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Original Research Article

Using AMUN_Sihc for Modeling the Plant Silicon Hydraulic Capacitance and Passive Uptake Under Drought and Saline Conditions

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Abstract

The soil water hydraulic capacitance, β, a tank like the plant water reservoir, is being controlled by signals, valves like the switches. There are three types of signaling devices control the mass flow of water and nutrients, Geo, Bio, and weather controlled. The Darcian flow of water carries with its nutrients toward root in accordance with their concentration. The property of soil hydraulic capacitance determines the type of root water and nutrient uptake under drought and saline conditions in accordance with stress, strain and weather-controlled forces. It was first discovered by the author when modeling the wheat root water uptake under drought and saline stress conditions. Treating plants with silica products was the common managerial practice used for enhancing uptake and plantation under the extreme drought and saline conditions. As the silicon uptake process is mainly passive with mass flow, the term β was modified to express the process of silicon passive uptake as each soil skeleton type has its unique concentration of silica due to its mineralogical decomposition. Silicon hydraulic capacitance, B_Si represents the fast reservoir of the soluble form of silica ready for root uptake and translocation to do its best for combating the adverse impacts of global climatic changes on the agro ecosystem's continuum such as water and nutrients deficits, salinity stress, heat sock, and diseases. AMUN_SiHC model which is created to calculate the soil water and silicon hydraulic capacitance and uptake, was derived, run, and discussed.

Keywords: Silicon passive uptake, Silicon hydraulic capacitance, Drought, Salinity

Abbreviations: β: Soil Water Hydraulic Capacitance; β_Si: Silicon Hydraulic Capacitance; RPD: Partial Root Zone Drying; MENA: Middle East North Africa Countries; AMUN_SiHC: FORTRAN Code for Calculating Soil Water and Silicon Hydraulic Capacitance and Uptake; SSI: Soil Stress Index; PSI: Plant Stress Index; Tp: Potential Transpiration

INTRODUCTION

Soil moisture reservoir represents the plant available water affects the recharge of aquifers capacitors. It is also a vital source of upward atmospheric humidity and accordingly, the downward precipitation. Soil moisture contributes to regulating the global energy balance of terrestrial ecosystems, controlling soil temperature, air humidity, and surface albedo [1]. Moisture deficit causes drought attack. By the year 2030, the global climate change will be changing the half of the world's population to be lived in areas of water scarcity. In some arid and semi-arid regions, it will displace up to 24: 700 million people due to water stress problem [2]. United Nations [2] chose the decade 2010-2020 for the fight against desertification. This is because the following reasons: 41.3% of the earth surfaces are drylands, approximately 44% of all the world's cultivated area located in the dry lands. The desertification, land degradation may cause severe dust storms, which can lead to respiratory diseases and other health problems [3]. Drought threats more than 1 billion people from the 2.1 billion people who live in the dry regions and responsible for an income loss of US$42 billion per year. In the most dried year, the cropping season 2009/2010, most of the world cropland faced severe drought waves which affected the crop productivity.

Soil salinization can be enhanced by the climatic changes, rising temperatures, increase soil evaporation, and crop water requirements. The coastal regions are vulnerable to see water intrusion, thereby deteriorating the coastal aquifers. The extreme storms and tsunamis waves can flow overland resulting in saltwater infiltration into soils contaminating soil and water resources [4]. The problems of arid zones and their accompying results, salinization and desertification, are highlighted in the countries where no renewable water resources exist such as Libya [5], Saudia Arabia [6] and Kwait [7].

Robinson [1] defined soil hydraulic function as the ability of soils to store water to serve the moisture pool that sustains the agro ecosystem system. They said that soil hydraulic functions are always estimated as static property, such as relating to hydraulic conductivity and soil water retention.

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They neglect the interaction between the agro-ecosystem components which do their best either alone or in combination reducing the moisture deficit signal. The soil living organisms could change soil structural and accordingly the moisture deficit. As soil available water decreases due to drought and salinity stress conditions, the agro-ecosystem components, plant and soil, start to do on their relative extreme response functions. The relative extremes may be achieved by root through choosing the easiest bath to navigate soil system, categorizing the energy states of soil water, preferring the easiest available water to water, and following model of minimizing the consumed energy for combating stress conditions. The interaction between ecosystem components, plant and soil; due to drought cycles, the soil is shrinking its energy now to the half of its value at the wetting cycles to save plant's life and prevent the hydrological release. By limiting crown roots number per plant, plant causes a degree of response towards the drought stress, a compensatory growth in existing roots, which subsequently reaches deeper soil layers, categorizing the energy states of soil water seeking the easiest available water and nutrient for compensation. In tillering crops such as wheat, a drying soil was found to limit root growth at the top 30 cm using the hydraulic signal for increasing cell wall elastic modulus and maintaining turgidity while promoting root extension and growth into depth.

Estimating the root water uptake when using the stress form of modified Richard's equation, S= SSI*B, involves the term soil water hydraulic capacitance. SWHC represents the response of the soil moisture reservoir toward a certain plant water demand under a certain atmospheric condition. Soil profile consists of layered capacitors. Each of which is recharged during the precipitation, irrigation, capillarity, or water table rise forming the constant shaped soil moisture profile after moisture redistribution. The easily available water is being stressed by discharging the soil capacitors during the root water uptake creating the variably saturated zone. In between the sink/source terms of Richard's equation, the discharge/ recharge terms of soil capacitors or the root uptake, hydrological release terms, root navigates soil capacitors categorizing their energy states to select what has the easiest available water and bath to pass and water by exerting a minimum consumed energy. SHC depends on soil genesis, plant species, varieties, ages, adaptability, atmospheric conditions, and the high tensile strength of liquid phase. Under deficit irrigation and or the harsh extreme conditions of aridsols, SHC determines the types of water uptake in accordance with weathering induced stress-strain signaling devices [8]. The latter devices are being regulated for the sake of preventing the hydrological release and complete the life cycle.

It had been the big bang separated planet earth from star sun. The separated mass had cooled and the basic element had cocked in a hydrothermal environment to form minerals [9,10]. Silicon and aluminum bonded with oxygen forming silica tetrahedron and alumina octahedron, the basic units of clay minerals with their distinguishable isomorphs' substitution [11]. The merciful behavior between silicon as a basic soil skeleton constituent and mankind as a clayey apped creature, under harsh extreme stress conditions, may be summarized as dust support dust in order to let the life continue [12]. Silicon the second abundant element in earth's crust, the beneficial functional nutrient element for human, animal, and plant is from the types of environmental managerial practices should have been taken into consideration when dealing with the natural abiotic stress of drought and salinity due to global climatic changes or artificial one due to irrigation deficit scenario because of the three incoming reasons:

- Since the geo-signal is being induced by more compacted electric double layer, hysteric behavior and the Albert Ainkhtien's relativity of clayey lattice [8].
- As the bio signal is being induced by osmoregulation strain and turgidity strain [12].
- As the weather controlled signaling device is being induced by canopy evaporative demand [13].

Silicon enhances the overall signaling devices to be in favorable states under the abiotic stress conditions. It deposits in tricombs enhancing its function in cooling leaves acting as antenna reflects the solar short incoming radiation. Treating the sulfuric acid aerosols in the stratosphere with silica aerosols reduces significantly the short incoming radiation. Accordingly, increases the Mie scattering in the stratosphere. Accordingly, reducing the impact of global temperature rise by cooling the atmosphere in general and plant canopy in particular. However, the silicon aerosols are an effective managerial practice for albedo modification, particular technology should be adopted control the silicon radioactivity.

Silicon deposits in root enhancing the plant roots to be in a higher negative potential state for overcoming the total potential of soil water. The siliceous nutrition of plants is not only scientifically intriguing but also important in a world where more food will have to be wrung from a finite area of land especially for the deficit irrigation and partial root zone drying scenarios which will put crops under stress [14-16].

In the agro-lands of MENA countries with marine and lacustrine origins, the overexploitation of groundwater under the conditions of water scarcity and global climatic changes causes the intrusion of seawater [4]. As the saline water intrudes the variably saturated zone under a harsh extreme condition, the potentially guided Darian flow charges the capacitors from the bottom upwardly. Charging the capacitors in the electrical model defined by Hillel [17] is different than that of the AMUN_SHC electrical model defined by Hegazy [18] as the former did not consider that water quality affects its uptake. For instance, the water salinity decreases the availability of irrigation water.

AMUN_SHC model takes the concept of total energy states into consideration. Assessing the impact of specific ion toxicity has a certain value of salt index under abiotic stress conditions may be achieved by making SSI speciation. The latter speciation may be done in order to know the combined stress of drought, salinity and specific ion effects such as in the case of using potassium chloride instead of potassium sulfate fertilizers. SSI speciation, SSIS, is still under investigation. Moreover, SSIS needs to be validated when assessing the impact of saline contaminated groundwater with iron and manganese on plant growth under deficit irrigation scenario.

The plant response under environmental abiotic stressed conditions could be discussed from the side of dynamics in plant roots and shoots used to minimize stress, reduce consumed energy, and maintain water and nutrient uptake [19,20]. Firstly, plant enhances the uptake of nutrient element responsible for combating abiotic stress, silicon. Secondly, the beneficial functional element, silicon, interact positively with macro and micronutrient and stimulate the biophysical functions inside plant's tissues [14]. Thirdly, Silicon also appears to be a part of the osmoregulation within cells subjected to drought stress which enables the plant to uptake and transpirate more water for combating the stressed conditions [21]. Fourthly, the wheat's hydraulic signal reduces water loss via transpiration by decreasing leaf area index and increasing leaves rolling [22]. Fifthly, the adaptive root growth [23], the compensated root water uptake [24], and root hydraulic redistribution to cope with the heterogeneity in soil moisture regime [25]. Under such conditions. It makes sense to but silicon uptake in one side and other nutrients and water uptake in the other in order to complete the plant life and prevent the hydrological release.

The object of this research is to quantify the Darcian silicon uptake by changing the water uptake response function, S= [β, SSI], to be the silicon Darcian uptake response function, Si_Up= [β_Si, SSI]. Silicon, the master element under such stress conditions, may be correlated with other nutrients and water uptake.

MATERIAL AND METHODS

Drought and salinity were managed by foliar spraying of silica products as potassium silicates and sodium silicates in three concentrations 0.0, 30.6, and 40.8 ppm. All of them were foliar sprayed at ages of 40, 60, and 75 days from seed emergence at the early morning. The 6 treatment combinations were distributed in 3 salinity levels, 3.12, 4.82, and 5.12 dS/m, in a split-split plot design with four replicates. Soil hydro physical properties and water flow parameters were estimated by HYDRUS-1D [Vr. 4.17] at depth z dimension [26]. ETC was calculated from metrological data according to FAO [27]. The irrigation interval each 20: 25 day. The relation between soil stress index and plant stress index was developed according to Hegazy [8]. The AMUN_SiHC was built and run to calculate silicon hydraulic capacitance, β_Si **(Figure 1).**

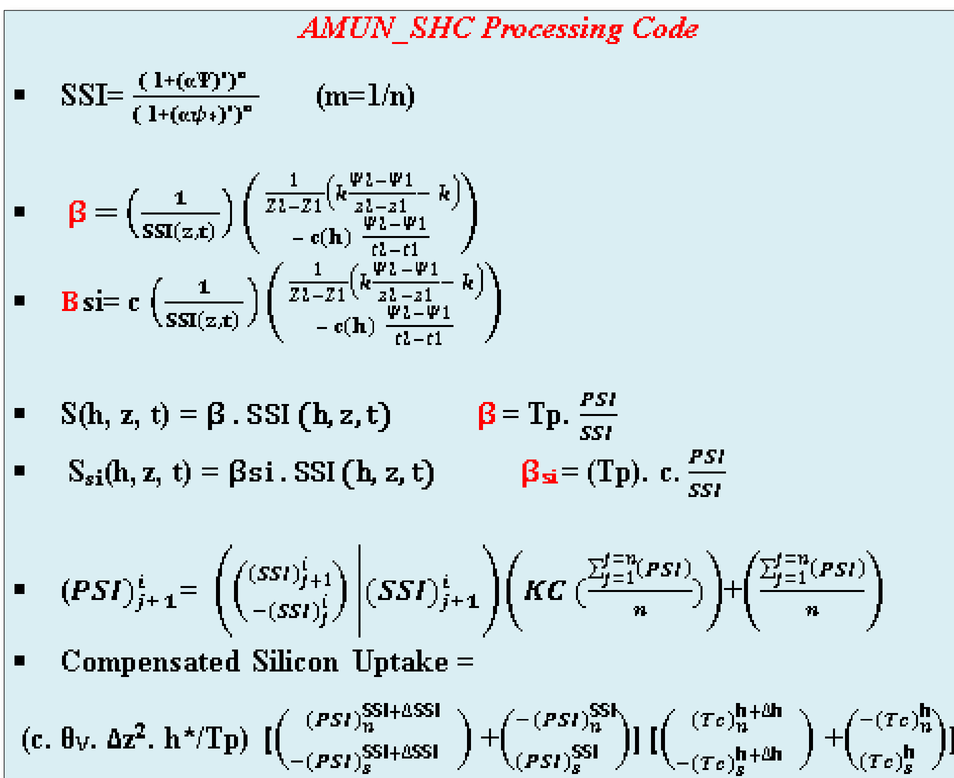

Figure 1. AMUN_SHC Processing Code.

All the read input parameter was taken, processed to output PSI, SSI, β, β_Si, and Si_Up, and by run the program according to Hegazy [13].

RESULTS AND DISCUSSION

Figure 2 indicated that silicon hydraulic capacitance [SiHC] and therefore passive silicon uptake [Si_Up] decreases. Whereas the slightly saline soils have SiHC much more than saline ones and so as in the case of irrigation water. Accordingly, seawater intrusion diminishes the SiHC with the exception for the case of special soil, water, and plant managerial practices such as leaching and drainage for soil, magnetism for water, and silicon foliar application and gene transfer for the plant which use to raise SHC, Si_HC, and Si_Up in some degree of extend. In halophytes, PSI is always greater than SSI. Accordingly, SiHC and all the related parameter will be exceeded, according to the Tp and the opposite is true in sensitive plants. As silicon concentrates straw sap, it makes the root sap more strained. Therefore, silicon allowed plants to withstand abiotic stress by shaking down the limits of actual stress plant roots may bear from the log phase until disappear. SiHC in control treatment is higher than in silicon treatments. The latter means that SSI is greater than PSI. Moreover, a little pulse of environmental abiotic stress will cause a greater negative response on crop yield without silica fertilization. Potassium silicate is better than sodium silicate in the latter manner because the soil under investigation is rich in clay mineral fixes potassium between its layers, Attapulgite **(Figure 2)**. As SiHC reveals the overall interaction between the ecosystem components the managerial practices affect the plant, soil and atmosphere and their interaction each to other may affect it. Treating the plant and soil with silica affects SiHC **(Figure 2).**

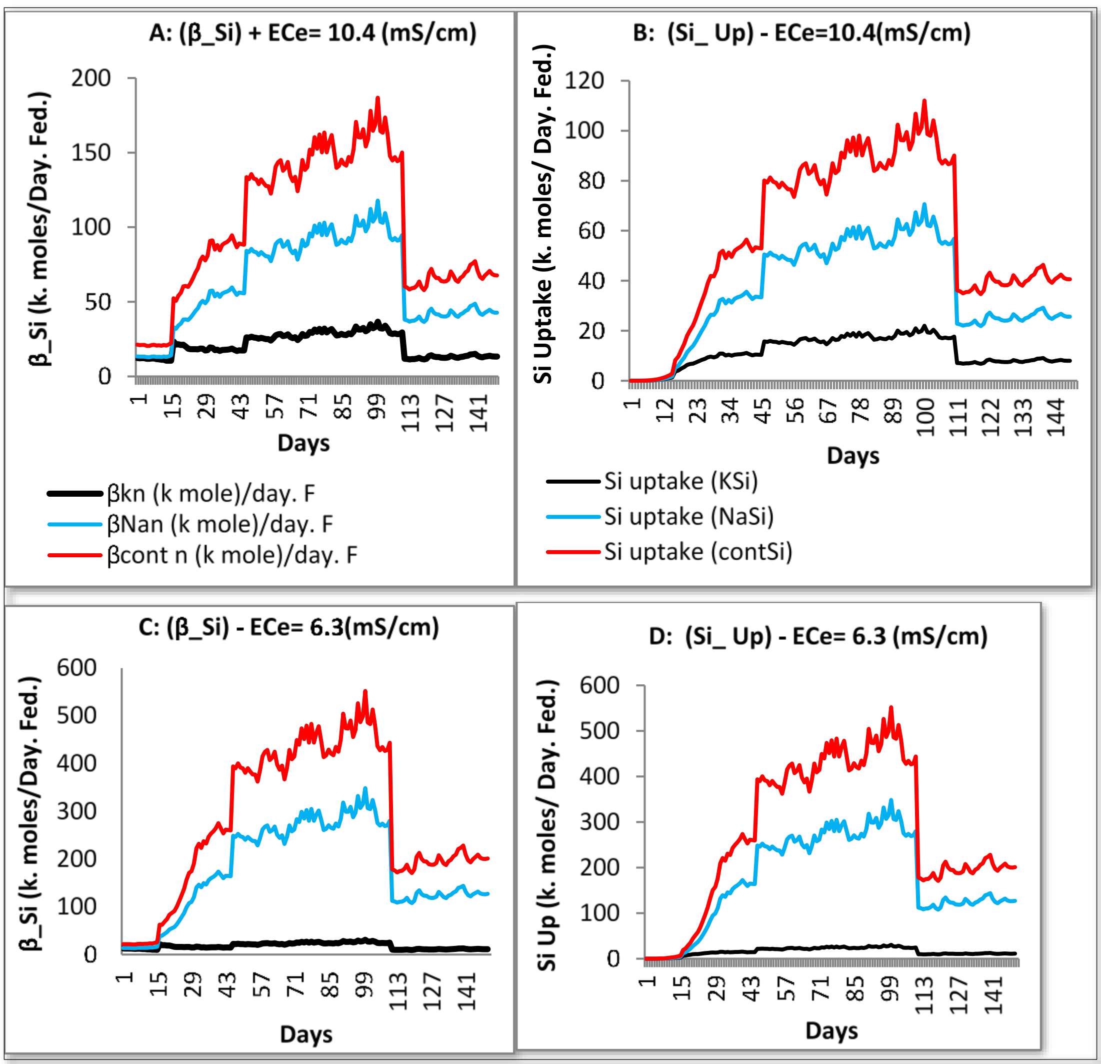

Figure 2. [A]: Silicon hydraulic capacitance, [β_Si], for saline soil ECe= 10.4. [B]: Silicon passive uptake, Si_ Up, for saline soil ECe= 10.4. [C]: Silicon hydraulic capacitance, [β_Si], for non-saline soil, ECe= 6.3. [D]: Silicon passive uptake, Si_ Up, for non-saline soil ECe= 6.3. The unit of both β_Si and Si_Up is K. moles/ Day. Fed.

CONCLUSION

AMUN_SHC was modified to calculate the silicon hydraulic capacitance and mass flow passive silicon uptake, AMUN_SiHC. The latter was achieved by replacing β with β_Si. The data clearly showed the positive interaction between silicon uptake and soil hydraulic capacitance under abiotic stress conditions. Silicon plays a vital role in reducing the side effects of climatic changes on the agro ecosystem continuum. As silicon is the master nutrient element under the studied abiotic stress conditions, predicting of other nutrient dynamic toward root may be achieved by correlating them to silicon uptake.

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