrient in plants with a generally known role in directing stomatal opening/closure, yet it can likewise act as a signaling molecule [58].

6. POTASSIUM EFFECTS ON GROWTH, YIELD AND NUTRIENT CONTENT UNDER SALT STRESS

6.1 Plant Growth

Foliar utilization of potassium fertilizer could be effective in adjusting salinity prompted

potassium-inadequacy, fundamentally diminishing salinity-initiated harm to membranes and increasing biomass production in tomato and straw berry as revealed by [59]. The effect of potassium application (zero, 5, 10, 18 and 28 mM as potassium nitrate) on growth of cucumber embryos grown under NaCl stressed (0, 100 and 150 mM) was studied by [60]. Sodium chloride caused diminish root and shoot growth of cucumber embryos which was enhanced by potassium 10 mM potassium nitrate.

Dry weight of shoots has been increased significantly with the increasing supplement of potassium during vegetative growth. The parameter of dry weight has not been affected by the salinity and that's due to the high availability of potassium in the soil [61]. The growth of strawberry was developed with potassium application with exposed to high NaCl concentration (35 mmol L⁻¹) the conditions of greenhouse. The negative effects of NaCl stress on strawberry fruit was reduced by the potassium application as reported by Mehdi [62].

Growth parameters of Endives such as root dry weight, leaf length and leaf regions were influenced by NaCl. While, leaf dry weight and leaf region were influenced by application of potassium sulfate. From examination of the interaction of the above parameters, it resulted that leaf dry weight and leaf area were influenced by the interaction of the NaCl and K₂SO₄ concentration as shown in Table 1 by [63]. Dry biomass increased by the presence of potassium fertilizer. Total dry mass production can be increased by increasing the utilization of potassium fertilization on plant under salt stress compared with lower content of potassium fertilizer [64].

The effect of potassium sulphate at a rate of 50, 100, 150 and 200 mM on the growth and uptake of nutrients in wheat grown under 150 mM sodium chloride stress were illustrated by [65].

The biomass production increased irrespective of the potassium application rate. Biomass production can be enhanced by application of potassium at a rate of 200 mM under saline conditions. The effect of soil addition of potassium fertilizer at rates 0, 3.3, and 6.6 mmol kg⁻¹ and foliar application at a rate of 4.5 and 9 mM on tomato yield and quality grown under three salinity treatments (0.0, 7.5, and 15 dS m⁻¹), using 2 salt-tolerant (Indent-1 and Nagina)

and 2 salt-sensitive varieties was studied by [66]. Potassium application either soil applied or foliar forms alleviated the negative effects of salinity and resulted in a significant increase in dry weight of both salt-tolerant and salt-sensitive groups compared with respective controls presented.

6.2 Yield Production

Potassium assumes an especially basic part in plant development, digestion, and enormously to the survival of plants that are under different biotic and abiotic stresses. The significance of potassium manure for the arrangement of yield production and its quality is known. As a result, potassium utilization has expanded dramatically in many locales of the world [67].

The impact of four irrigation water salinities; EC_{iw} (1.25, 2.5, 5 and 10 $dS\ m^{-1}$) and four potassium levels; potassium (0, 40, 80 and 120 $kg\ K_2O\ fed^{-1}$) on yield and some quality parameters and water consumptive use; WCU of tomato grown under Siwa Oasis conditions were investigated by [68]. Increasing the EC_{iw} led to decreasing both of water consumptive use and water use efficiencies. While, under moderate EC_{iw} and high level of potassium enhanced the plant growth parameters, total and marketable yield and water consumptive use. However, the effect of the EC_{iw} on the tested parameters was more pronounced than the effect of the potassium as shown in (Table 2). The influence of salinity levels and methods of potassium application on some of rice plant characteristics was illustrated by [69].

Table 1. Influence of NaCl, potassium and calcium on endives biomass

NaCl (mmol/l)	KSO4 (mmol/l)	CaNO3 (mmol/l)	Plant biomass (g/plant)	Leaf fresh weight (g/plant)	Leaf dry weight (g/plant)	Leaf Length (cm)	Leaf area (dm ² /plant)
0	0	0	317.1	265.0	5.2	40.7	44.9
	0	15	314.7	254.5	6.3	38.1	38.2
	10	0	462.0	387.7	5.1	42.7	119.7
	10	15	262.7	218.0	5.7	37.0	52.1
40	0	0	294.2	246.0	4.9	43.0	74.5
	0	15	336.2	275.3	5.7	42.1	90.8
	10	0	285.7	247.5	5.1	44.2	61.6
	10	15	278.2	244.7	6.1	43.5	36.8

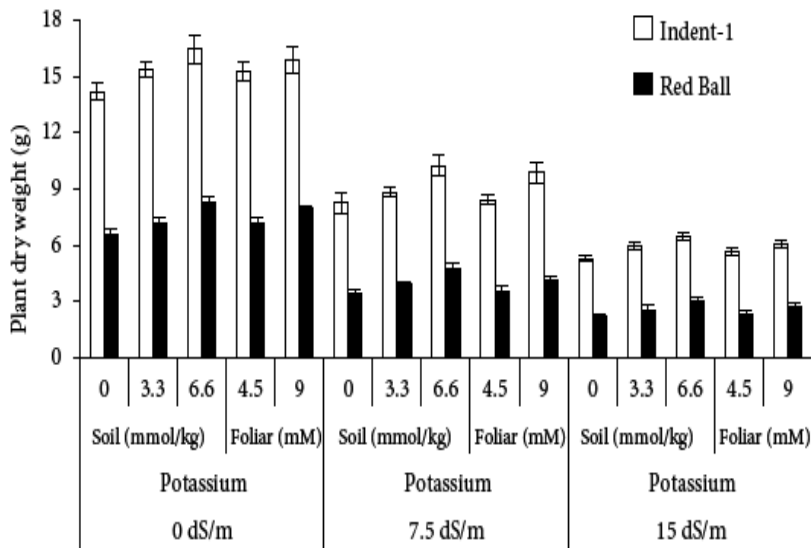


Fig. 5. Plant dry weight of salt-tolerant and salt sensitive tomato

Table 2. Tomato yield as affected by different irrigation water salinity and potassium fertilizer levels

Treatment	Growth and productivity tomato parameters		
	Fresh weight (g plant ⁻¹)	Total yield (ton fed ⁻¹)	Marketable yield (ton fed ⁻¹)
EC (2.5 dSm ⁻¹)	1223.8	16.45	14.55
EC (5.0 dSm ⁻¹)	851.3	12.89	10.23
EC (10 dSm ⁻¹)	642.5	7.65	4.69
2.5 dSm ⁻¹ + K 40 K ₂ O fed ⁻¹	1065	15.60	14.25
2.5 dSm ⁻¹ + K 80 K ₂ O fed ⁻¹	1385	18.00	16.35
2.5 dSm ⁻¹ + K 120 K ₂ O fed ⁻¹	1465	18.20	16.25
5.0 dSm ⁻¹ + K 40 K ₂ O fed ⁻¹	850	12.35	9.90
5.0 dSm ⁻¹ + K 80 K ₂ O fed ⁻¹	885	13.90	10.80
5.0 dSm ⁻¹ + K 120 K ₂ O fed ⁻¹	900	14.10	11.10
10 dSm ⁻¹ + K 40 K ₂ O fed ⁻¹	635	7.65	4.35
10 dSm ⁻¹ + K 80 K ₂ O fed ⁻¹	650	7.90	5.30
10 dSm ⁻¹ + K 120 K ₂ O fed ⁻¹	675	7.85	5.25

The highest grain yield (18.7 g pot⁻¹), straw yield (22.8 g pot⁻¹) were reported in K3 rice cultivar which were supplied with potassium in soil plus foliar spray. This pronounced increase may be attributed to the potassium participation in mechanism of stomata movement, osmo-regulatory adaptation and photosynthesis of plants to water stress in saline soils. Potassium application play a critical role in alleviating of damage of wheat irrigated with saline water rely upon the level of salinity. The yield of the two cultivars significantly diminished as the level of salinity increased. Potassium at a rate of 150 mg K₂O kg⁻¹ soil was effective in decreasing the adversely impact of salinity, particularly at lower levels on yield [70]. Application of potassium levels (50 and 100 kg K ha⁻¹) significantly increased grain yield and dry matter (ton fed⁻¹) as shown in Fig. 6 and revealed by [71]. The potassium-solubilizing plant growth advancing organisms may demonstrate a helpful apparatus in developing approaches to enable plant growth in salt affected soils. Sugar beet crop was developed by combination of potassium with yeast foliar spray and it was observed increase root yield production and white sugar yield, as well as decrease in sodium and α -amino N content under saline soil [72].

Hellal [73] indicated that application of natural K as feldspar enriched with compost at recently reclaimed soil will give high yield and quality close to those obtained by chemical potassium application. Thus, replacing the chemical potassium fertilizers by natural one will help in reducing environmental pollution, cheaper in price and produce safe human food. Fayed [74] concluded that potassium application at rate 120

% of RDF with boron fertilizer at different doses particularly at a rate of 120 % of RDF gradually increased the yield and sugar production of sugar beet, as well as, juice purity and sucrose percentage. The highest growth and yield parameter represented by root and shoot of Turnip and Chard was obtained with 40kg fed-1 applied calcium (Ca) and potassium (K) combined with 0.05 mM salicylic acid (SA) as compared with same levels of Ca and K without SA and control treatment. At 40 days of sowing, Chlorophyll a and Chlorophyll b and carotene of Turnip and Chard significantly increased by Ca and K combined with SA application [75].

6.3 Nutrient Content

Genotypic differences for salt tolerance among the crop cultivars are often clarified on the variety's ability to preclude sodium from root with least imbalance in potassium uptake. The salt tolerant varieties demonstrate a lower Na: K proportion all through an extensive cultivar of saline conditions [76]. Potassium addition to a saline culture solution has been found to increase potassium content in plant parts that corresponds with low in sodium content. Salt resistance is not depending on the absolute amount of sodium per se, but rather the cytosolic K⁺/Na⁺ ratio that determines plant salt tolerance [5]. This lessening is credited to both diminished mobility of potassium in the soil, decreased transpiration rate, and disabled movement of root membrane transporters [77]. Potassium is one of the three Macro primary nutrients which is necessary for plant growth grown under different levels of salinity. Hai Yun Li [78] indicate that addition of K⁺ increased K⁺ concentrations and

suppressed sodium (Na^+) concentration, which eventually increased the K^+/Na^+ ratios in roots or shoots. Application of K^+ enhanced the uptake of K^+ and suppressed the uptake of Na^+ . Moreover, the ratios of shoot- $\text{K}^+/\text{root-}\text{K}^+$ increased considerably, but the ratios of shoot- $\text{Na}^+/\text{root-}\text{Na}^+$ decreased in response to K^+ application.

Leaf tissue potassium and sodium and potassium: sodium was affected significantly by the application of potassium as revealed by [71]. Sodium and potassium had been affected significantly by the soil potassium interaction but (Ca+Mg) and potassium: sodium ratio had been affected non-significantly. Leaf tissue sodium decreases consistently but potassium increases by application of 50 and 100 kg potassium ha^{-1} at both the sites (Table 3). Sodium uptake was reduced by the uptake of potassium by wheat resulting in significant increase in potassium: sodium ratio of leaf tissues which might have enhanced grain yield production by lowering sodium toxicity.

Plant macronutrient (N and Ca) status is affected by foliar and soil application. Generally, macronutrient concentration of plant was decreased significantly by increasing of salinity in salt-tolerant and salt-sensitive plants, with a

significantly greater decrease in the salt sensitive group compared to the salt-tolerant plants. Macronutrient concentrations of the leaf were increased significantly by application of potassium in both soil and leaves, with significantly higher concentrations in the salt-tolerant group [66]. Uptake of essential nutrients like potassium calcium, magnesium and phosphorus in saline soils was increased by the application of 200 mM K_2SO_4 that was proved by [65].

Consequently, the utilization of potassium solubilizing, plant growth–advancing organisms in agronomic practice would not only counterbalance the high production cost of potassium applied fertilizers, yet in addition change the insoluble potassium in the soil or in fertilizers applied for crop growth and yield [79]. Salinity increases the Na: Ca ratio in both the soybean genotypes as indicated by [80]. The ratio was decreased substantially by potassium application at all levels of salinity. The increase in K levels decreases the ratio steadily. Sodium, potassium and potassium: sodium ratio in shoot except P and Mg were affected significantly by the potassium addition. The addition of potassium in root significantly affected all other parameters. Other parameters of shoot and root

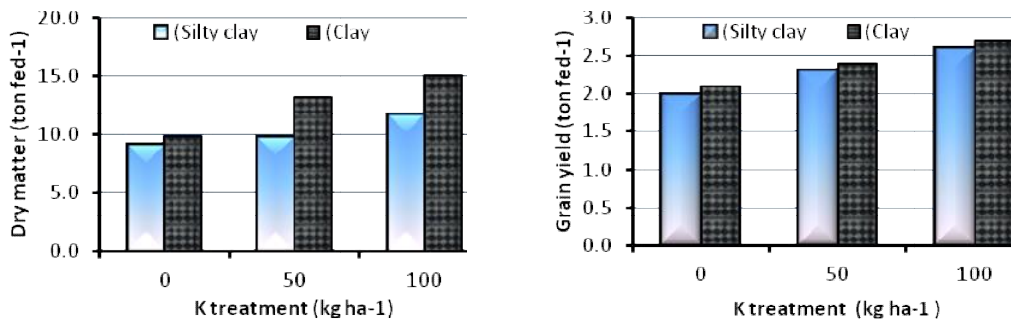


Fig. 6. Wheat grain yields as affected by K application to saline soils

Table 3. Nutrient content of Wheat as affected by K application to saline soils

Treatment K (kg ha ⁻¹)	Leaf tissue composition (mmol kg ⁻¹)			
	K	Na	Ca+Mg	K:Na
Site 1 (Silty clay loam saline-Sodic soil)				
0	420.3	54.5	1433	7.79
50	527.2	46.6	1533	11.4
100	668.4	33.6	1633	19.9
Site 2 (Clay loam saline soil)				
0	428.6	89.7	1500	4.78
50	474.3	62.6	1533	7.62
100	499.1	36.1	1767	14.2

EC 4.23 dS m⁻¹ for Site 1 and 3.2 for site 2

tissue could not be affected by the EC_{iw} x potassium interaction. The Phosphorus with potassium interactions significantly affected calcium and magnesium in root tissue. Calcium and magnesium in root tissue were affected significantly by the phosphorus with potassium interactions. EC_i x P_w x potassium interaction didn't effect on all other parameters, except Mg in shoot and Ca and Mg in root tissue by [81].

7. CONCLUSION

Potassium (K) is an essential nutrient and is also the most abundant cation in plants. Potassium plays a critical role in plant growth and metabolism, and it contributes significantly to the survival of plants under various biotic and abiotic stresses. Potassium fertilizer is very important for crop production and quality. Potassium deficiency can occur under salt stress because the high concentrations of Na inhibit K activity in the soil solution, result in a decrease of K availability. Sodium also interferes with K translocation from root to shoot, especially at low K status. Under salt stress, the plasma membrane disintegrates and favors K leaking, resulting in a rapid decline in cytosolic K. Increase in K supply corresponded with higher K accumulation in plant tissue, which reduced Na concentration and resulted in a higher K/Na ratio and could enhance the salt tolerance in crops.

DISCLAIMER

This paper is based on preliminary dataset. Readers are requested to consider this paper as preliminary research article, as authors wanted to publish the initial data as early as possible. Authors are aware that detailed statistical analysis is required to get a scientifically established conclusion. Readers are requested to use the conclusion of this paper judiciously as statistical analysis is absent. Authors also recommend detailed statistical analysis for similar future studies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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