
Response of *Jatropha integerrima* Plants Irrigated with Different Levels of Saline Water to Nano Silicon and Gypsum

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Abstract

An open field experiment was carried out during 2015 and 2016 seasons at the experimental nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Egypt. The purpose of present research was to investigate the effect of foliar application of nano silicon with different concentrations and gypsum soil application on growth, flowering and chemical constituents of *Jatropha integerrima* plants irrigated with different levels of saline water. The concentrations of saline water were (1000, 2000 and 4000 ppm), in addition to tap water (270 ppm) as a control, simultaneously plants were received monthly foliar application of nano silicon 1 and 2 mM or soil application of gypsum at 20 g/plant, either applied individually or in combination.

The results showed that, elevating salt concentration in irrigation water decreased vegetative growth characteristics, flowering traits, leaves anatomy and chemical constituents. In contrast, increasing salinity of irrigation water boosted contents of proline, Ca%, Na%, Cl%, total phenolic and flavonoids. On the other hand, foliar application of nano silicon and soil addition of gypsum treatments either individually or in combination had favorable effects on enhancing vegetative parameters and chemical constituents, meanwhile decreasing accumulation of Na%,

Cl⁻, total phenolic and flavonoids in leaves. It can be concluded that, foliar spray of nano silicon combined with soil addition of gypsum was the best effective and economic treatment recommended for mitigating the harmful effect of salinity stress on *Jatropha* plants irrigated with saline water at concentration up to 4000 ppm.

Keywords: *Jatropha integerrima*, water salinity stress, nano silicon, gypsum.

1. Introduction

Jatropha integerrima Jacq. (syn. *J. panduraefolia*) is an evergreen woody shrub or small tree belongs to the family of Euphorbiaceae. It is native to West Indies, Cuba and widely cultivated in many tropical and subtropical countries. It is commonly known as peregrina or spicy jatropha and firecracker. Plants are reaching 3-4.5 m tall and 2 -3 m wide with slender, graceful branches. The leaves are 10-20 cm long and 3-8 cm wide, simple, alternate, green in color, entire margins with cuspidate or acuminate tip and sometimes have three-lobed. The flowers are in cymes and borne in terminal clusters, measuring about 2.5 cm wide, they are star-shaped with five-petal bright crimson-red in color and filled centrally with yellow stamens. Plant flowers in late spring and summer and almost extended throughout the year. The fruits are capsules, greenish red in color, oval-shaped, measuring about 1 cm in diameter and length. Seeds are small, ovoid and brown with dark dots, 8 mm long (Ghani, 2003; Ratha and Paramathma, 2009 and Kolawole *et al.*, 2016). In addition to utilize of *J. integerrima* for landscape as a flowering ornamental shrubs, it has been reported to be traditionally used as purgative, styptic and emetic, and in treatment of warts, tumor, rheumatism, herpes, pruritis, toothache, scabies, eczema, and ringworm (Akhter *et al.* 2008; Sharma and Singh, 2013).

Unequivocal, salinity is considered one of the main abiotic stresses reduce growth and production of plants. According to (Abbasi *et al.* 2016) the harmful effect of salinity stress on plant growth can be divided into four aspects; (i) Osmotic effect, salinity causes a reduction in the osmotic potential of the soil solution that reduces plant water uptake. (ii) Specific ion effects, resulting from accumulation of certain toxic ions to a level at which inhibit plant growth. (iii) Nutritional imbalance, resulting from competition of Na⁺ and Cl⁻ ions in soil solution with the uptake of other nutrients ions such as K⁺, Ca²⁺ and Mn²⁺ that resulting in excessive accumulation of Na⁺ and Cl⁻ in plant cells and reduced such important nutrients needed for essential metabolic processes. (iv) Production of reactive oxygen species (ROS), such as superoxide (O₂⁻), hydrogen peroxide (H₂O₂), hydroxyl radical (HO⁻) and singlet oxygen (¹O₂) that increased under salt stress and its accumulation in the chloroplasts and other organelles enhance lipid peroxidation, proteins oxidation, enzyme inhibition and DNA mutation which in turn causes chloroplast damages and inhibits photochemical reactions and photosynthesis.

Gypsum (calcium sulfate dehydrate) is a mineral form occurs in nature by precipitating dissolve calcium sulfate due to evaporation of soil water in arid and semiarid climate conditions. The most-important property of gypsum relating to agricultural applications is its solubility, low cost, availability and ease of handling. Gypsum consider is an organic soil amendment or nutrition as a source of Ca and S, changes structure and fertility of heavy clay soils, improves soil infiltration and drainage, decreases acidity and eliminate sodium-affected soils by removing sodium form the soil and replacing it with calcium (Korcak,1993; Chen and Dick, 2011). Various studies on the effect of gypsum application on saline-sodic soil have been showed that, gypsum removes the

greatest amount of Na^+ from the soil and causes a substantial decrease in soil pH, electrical conductivity (EC) and exchangeable sodium percentage (Qadir *et al.* 1996; Makoi and Verplancke, 2010; Cucci *et al.* 2012 and Negim, 2015). It has been reported that gypsum addition to salinity stressed of some plants increased plant height, stem diameter, number of leaves, leaf area, root length and fresh and dry weight of the aboveground parts and roots as well as increased total chlorophylls, carbohydrates and NPK contents, while caused a reduction in the accumulation of Na^+ and Cl^- toxic ions in plant tissues (Picchioni *et al.* 2004; Mazhar *et al.* 2011; Habba *et al.* 2013 and Abdel Fattah *et al.* 2014)

Recently, use of Nanoparticles (NPs) has been broadly exploited in the agricultural system throughout the world. NPs Nanomaterials usually consist of particles smaller than 100 nm and their extreme small size implicates new physical, chemical and biological properties as they have higher surface area, solubility and surface reactivity than bulk counterpart materials. NPs interact with plants causing various changes in morphological and physiological traits of the plants, depending on the particles properties, plant species and the concentration at which the responses may differ from plant to other (Ruffini and Cremonini, 2009; Siddiqui *et al.*, 2015). Nano- SiO_2 particles are one of NPs take a great concern by researchers in agricultural practices during the last few years. Silicon is a beneficial element plays vital role for rigidity, mechanical strength, plant growth and development and induced plant's resistance against many abiotic stresses such as salinity, drought, heavy metal toxicities, high temperature and cold stress as well as enhanced the resistance against pests and diseases caused by both fungi and bacteria in different plant species (Ma, 2004; Liang *et al.*, 2007 and Vasanthi *et al.*, 2014). Nano- SiO_2 particles have greater spread in wide area, one gram of such particles exhibit wide absorption surface equal to 400 m^2 , so they absorbed better and faster than Si in bulk materials which leads to immediately utilized by plants to achieve their growth and development. Strategy or mechanism at which nano- SiO_2 particles adopts to mitigate salinity stress on plants is reducing the absorption and accumulation of Na^+ toxic ion in plant organs as well as inducing enzymatic and non-enzymatic antioxidant defense systems protected cells from oxidative damage caused by reactive oxygen species (Abdul Qados, 2015 and Saxena *et al.* 2016). Previous studies revealed that, exogenous application of nano- SiO_2 to some plants in non-stressed conditions increased vegetative growth traits, chlorophylls content, nutrients content, soluble protein, free amino acids, antioxidant enzymes activity, stomatal regulation and gas exchange (Bao-shan *et al.* 2004; Li *et al.* 2012; Xie *et al.* 2012 and Janmohammadi *et al.* 2016). Under salinity stress conditions it has been showed that nano- SiO_2 application increased leaf fresh and dry weight, chlorophylls content, proline accumulation, while reducing the accumulation of Na^+ toxic ion in plant organs (Kaltah *et al.* 2014) . Although, the effect of nano- SiO_2 on alleviating the adverse effect of salinity stress on different crop plants have been carried out by various studies (Siddiqui *et al.* 2014; Sabaghnia and Janmohammadi *et al.* 2015; Tantawy *et al.* 2015 and Almutairi, 2016). However, there are no available researches about its influences on salinity stressed many plant species including ornamental shrubs.

Hence, the objective of this work was to study possibility alleviation of salinity stress effects on growth, flowering and chemical constituents of *Jatropha integerrima* plants using nano silicon and gypsum either individually or in combination.

2. Materials and Methods

This study was conducted at the experimental area of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, Egypt during two successive seasons 2015 and 2016.

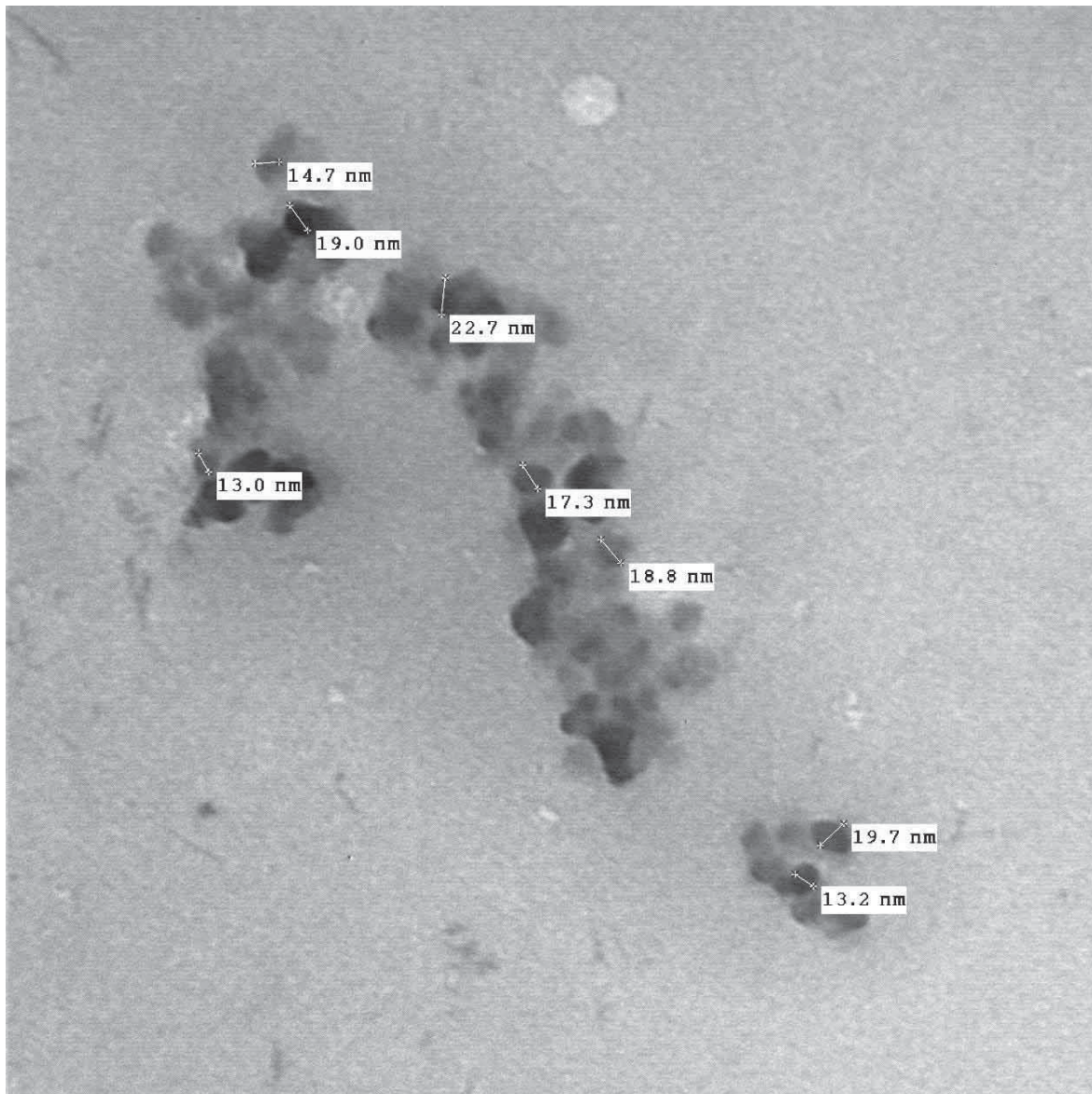
On 15th March, in both seasons, seedlings of *Jatropha integerrima* plants were obtained from a commercial nursery with an average plant height 30 cm and transplanted to open field with a distance 60 cm between rows, and 50 cm spacing between plants in plots 2 x 12.5 m. The physical and chemical properties of soil were carried out as described by (Page *et al.*, 1982) and recorded in Table 1.

Table 1: Some physical and chemical properties of soil mixture used for growing *Jatropha integerrima* during 2015 and 2016 seasons.

| Physical properties | | | | | | | | | | |
|-----------------------|------|----------|-------|-----------------|--------------------|---------------|-----------------|-----------------------|--|--------------|
| Field capacity (% V) | | Clay (%) | | Coarse sand (%) | | Fine sand (%) | | Silt(%) | | Soil texture |
| 29.58 | | 3.4 | | 35.7 | | 53.4 | | 7.5 | | sandy |
| Chemical properties | | | | | | | | | | |
| Macro-nutrients (ppm) | | | | | | | | | | |
| N | P | K | Mg | PH | Organic matter (%) | EC (dS/m) | CEC (meq/100 g) | CaCO ₃ (%) | | |
| 29.17 | 9.17 | 62.78 | 33.98 | 7.12 | 3.17 | 2.75 | 19.64 | 2.44 | | |

Initiation of treatments was started on 15th of April; the plants were subjected to salinity stress irrigation twice/week at concentration of 1000, 2000 and 4000 ppm and tap water (270 ppm, as a control). The different concentrations of saline water were prepared by mixing salts of NaCl and CaCl₂ at the ratio of 1:1 (w/w).

In both seasons, plants received each concentration of saline water treatments were received different additives including, foliar application of silicon nano-particles (NSi, with 5-15 nm and purity of 99.5%) (Fig.1)



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Structure of nano-silicon was done using Scanning Electron Microscope (SEM)

at concentrations of 1 and 2 mM and soil application of gypsum (95% $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, calcium sulfate dihydrate) at 20 g/plant, either applied individually or in combination. While, control plants sprayed only with tap water and without gypsum. Gypsum purchased from Global Company for Supplies fertilizers- lab chemicals, Egypt and added to soil 2 times: after one and five months from planting (the first addition on 15th April and 15th August for the second one).

Silicon nano-particles purchased from Sigma-Aldrich Company and was foliar sprayed every month for 8 times (from 15th April till 15th November). Bio-new film at 1 ml /L was added to the solution of nano particles of silicon as wetting agent and the plants foliage were sprayed until run off point (60 ml of solution/ plant) using plastic atomizer. All plants were fertilized monthly with (NPK 19:19:19) during the growth season at a rate of 2.5 g/plant, and all agricultural practices were performed as recommended during both seasons.

The layout of the experiment was randomized complete blocks design with 24 treatments [4 salt concentrations (including control) X 6 different additives (including control)] each treatment consisting of 12 plants arranged in 4 replicates, each replicate containing 3 plants/treatment.

On 15th December, in both seasons, the experiment was terminated and the vegetative growth characteristics were recorded, including plant height (cm), number of branches/plant, stem diameter (mm, at 5 cm above soil surface), leaf area (cm²), number of leaves, root length (cm), as well as fresh and dry weights of leaves, stems and roots/plant. Also, flowers parameters including number of flowers /plant, fresh and dry weights of flowers (g/ plant), as well chemical constituents including total chlorophylls in fresh leaf using chlorophyll meter Model SPAD 502 (Netto *et al.* 2005). Total carbohydrates content (% of dry matter) was determined in dried leaves samples (Dubois *et al.* 1956). Dried leaves samples were digested to extract nutrients (Piper, 1947), Nitrogen, Potassium, Calcium, Sodium, and Chloride contents [Karla, 1998 and Estefan *et al.* 2013]. The proline content in fresh leaves (μ moles /g fresh matter of leaves) was also determined (Bates *et al.* 1973).

Total phenolic content were determined spectrophotometrically according to the Folin–Ciocalteu colorimetric method and expressed as milligram gallic acid equivalent per gram of leaves dry weight extract (mg GAE/g DW). The flavonoids content was also determined (John *et al.* 2014).

Anatomical studies

At the end of each season (first and second), specimens of leaves were taken and fixed for at least 48 hours in F.A.A. solution (5ml. formalin, 5ml. glacial acetic acid and 90 ml. ethyl alcohol 70%), washed in 50 % ethyl alcohol, dehydrated in a series of ethyl alcohols (70, 90, 95 and 100%), infiltrated in xylene, embedded in paraffin wax of a melting point 60-63 °C (Sass,1950), sectioned to 20 microns in thickness using a rotary microtome, double stained with fast green and safranin, cleared in xylene and mounted in Canada balsam (Johnason, 1940). Sections were microscopically examined using a micrometer eye piece read to detect histological manifestation of noticeable responses resulted from treatments. Averages of readings from 4 slides / treatment were calculated.

The data recoded on vegetative growth, flowering and chemical constituents were subjected to an analysis of variance (ANOVA), and the means of the recorded data were compared using the "Least Significant Difference (LSD)" test at the 0.05 level (Steel *et al.* 1997).

3. Results and Discussion

3.1 Vegetative growth and flowering parameters

Effect of irrigation water salinity: Data recorded on growth and flowering parameters of *Jatropha integerrima* plants (Tables 2 - 4) showed that, salt concentrations in irrigation water

substantially had an adverse effect on growth and flowering performance of plants. Generally in both seasons, all growth and flowering parameters were significantly decreased in parallel with raising salt concentration in irrigation water 1000, 2000 or 4000 ppm, as compared to plants irrigated with tap water (control). However, plant height, number of leaves, fresh and dry weights of leaves as well as dry weights of stems (in second seasons) showed insignificant reduction as a result of irrigation with lower salt concentrations (1000 ppm), whereas higher salt concentrations (2000-4000 ppm) caused significant reduction in recorded mean values as compared to control plants. The obtained results of reduced growth and flowering parameters due to unfavorable effects salt stress are concordant with those obtained by various researches (Hardikar *et al.* 2011; Mobasheri, 2011; Mazhar *et al.* 2012; Niu *et al.* 2012; El-Juhany *et al.* 2014; Ejaz *et al.* 2015; Bahadoran and Salehi, 2015; Abbas *et al.* 2016; Breš *et al.* 2016; Ashour and El-Attar, 2017)

Effect of Additives treatments: The data presented in Tables (2 - 4) revealed that, any of the tested additives treatments had a positive effect on vegetative and flowering parameters of *Jatropha integerrima* plants. Where in both seasons, plants treated with foliar application of nano silicon with both two concentrations (1 or 2 mM) or soil addition of gypsum either applied separately or in combination resulted in significantly higher values for all studied parameters than those recorded with the control plants. Although number of branches/plant as well as fresh and dry weights of stems were recorded insignificant increments over control when sprayed with concentrations of nano silicon (1 mM) in both seasons. The data in Tables (2-4) also indicated that, both concentrations of nano silicon, individually or in combination with gypsum caused a progressive increases for all studied characters. However the combined treatments of nano silicon with gypsum were more effective for increasing mean values of all studied parameters than application each of them separately. Also it was clear that there is no significant difference between application of nano silicon at 1 or 2 mM concentration in most cases. Similar increases in growth and flowers parameters as a result of gypsum treatments have been reported by prior studies (Arafa *et al.* 2002; Kakaraparthi *et al.* 2013; Reddy *et al.* 2014 and Kumar *et al.* 2014) , also such increases due to nano silicon treatments confirmed the reports of other researches (Bao-shan *et al.* 2004; Ashkavand *et al.* 2015; Janmohammadi *et al.* 2016; Sharifi-Rad *et al.* 2016 and Khalaki *et al.* 2016). Additionally, previous studies (Kamenidou and Cavins, 2008 & Sivanesan *et al.* 2013) reported that application of Si in bulk materials (potassium silicate or sodium silicate) increased plants growth and flowering parameters.

The favorable effects of gypsum on vegetative and flowering parameters may be attributed to gypsum supplying readily available Ca and S ions for plant nutrition in addition to improve soil physical and chemical properties by promoting better aggregation, increasing water infiltration and percolation, improving root growth and reclaiming sodic soil by replacing Na with Ca in soil particles (Korcak, 1993, Chen and Dick, 2011). While the proper effect of foliar application of nano silicon particles on vegetative and flowering parameters may be due to its effect on promoting absorption of water and fertilizers, enhancing transport of some elements in xylem sap, increasing enzymes such as nitrate reductase, increasing concentration of IAA hormone and antioxidant activity (Lu *et al.*, 2002; Le *et al.*, 2014).

Interaction between Effects of irrigation water salinity and additives treatments:

From data presented in Tables (2 - 4) it can be noticed that, raising salt concentration in irrigation water caused insightful reduction in vegetative growth and flowering parameters of *Jatropha integerrima* plants. Concerning different salt concentrations, overall, individual application of nano silicon concentrations or soil addition of gypsum rate resulted in insignificant differences values for most studied parameters compared to the values out from control plants (plants irrigated and sprayed with tap water). Meanwhile in both seasons it was remarkable that, plants treated with gypsum only resulted in significantly higher stem diameter and fresh and dry weights of stems than the control plants. However, the combined treatments of nano silicon concentrations with gypsum rate resulted in significantly higher values for the most studied growth and flowering parameters than the values obtained from the control plants. Exception to this general trend were detected in both seasons with the number of leaves as well as dry weights of leaves and roots which had insignificant higher values than control plants. In both seasons the highest values for most different vegetative growth and flowering parameters, were resulted from plants irrigated with tap water and foliar sprayed with nano silicon at 2 mM in combined with soil addition of gypsum at 20 g/plant, whereas the lowest values for growth and flowering parameters were obtained from plants irrigated with the highest salt concentration (4000 ppm) and sprayed with tap water.

Increasing vegetative parameters under salt stressed plants as result of gypsum application are concordant with those obtained by Picchioni *et al.* 2004; Mazhar *et al.* 2011; Habba *et al.* 2013 and Abdel Fattah *et al.* 2014. Also, the slight increases (insignificant) in vegetative growth and flowering parameters of salt stressed plants due to nano silicon treatments are in agreement with those reported by Kalteh *et al.* (2014) who found that nano silicon application increased leaves fresh and dry weights of basil salinity stressed plants. Furthermore, previous studies (Rahimi *et al.* 2011; Bayat *et al.* 2013 ; Mateos-Naranjo *et al.* 2013; Gengmao *et al.* 2015 and Esmaeili *et al.* 2015) reported that application of Si in bulk materials (potassium silicate or sodium silicate) increased growth and flowering parameters of salt stressed ornamental plants.

Based on the above obtained results it can be concluded that, foliar application of nano silicon and soil addition of gypsum either applied separately or in combination ameliorate the adverse effects of salinity stress on *Jatropha integerrima* plants irrigated with saline water at concentration up to 4000 ppm. However, the combined treatments were more effective than single one. Among the combined treatments, foliar spray of nano silicon at 1 mM with soil addition of gypsum at 20 g/plant was the best effective and economic treatment since resulted significantly higher values for most growth and flowering parameters than those obtained from plants irrigated and sprayed with tap water (control plants).

Chemical constituents

Contents of total chlorophylls, total carbohydrates, N% and K%:

Data in Table (5) indicated that, different salt concentrations of irrigation water had a negative effect on the synthesis of total chlorophylls, total carbohydrates N% and K% in leaves of *Jatropha integerrima* plants. Generally in both seasons, recorded mean values for the tested parameters were decreased significantly in response to increasing salt concentration in irrigation

water 1000, 2000 or 4000 ppm compared to the control plants. Excluded to this general trend was detected in both seasons with plants irrigated with the lowest salt concentration (1000 ppm) which gave insignificant lower K% in plant leaves compared with control plants. Similar reductions in total chlorophylls, total carbohydrates N% and K% as a result of raising salt stress are in agreement with the results reported by Sakr, 2008; Mazhar, *et al.* 2012; Soliman *et al.* 2012; Shanan, 2015; Abbas *et al.* 2016; Breš *et al.* 2016 and Ashour and El-Attar, 2017.

The adverse effect of salt stress on total chlorophylls may be attributed to accumulation of toxic ions in plant tissue produces reactive oxygen species that causes damage to chloroplasts and photosynthesis inhibition. The reduction photosynthetic activity under salinity stressed plants due to chlorophylls loss could indirectly lead to decreases in carbohydrates accumulation, while the negative effect of salinity stress on K% may be due to its effect on reducing osmotic potential of soil solution which reduced plant absorption of water and nutrients like K. Furthermore, increases Na⁺ ions in soil solution competing with K⁺ ions and reduces its uptake and accumulation in plant tissues (Abbasi *et al.* 2016).

Concerning the effect of additives treatments, the data presented in Table (5) revealed that, accumulation of total chlorophylls, total carbohydrates, N% and K% in leaves of *Jatropha integerrima* plant was obviously enhanced by different nano silicon and gypsum treatments. In both seasons, foliar application of nano silicon using two concentrations (1 or 2 mM) or soil addition of gypsum at the rate of 20 g /plant either individually or in combination caused significant increase in recorded mean values as compared to control plants. However the combined treatments were more effective in enhancing the synthesis and accumulation of total chlorophylls, total carbohydrates and K% in leaves than individual one. The results of increasing total carbohydrates, N% or K% as a result of gypsum treatments are in conformity with that demonstrated by prior studies (Mora *et al.* 1999; Arafa *et al.* 2002; Lee and Mudge, 2013), while increasing in total chlorophylls, N% or K% as a result of nano silicon treatments are consistent with those reported by other studies (Bao-shan *et al.* 2004; Li *et al.* 2012; Xie *et al.* 2012; Ashkavand *et al.* 2015; Janmohammadi *et al.* 2016, Sharifi-Rad *et al.* 2016). The results of increasing total carbohydrates as a result of nano silicon treatments are disagreement with findings of Ashkavand *et al.* (2015) who reported decreasing in carbohydrate contents due to application of SiO₂ nanoparticles.

Regarding interaction effects between salt concentrations and additives treatments, the data in Table (5) clarified that, under different salt concentrations, the combined treatments of nano silicon concentrations with gypsum appeared to be more effective in accumulation of total chlorophylls, total carbohydrates, N% and K% in leaves than individual one. Also, there is no significant difference recorded between foliar applications of nano silicon either 1 or 2 mM when combined with gypsum. In both seasons, the highest values for total chlorophylls, carbohydrates, N% and K% were resulted from plants irrigated with tap water and foliar sprayed with nano silicon at 2 mM in combined with soil addition of gypsum at 20 g/plant, whereas the lowest values were obtained from plants irrigated with the highest salt concentration (4000 ppm) and sprayed with tap water. These results confirmed those obtained by previous authors (Picchioni *et al.* 2004; Mazhar *et al.* 2011; Habba *et al.* 2013 and Abdel Fattah *et al.* 2014), which reported that, gypsum treatments increased total chlorophylls, total carbohydrates, N% or K% in salinity stressed plants. Also, the results of increasing total chlorophylls in salinity stressed plants due to

nano silicon application are in harmony with those reported by Kalteh *et al.* (2014). Other studies (Bayat *et al.* 2013 ; Mateos-Naranjo *et al.* 2013; Gengmao *et al.* 2015 and Esmaeili *et al.* 2015) reported that application of Si in bulk materials (potassium silicate) resulted in increasing total chlorophylls or K% in salinity stressed plants.

Proline contents and Ca %:

From data in Table (5 and 6) it's possibly discerned that, both proline content and Ca% as well in leaves of *Jatropha integerrima* plants were increased parallel with increasing salt concentrations in irrigated water 1000, 2000 or 4000 ppm as compared to plants irrigated with tap water (control). In both seasons, the increments in both proline content and Ca % in plant leaves were insignificant with the lowest salt concentration (1000 ppm), while higher salt concentrations (2000- 4000 ppm) resulted in significant increases in recorded mean values compared to control plants. The results of increases proline content and Ca % due to salt stress are concordant with those obtained by other researches (Sakr, 2008; Soliman *et al.* 2012; Acosta-Motos *et al.* 2015; Shanan, 2015; Theerawitaya *et al.* 2015 and Ashour and El-Attar, 2017).

The accumulation of proline contents in response to salinity treatments may be due to its protective role in plants as one of the defense mechanisms for overcoming the adverse effects of salt stress and increasing stress tolerance. In addition to proline enhances the activities of different enzymes; maintain cell turgor pressure necessary for cell expansion during stress conditions and osmotic balance, it also has the ability to scavenge reactive oxygen species (ROS) and other free radical compounds, thereby ensuring membrane stabilization and preventing protein denaturation during severe osmotic stress (Szabados and Saviouré, 2010; Hayat *et al.* 2012).

As for the effect of additives treatments data in Table (5 and 6) indicated that in both seasons, treating plants with different nano silicon concentrations and gypsum rate either individually or in combination caused significant increase in proline content and Ca % in leaves of *Jatropha integerrima* plant as a compared to control. The data also showed that when nano silicon was applied at two concentrations, their combination with gypsum rate were more effective for increasing the accumulation of proline content and Ca % in leaves than application each of them singly. Similar increases in proline contents or Ca% as a result of gypsum treatments have been reported by previous studies (Mora *et al.* 1999; Lee and Mudge 2013 and Sekar, 2016). Also, increases proline contents as a result of nano silicon treatments are in agreement with the results obtained by Sharifi-Rad *et al.* (2016).

Concerning the interaction effects between salt concentrations and additives treatments, the data in Table (5 and 6) showed that both seasons, the lowest values of proline content and Ca% were resulted from plants irrigated with tap water and sprayed with tap water (control). On the other hand, the highest values were obtained from plants irrigated with saline water at concentration 4000 ppm and treated with foliar application of nano silicon at 2 mM in combined with soil application of gypsum at 20 g/plant. Moreover in both seasons, plants irrigated with saline water 1000, 2000 or 4000 ppm and treated with either nano silicon or gypsum either applied individually or in combination resulted in significantly higher values of proline contents or Ca% in leaves than those recorded with the control plants (plants irrigated and sprayed with tap water). These results are in accordance with those obtained by prior researches (Picchioni *et al.* 2004;

Mazhar *et al.* 2011 and Habba *et al.* 2013) who found that increases in proline contents or Ca% in salt stressed plants as a result of gypsum treatments. Likewise, similar findings have been documented that nano silicon able to increase contents of proline in plants grown under salinity conditions (Kalteh *et al.* 2014).

Na and Cl %

Going along with data presented in Table (6) we can conclude that, generally raising salt concentration in irrigation water 1000, 2000 or 4000 ppm caused significant increases in Na and Cl % in leaves of *Jatropha integerrima* plants compared to control. However, in the second season plants irrigated with saline water at the lowest concentration (1000 ppm) led to insignificantly higher Cl% in their leaves than those recorded with the control plants. The results of increased Na% and Cl% with increasing salt concentrations are in agreement with findings of many previous studies (Immanuel and Ganapathy. 2007; El-Juhany *et al.* 2008; Ramezani, *et al.* 2011; Ali *et al.* 2014; Shanan, 2015; Bahadoran and Salehi, 2015; Acosta-Motos *et al.* 2015; Breš *et al.* 2016; Abbas *et al.* 2016 and Ashour and El-Attar, 2017).

The reduction in different growth and flowering parameters of *Jatropha integerrima* plants as a result of increasing salt concentration in irrigation water may be attributed to accumulation of Na⁺ and Cl⁻ toxic ions in soil and leaves causes osmotic stress, ion toxicity, nutritional imbalance and formation of reactive oxygen species which caused oxidative damages in various cellular components such as proteins, lipids and DNA as well as reduction in various physiological and metabolic processes (Sharma *et al.* 2012, Gupta and Huang, 2014, Abbasi *et al.* 2016). Such troubles lead to low vegetative biomass that consequently leads to low flowering parameters.

Also, it is obvious from data presented in Table (6) that the effect of additives treatments had a markedly effect on the uptake and accumulation of Na and Cl in leaves of *Jatropha integerrima* plant. In both seasons, foliar application of nano silicon concentrations and soil addition of gypsum either separately or in combination resulted in significant reduction in the mean values of Na and Cl % in leaves compared to control plants. Additionally, The data showed that the combined treatments of nano silicon with gypsum was more effective for decreasing Na and Cl % in leaves than applied each one individually. The results of reduced Na% due to application of gypsum are in agreement with findings of Lee and Mudge (2013) which demonstrated that application of gypsum treatments resulted in reduction in Na % in plant tissue.

About the interaction effects between salt concentrations and additives treatments, the data in Table (6) indicated that, in both seasons, the highest values of Na and Cl % were recorded with plants irrigated with saline water at the highest concentration (4000 ppm) and sprayed with tap water. The data also in Table (6) generally cleared that, in both seasons treating plants irrigated with saline water concentrations (1000-4000 ppm) with nano silicon or gypsum either applied individually or in combination resulted in significantly lower values of Na and Cl% ions in leaves than that produced from control plants. Moreover, in both seasons application of nano silicon in combined with gypsum was more effective in reducing Na and Cl% than application each of them separately.

Similar results have been obtained by other studies (Mazhar *et al.* 2011; Habba *et al.* 2013 and

Abdel Fattah *et al.* 2014)] which reported that, decreases in accumulation of Na % or Cl% in salt stressed plants as a result of gypsum treatments. Also previous researches (Gengmao *et al.* 2015 and Esmaeili *et al.* 2015) reported that application of Si in bulk materials (potassium silicate) reduced Na % in salinity stressed plants.

Total phenolic and flavonoids content

Data recorded in Table (6) manifestly that, total phenolic and flavonoids content were generally increased significantly as a result of increasing salt concentration in irrigation water 1000, 2000 or 4000 ppm compared to control. Although in the first season plants irrigated with saline water at the lowest concentration (1000 ppm) resulted in insignificantly higher total flavonoids content than those recorded with the control plants. Increasing both phenolic and flavonoids in leaves of salt stressed plants are in agreement with findings of recent researches (Kumar *et al.* 2017; Yan *et al.* 2017) who stated that phenolic and flavonoids compounds are secondary metabolites that act as antioxidants and their accumulation in plants may be reduce the oxidative damage caused by salt stress.

The data in Table (6) also showed that, in both seasons the values of total phenolic and flavonoids content were reduced significantly as a result of nano silicon and gypsum treatments either applied separately or in combination compared to control plants. The reductions in total phenolic content due to gypsum application are consistent with those obtained by El-Quesni *et al.* (2014).

With reference to the interaction effects between salt concentrations and additives treatments, the data in Table (6) disclosed that, the combined of gypsum with nano silicon concentrations resulted in significantly lower values of total phenolic and flavonoids content than those recorded with plants irrigated and sprayed with tap water (control). In both seasons the lowest values of total phenolic and flavonoids were obtained from plants irrigated with tap water and treated with combined treatments of foliar application nano silicon at 2 mM with soil gypsum at 20 g/plant. On the other hand, the highest values were resulted from plants irrigated with saline water at the highest concentration (4000 ppm) and sprayed with tap water.

Leaf anatomy

Salinity, nano silicon and gypsum induced anatomical adjustments and realized by leaf sectioning on *Jatropha integerrima* as shown in (Fig. a and b). There was significant alterations in anatomical features of leaf, where (Fig. a) represented the effect of highest salt concentration 4000 ppm without addition of either nano silicon or gypsum, resulted in changes in the cells shapes mostly deformed (cytorrhysis) and shrunk, rigorous plasmolysis and serious disorders of cell shape and structure could be observed (Boughalleb *et al.* 2009). bigger glandular trichomes, intercellular air spaces increased but, the thickness of the leaf, and that of the adaxial epidermis of palisade, and spongy parenchyma were significantly reduced in comparison with the same anatomical structures in (Fig. b) which symbolized plants treated by nano silicon and gypsum.

Spotlighting on plasmolysed cells in (Fig. a) vacuoles shrank plasmalemma in many places lost contact with cell wall and wide periplasmic space appeared, furthermore, groups of some cells were degenerated (Sam *et al.* 2003). In such cells plasmalemma and especially tonoplast were often collapsed; swollen, rounded chloroplasts and other organelles seemed to be incorporated

into the remnants of a vacuole; cytoplasm showed degeneration and occasionally even a cell wall collapsed. On the other side (Fig. b) revealed that, the epidermis cells were similar in shape and size, and reached a maximum size. Additionally, it was remarkable that, the thickness of mesophyll tissue, which is specialized photosynthetic and contains chloroplasts in palisade and size of spongy cells tissue became larger. These results suggest that the anatomical mechanisms occurred to adaptation of salt stress conditions.

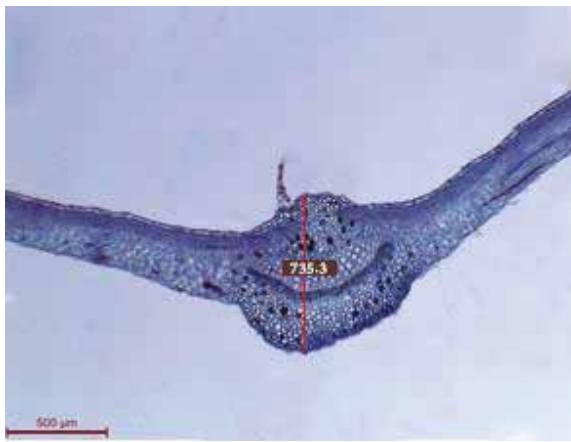


Fig. a.

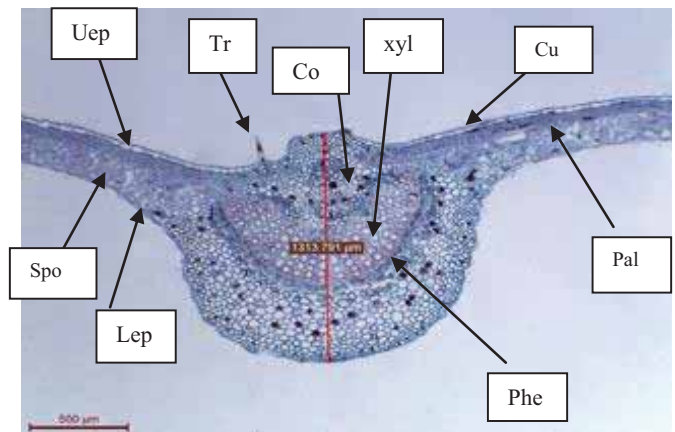


Fig. b

Uep: upper epidermis, **Tr:** trichome, **Co:** collenchyma, **Xyl:** xylem, **Cu:** cuticle, **Spo:** spongy mesophyll
Lep: lower epidermis, **Phe:** Phloem, **Pal:** palisade mesophyll

4. Conclusion

From the above mentioned results it can be concluded that, foliar spray of nano silicon at 1 mM combined with soil addition of gypsum at 20 g/plant was the best effective and economic treatment recommended for mitigating the harmful effect of salinity stress on *Jatropha integerrima* plants irrigated with saline water at concentration up to 4000 ppm.

Table 2: Effect of irrigation water salinity, nano silicon (NSi) and gypsum treatments on plant height, number of branches/plant, stem diameter, number of leaves and leaf area of *Jatropha integerrima* during the 2015 and 2016 seasons.

| Additive Treatments (AT) | First season (2015) | | | | | Second season (2016) | | | | |
|--------------------------|---------------------------------|--------|--------|--------|----------|-----------------------------|--------|--------|--------|----------|
| | Salt concentration (S), ppm | | | | | Salt concentration (S), ppm | | | | |
| | Control | 1000 | 2000 | 4000 | Mean (T) | Control | 1000 | 2000 | 4000 | Mean (T) |
| | Plant height (cm) | | | | | | | | | |
| Control | 82.52 | 77.74 | 83.01 | 56.40 | 74.92 | 88.47 | 81.39 | 74.09 | 59.89 | 75.96 |
| NSi (1) at 1 mM | 93.18 | 91.83 | 85.36 | 71.20 | 85.39 | 91.96 | 93.48 | 84.48 | 76.23 | 86.53 |
| NSi (2) at 2 mM | 99.62 | 97.18 | 89.89 | 82.81 | 92.37 | 92.44 | 93.33 | 88.08 | 78.30 | 88.04 |
| Gypsum at 20 g/plant | 115.58 | 97.14 | 95.68 | 93.44 | 100.46 | 110.54 | 98.20 | 96.78 | 86.85 | 98.09 |
| NSi (1) + Gypsum | 122.49 | 117.52 | 104.28 | 98.52 | 110.70 | 110.84 | 113.19 | 109.66 | 90.92 | 106.15 |
| NSi (2) + Gypsum | 121.58 | 119.00 | 111.68 | 102.83 | 113.77 | 129.58 | 111.04 | 110.81 | 109.39 | 115.20 |
| Mean (S) | 105.83 | 100.07 | 94.98 | 84.20 | ---- | 103.97 | 98.44 | 93.98 | 83.59 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | | 6.12 | | | | 8.35 | | |
| AT | | | | 7.50 | | | | 10.23 | | |
| SX AT | | | | 15.00 | | | | 20.46 | | |
| | Number of branches/plant | | | | | | | | | |
| Control | 6.25 | 6.50 | 5.50 | 4.00 | 5.56 | 5.25 | 4.34 | 4.25 | 3.25 | 4.27 |
| NSi (1) at 1 mM | 7.67 | 5.92 | 6.50 | 5.25 | 6.33 | 5.50 | 4.50 | 4.25 | 3.34 | 4.40 |
| NSi (2) at 2 mM | 8.17 | 6.25 | 6.50 | 5.09 | 6.50 | 6.00 | 5.25 | 5.00 | 4.50 | 5.19 |
| Gypsum at 20 g/plant | 7.67 | 6.17 | 6.09 | 6.09 | 6.50 | 6.50 | 5.50 | 5.09 | 5.25 | 5.58 |
| NSi (1) + Gypsum | 10.09 | 9.09 | 8.50 | 7.67 | 8.83 | 8.09 | 7.34 | 7.00 | 7.34 | 7.44 |
| NSi (2) + Gypsum | 10.34 | 10.25 | 8.84 | 7.42 | 9.21 | 8.50 | 8.00 | 8.17 | 8.00 | 8.17 |
| Mean (S) | 8.36 | 7.36 | 6.99 | 5.92 | ---- | 6.64 | 5.82 | 5.63 | 5.28 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | | 0.74 | | | | 0.71 | | |
| AT | | | | 0.91 | | | | 0.87 | | |
| SX AT | | | | 1.82 | | | | 1.74 | | |
| | Stem diameter (mm) | | | | | | | | | |
| Control | 7.16 | 7.21 | 5.93 | 4.79 | 6.27 | 7.45 | 7.04 | 6.74 | 5.38 | 6.65 |
| NSi (1) at 1 mM | 8.46 | 7.22 | 7.93 | 5.64 | 7.31 | 7.78 | 7.47 | 7.26 | 7.09 | 7.40 |
| NSi (2) at 2 mM | 8.48 | 7.05 | 7.45 | 6.37 | 7.34 | 8.63 | 7.95 | 7.69 | 6.55 | 7.70 |
| Gypsum at 20 g/plant | 12.34 | 12.00 | 9.24 | 9.05 | 10.66 | 10.34 | 9.24 | 9.01 | 8.64 | 9.31 |
| NSi (1) + Gypsum | 13.47 | 12.82 | 12.68 | 11.73 | 12.67 | 12.99 | 11.90 | 11.53 | 10.02 | 11.61 |
| NSi (2) + Gypsum | 14.33 | 13.25 | 12.59 | 11.65 | 12.95 | 13.08 | 12.28 | 12.26 | 10.48 | 12.02 |
| Mean (S) | 10.71 | 9.93 | 9.30 | 8.20 | ---- | 10.04 | 9.31 | 9.08 | 8.02 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | | 0.75 | | | | 0.46 | | |
| AT | | | | 0.92 | | | | 0.57 | | |
| SX AT | | | | 1.84 | | | | 1.14 | | |
| | Number of leaves | | | | | | | | | |
| Control | 45.17 | 40.17 | 37.67 | 32.67 | 38.92 | 47.00 | 45.00 | 40.25 | 31.00 | 40.81 |
| NSi (1) at 1 mM | 45.42 | 42.42 | 39.92 | 38.92 | 41.67 | 48.00 | 45.50 | 43.50 | 40.25 | 44.31 |
| NSi (2) at 2 mM | 45.42 | 44.67 | 44.67 | 44.17 | 44.73 | 49.00 | 48.50 | 48.00 | 44.50 | 47.50 |
| Gypsum at 20 g/plant | 48.17 | 48.17 | 47.67 | 47.42 | 47.86 | 51.25 | 49.00 | 48.50 | 48.00 | 49.19 |
| NSi (1) + Gypsum | 49.67 | 48.92 | 48.67 | 48.42 | 48.92 | 51.00 | 49.50 | 49.00 | 48.50 | 49.50 |
| NSi (2) + Gypsum | 50.00 | 49.92 | 48.42 | 47.67 | 49.00 | 51.50 | 51.50 | 51.50 | 49.00 | 50.88 |
| Mean (S) | 47.31 | 45.71 | 44.50 | 43.21 | ---- | 49.63 | 48.17 | 46.79 | 43.54 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | | 2.00 | | | | 1.88 | | |
| AT | | | | 2.45 | | | | 2.31 | | |
| SX AT | | | | 4.91 | | | | 4.61 | | |
| | leaf area | | | | | | | | | |
| Control | 49.30 | 43.20 | 42.92 | 40.44 | 43.97 | 52.36 | 50.45 | 49.10 | 41.09 | 48.25 |
| NSi (1) at 1 mM | 49.80 | 47.93 | 47.90 | 44.20 | 47.46 | 51.73 | 52.85 | 49.88 | 48.89 | 50.84 |
| NSi (2) at 2 mM | 47.90 | 48.89 | 48.15 | 43.27 | 47.05 | 53.02 | 51.40 | 52.69 | 49.44 | 51.64 |
| Gypsum at 20 g/plant | 51.66 | 50.93 | 46.85 | 47.41 | 49.21 | 53.83 | 52.60 | 51.19 | 49.47 | 51.77 |
| NSi (1) + Gypsum | 60.92 | 57.48 | 55.80 | 54.00 | 57.05 | 61.55 | 60.59 | 57.73 | 57.30 | 59.29 |
| NSi (2) + Gypsum | 65.80 | 61.85 | 58.64 | 55.96 | 60.56 | 64.73 | 58.50 | 59.93 | 59.67 | 60.71 |
| Mean (S) | 54.23 | 51.71 | 50.04 | 47.55 | ---- | 56.20 | 54.40 | 53.42 | 50.98 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | | 2.32 | | | | 1.78 | | |
| AT | | | | 3.07 | | | | 2.18 | | |
| SX AT | | | | 6.14 | | | | 4.36 | | |

Table 3: Effect of irrigation water salinity, nano silicon (NSi) and gypsum treatments on fresh and dry weights of stems and leaves as well as root length of *Jatropha integerrima* during the 2015 and 2016 seasons.

| Additive Treatments (AT) | First season (2015) | | | | | Second season (2016) | | | | |
|---|-----------------------------|-------|-------|-------|----------|-----------------------------|-------|-------|-------|----------|
| | Salt concentration (S), ppm | | | | | Salt concentration (S), ppm | | | | |
| | Control | 1000 | 2000 | 4000 | Mean (T) | Control | 1000 | 2000 | 4000 | Mean (T) |
| Fresh weight of stems (g/plant) | | | | | | | | | | |
| Control | 75.71 | 64.68 | 65.37 | 51.72 | 64.37 | 77.41 | 67.08 | 68.56 | 56.43 | 67.37 |
| NSi (1) at 1 mM | 69.91 | 73.14 | 60.53 | 61.54 | 66.28 | 78.68 | 75.21 | 70.36 | 57.76 | 70.50 |
| NSi (2) at 2 mM | 77.80 | 73.06 | 75.66 | 62.12 | 72.16 | 80.22 | 77.18 | 70.73 | 64.95 | 73.27 |
| Gypsum at 20 g/plant | 103.27 | 94.92 | 84.93 | 81.30 | 91.10 | 98.11 | 90.82 | 87.56 | 83.74 | 90.06 |
| NSi (1) + Gypsum | 110.64 | 96.39 | 90.34 | 84.84 | 95.55 | 101.29 | 94.29 | 92.51 | 87.09 | 93.79 |
| NSi (2) + Gypsum | 114.12 | 98.21 | 96.19 | 90.38 | 99.72 | 107.50 | 95.02 | 92.82 | 91.62 | 96.74 |
| Mean (S) | 91.91 | 83.40 | 78.83 | 71.98 | ---- | 90.53 | 83.26 | 80.42 | 73.60 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | | 2.86 | | | | 2.76 | | |
| AT | | | | 3.51 | | | | 3.16 | | |
| SX AT | | | | 7.02 | | | | 6.32 | | |
| Dry weight of stems (g/plant) | | | | | | | | | | |
| Control | 27.61 | 25.66 | 22.37 | 21.91 | 24.38 | 28.27 | 27.08 | 26.84 | 24.77 | 26.74 |
| NSi (1) at 1 mM | 27.43 | 26.28 | 25.86 | 23.67 | 25.81 | 29.89 | 29.45 | 27.15 | 26.39 | 28.22 |
| NSi (2) at 2 mM | 29.27 | 28.80 | 29.55 | 26.73 | 28.59 | 30.83 | 31.33 | 32.11 | 27.78 | 30.51 |
| Gypsum at 20 g/plant | 35.82 | 35.27 | 34.90 | 32.60 | 34.65 | 37.16 | 33.55 | 32.33 | 31.88 | 33.73 |
| NSi (1) + Gypsum | 40.50 | 36.15 | 36.51 | 33.56 | 36.68 | 36.07 | 33.06 | 32.24 | 31.68 | 33.26 |
| NSi (2) + Gypsum | 40.74 | 38.83 | 37.74 | 36.90 | 38.55 | 37.28 | 36.94 | 35.12 | 32.46 | 35.45 |
| Mean (S) | 33.56 | 31.83 | 31.15 | 29.23 | ---- | 33.25 | 31.90 | 30.96 | 29.16 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | | 1.50 | | | | 1.39 | | |
| AT | | | | 1.83 | | | | 1.70 | | |
| SX AT | | | | 3.67 | | | | 3.40 | | |
| Fresh weight of leaves (g/plant) | | | | | | | | | | |
| Control | 55.49 | 51.89 | 50.44 | 44.87 | 50.67 | 60.47 | 54.69 | 49.21 | 47.43 | 52.95 |
| NSi (1) at 1 mM | 60.05 | 56.90 | 55.26 | 53.60 | 56.45 | 58.25 | 58.10 | 58.78 | 54.19 | 57.33 |
| NSi (2) at 2 mM | 64.33 | 56.75 | 55.46 | 52.21 | 57.18 | 62.47 | 59.39 | 58.36 | 51.38 | 57.90 |
| Gypsum at 20 g/plant | 63.44 | 60.99 | 59.40 | 54.64 | 59.61 | 65.22 | 61.93 | 58.51 | 56.00 | 60.41 |
| NSi (1) + Gypsum | 73.15 | 71.14 | 68.79 | 66.65 | 69.93 | 79.59 | 74.63 | 75.98 | 69.17 | 74.84 |
| NSi (2) + Gypsum | 77.43 | 73.55 | 70.28 | 66.88 | 72.03 | 83.30 | 80.31 | 74.63 | 69.53 | 76.94 |
| Mean (S) | 65.65 | 61.87 | 59.94 | 56.47 | ---- | 68.21 | 64.84 | 62.58 | 57.95 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | | 4.51 | | | | 3.58 | | |
| AT | | | | 5.52 | | | | 4.39 | | |
| SX AT | | | | 11.05 | | | | 8.77 | | |
| Dry weight of leaves (g/plant) | | | | | | | | | | |
| Control | 14.15 | 12.51 | 11.54 | 10.25 | 12.11 | 16.31 | 14.59 | 12.23 | 11.51 | 13.66 |
| NSi (1) at 1 mM | 15.30 | 14.00 | 13.41 | 12.63 | 13.84 | 17.53 | 16.04 | 14.67 | 13.38 | 15.40 |
| NSi (2) at 2 mM | 15.56 | 14.60 | 13.87 | 12.20 | 14.05 | 17.25 | 16.18 | 14.90 | 14.06 | 15.60 |
| Gypsum at 20 g/plant | 16.25 | 15.24 | 13.15 | 12.04 | 14.17 | 17.30 | 15.66 | 15.57 | 14.56 | 15.77 |
| NSi (1) + Gypsum | 16.89 | 16.17 | 15.65 | 14.74 | 15.86 | 18.73 | 18.09 | 17.33 | 16.97 | 17.78 |
| NSi (2) + Gypsum | 17.29 | 17.05 | 16.33 | 15.77 | 16.61 | 18.97 | 18.20 | 18.04 | 16.90 | 18.03 |
| Mean (S) | 15.91 | 14.93 | 13.99 | 12.94 | ---- | 17.68 | 16.46 | 15.46 | 14.56 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | | 1.36 | | | | 1.41 | | |
| AT | | | | 1.67 | | | | 1.69 | | |
| SX AT | | | | 3.34 | | | | 3.28 | | |
| Root length (cm) | | | | | | | | | | |
| Control | 25.17 | 22.73 | 21.86 | 19.29 | 22.26 | 27.91 | 24.42 | 24.08 | 23.25 | 24.91 |
| NSi (1) at 1 mM | 25.28 | 24.82 | 23.71 | 22.71 | 24.13 | 28.29 | 27.13 | 27.41 | 25.32 | 27.04 |
| NSi (2) at 2 mM | 26.69 | 24.57 | 24.63 | 21.92 | 24.45 | 29.36 | 28.54 | 26.20 | 25.08 | 27.29 |
| Gypsum at 20 g/plant | 27.66 | 25.08 | 23.11 | 22.93 | 24.69 | 29.72 | 26.34 | 28.81 | 27.48 | 28.09 |
| NSi (1) + Gypsum | 29.78 | 27.81 | 27.75 | 25.53 | 27.72 | 31.58 | 30.73 | 29.21 | 27.87 | 29.84 |
| NSi (2) + Gypsum | 32.39 | 29.55 | 29.23 | 29.03 | 30.05 | 31.87 | 30.80 | 30.34 | 27.75 | 30.19 |
| Mean (S) | 27.83 | 25.76 | 25.05 | 23.57 | ---- | 29.79 | 27.99 | 27.67 | 26.12 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | | 1.05 | | | | 1.58 | | |
| AT | | | | 1.28 | | | | 1.72 | | |
| SX AT | | | | 2.57 | | | | 2.43 | | |

Table 4: Effect of irrigation water salinity, nano silicon (NSi) and gypsum treatments on fresh and dry weights of roots, number of flowers/plant as well as fresh dry weights of flowers of *Jatropha integerrima* during the 2015 and 2016 seasons.

| Additive Treatments (AT) | First season (2015) | | | | | Second season (2016) | | | | | |
|--------------------------|--|-------|-------|-------|----------|-----------------------------|-------|-------|-------|----------|--|
| | Salt concentration (S), ppm | | | | | Salt concentration (S), ppm | | | | | |
| | Control | 1000 | 2000 | 4000 | Mean (T) | Control | 1000 | 2000 | 4000 | Mean (T) | |
| | Fresh weight of roots (g/plant) | | | | | | | | | | |
| Control | 67.07 | 64.03 | 60.67 | 55.97 | 61.93 | 71.32 | 65.78 | 57.33 | 54.66 | 62.27 | |
| NSi (1) at 1 mM | 67.45 | 72.24 | 65.90 | 61.88 | 66.86 | 73.96 | 66.66 | 64.82 | 59.87 | 66.33 | |
| NSi (2) at 2 mM | 74.25 | 71.31 | 68.87 | 62.58 | 69.25 | 75.00 | 69.57 | 64.76 | 58.30 | 66.90 | |
| Gypsum at 20 g/plant | 75.99 | 71.71 | 69.11 | 65.24 | 70.51 | 71.80 | 69.44 | 68.21 | 59.46 | 67.23 | |
| NSi (1) + Gypsum | 83.12 | 79.75 | 75.00 | 73.85 | 77.93 | 85.20 | 83.91 | 82.57 | 79.56 | 82.81 | |
| NSi (2) + Gypsum | 90.33 | 81.34 | 81.88 | 77.35 | 82.72 | 88.90 | 84.36 | 84.72 | 81.15 | 84.78 | |
| Mean (S) | 76.37 | 73.40 | 70.24 | 66.14 | ---- | 77.70 | 73.29 | 70.40 | 65.50 | ---- | |
| L.S.D. (0.05) | | | | | | | | | | | |
| S | | | | 2.75 | | | | 2.62 | | | |
| AT | | | | 3.37 | | | | 3.89 | | | |
| SX AT | | | | 6.74 | | | | 7.77 | | | |
| | Dry weight of roots (g/plant) | | | | | | | | | | |
| Control | 27.86 | 21.62 | 19.75 | 17.22 | 21.61 | 24.88 | 22.11 | 18.83 | 16.93 | 20.69 | |
| NSi (1) at 1 mM | 26.09 | 25.03 | 22.67 | 21.52 | 23.83 | 25.67 | 24.00 | 20.92 | 19.24 | 22.46 | |
| NSi (2) at 2 mM | 25.64 | 24.97 | 24.50 | 21.48 | 24.15 | 26.61 | 23.95 | 23.31 | 20.21 | 23.52 | |
| Gypsum at 20 g/plant | 29.29 | 24.33 | 24.62 | 22.66 | 25.22 | 27.62 | 24.26 | 23.45 | 20.38 | 23.93 | |
| NSi (1) + Gypsum | 31.79 | 30.24 | 29.39 | 28.25 | 29.92 | 27.62 | 26.33 | 25.35 | 26.18 | 26.37 | |
| NSi (2) + Gypsum | 32.19 | 32.04 | 30.01 | 29.64 | 30.97 | 27.97 | 27.51 | 26.10 | 26.88 | 27.11 | |
| Mean (S) | 28.81 | 26.37 | 25.16 | 23.46 | ---- | 26.73 | 24.69 | 22.99 | 21.63 | ---- | |
| L.S.D. (0.05) | | | | | | | | | | | |
| S | | | | 1.77 | | | | 1.30 | | | |
| AT | | | | 2.17 | | | | 1.60 | | | |
| SX AT | | | | 4.34 | | | | 3.19 | | | |
| | Number of flowers/plant | | | | | | | | | | |
| Control | 6.50 | 6.75 | 6.00 | 5.75 | 6.25 | 7.42 | 6.42 | 6.25 | 5.50 | 6.40 | |
| NSi (1) at 1 mM | 7.25 | 6.75 | 6.50 | 6.50 | 6.75 | 7.42 | 6.92 | 6.34 | 6.67 | 6.83 | |
| NSi (2) at 2 mM | 7.25 | 7.50 | 7.00 | 6.50 | 7.06 | 7.17 | 7.09 | 6.92 | 6.92 | 7.02 | |
| Gypsum at 20 g/plant | 8.75 | 8.25 | 6.83 | 6.84 | 7.67 | 7.92 | 7.50 | 7.17 | 6.75 | 7.33 | |
| NSi (1) + Gypsum | 9.00 | 8.75 | 8.50 | 7.25 | 8.38 | 9.17 | 8.92 | 8.50 | 8.34 | 8.73 | |
| NSi (2) + Gypsum | 9.83 | 9.00 | 8.75 | 8.00 | 8.90 | 9.42 | 9.17 | 8.42 | 8.17 | 8.79 | |
| Mean (S) | 8.10 | 7.83 | 7.26 | 6.81 | ---- | 8.08 | 7.67 | 7.26 | 7.06 | ---- | |
| L.S.D. (0.05) | | | | | | | | | | | |
| S | | | | 0.20 | | | | 0.30 | | | |
| AT | | | | 0.24 | | | | 0.36 | | | |
| SX AT | | | | 0.49 | | | | 0.73 | | | |
| | Fresh weight of flowers (g/plant) | | | | | | | | | | |
| Control | 2.66 | 2.28 | 2.16 | 1.96 | 2.26 | 2.48 | 2.32 | 2.19 | 1.92 | 2.23 | |
| NSi (1) at 1 mM | 2.59 | 2.34 | 2.30 | 2.25 | 2.37 | 2.53 | 2.51 | 2.40 | 2.38 | 2.45 | |
| NSi (2) at 2 mM | 2.50 | 2.47 | 2.50 | 2.28 | 2.44 | 2.58 | 2.41 | 2.38 | 2.54 | 2.48 | |
| Gypsum at 20 g/plant | 2.85 | 2.84 | 2.77 | 2.58 | 2.76 | 2.82 | 2.61 | 2.56 | 2.44 | 2.61 | |
| NSi (1) + Gypsum | 3.11 | 2.94 | 2.92 | 2.89 | 2.96 | 2.98 | 2.92 | 2.87 | 2.84 | 2.90 | |
| NSi (2) + Gypsum | 3.56 | 3.33 | 3.17 | 2.90 | 3.24 | 3.41 | 3.13 | 2.95 | 2.88 | 3.09 | |
| Mean (S) | 2.88 | 2.70 | 2.63 | 2.47 | ---- | 2.80 | 2.65 | 2.56 | 2.50 | ---- | |
| L.S.D. (0.05) | | | | | | | | | | | |
| S | | | | 0.09 | | | | 0.15 | | | |
| AT | | | | 0.11 | | | | 0.18 | | | |
| SX AT | | | | 0.22 | | | | 0.36 | | | |
| | Dry weight of flowers (g/plant) | | | | | | | | | | |
| Control | 0.96 | 0.80 | 0.67 | 0.63 | 0.76 | 0.81 | 0.75 | 0.65 | 0.53 | 0.68 | |
| NSi (1) at 1 mM | 0.85 | 0.87 | 0.86 | 0.75 | 0.83 | 0.88 | 0.82 | 0.79 | 0.67 | 0.79 | |
| NSi (2) at 2 mM | 0.86 | 0.91 | 0.79 | 0.80 | 0.84 | 0.83 | 0.85 | 0.80 | 0.71 | 0.80 | |
| Gypsum at 20 g/plant | 1.08 | 0.98 | 0.99 | 0.88 | 0.98 | 1.01 | 0.89 | 0.83 | 0.73 | 0.87 | |
| NSi (1) + Gypsum | 1.27 | 1.11 | 1.17 | 1.09 | 1.16 | 1.29 | 1.09 | 1.07 | 1.02 | 1.12 | |
| NSi (2) + Gypsum | 1.36 | 1.24 | 1.18 | 1.14 | 1.23 | 1.34 | 1.19 | 1.11 | 1.07 | 1.18 | |
| Mean (S) | 1.06 | 0.98 | 0.94 | 0.88 | ---- | 1.03 | 0.93 | 0.87 | 0.79 | ---- | |
| L.S.D. (0.05) | | | | | | | | | | | |
| S | | | | 0.05 | | | | 0.09 | | | |
| AT | | | | 0.06 | | | | 0.11 | | | |
| SX AT | | | | 0.13 | | | | 0.21 | | | |

Table 5: Effect of irrigation water salinity, nano silicon (NSi) and gypsum treatments on total chlorophylls, total carbohydrates, N, K% as well as proline contents in leaves of *Jatropha integerrima* during the 2015 and 2016 seasons.

| Additive Treatments (AT) | First season (2015) | | | | | Second season (2016) | | | | |
|---|-----------------------------|-------|-------|-------|----------|-----------------------------|-------|-------|-------|----------|
| | Salt concentration (S), ppm | | | | | Salt concentration (S), ppm | | | | |
| | Control | 1000 | 2000 | 4000 | Mean (T) | Control | 1000 | 2000 | 4000 | Mean (T) |
| Total chlorophylls content (SPAD) | | | | | | | | | | |
| Control | 43.08 | 38.30 | 37.25 | 36.95 | 38.89 | 39.90 | 34.77 | 33.58 | 31.13 | 34.84 |
| NSi (1) at 1 mM | 46.91 | 46.53 | 46.38 | 40.50 | 45.08 | 39.97 | 39.10 | 38.87 | 35.88 | 38.45 |
| NSi (2) at 2 mM | 47.39 | 46.49 | 46.36 | 42.85 | 45.77 | 46.20 | 45.43 | 44.90 | 39.07 | 43.90 |
| Gypsum at 20 g/plant | 47.63 | 47.71 | 46.72 | 46.54 | 47.15 | 48.63 | 46.49 | 43.76 | 44.71 | 45.90 |
| NSi (1) + Gypsum | 56.03 | 53.29 | 51.79 | 48.80 | 52.47 | 51.92 | 49.96 | 49.14 | 45.73 | 49.19 |
| NSi (2) + Gypsum | 57.92 | 54.59 | 52.55 | 49.16 | 53.55 | 55.80 | 51.63 | 50.90 | 47.65 | 51.49 |
| Mean (S) | 49.82 | 47.82 | 46.84 | 44.13 | ---- | 47.07 | 44.56 | 43.52 | 40.69 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | 1.33 | | | | | 1.96 | | |
| AT | | | 1.63 | | | | | 2.40 | | |
| SX AT | | | 3.27 | | | | | 4.80 | | |
| Total carbohydrates (% of dry matter) | | | | | | | | | | |
| Control | 15.24 | 13.98 | 13.36 | 11.34 | 13.48 | 13.80 | 13.30 | 12.04 | 11.80 | 12.73 |
| NSi (1) at 1 mM | 17.15 | 16.94 | 15.92 | 15.14 | 16.29 | 15.65 | 15.57 | 16.55 | 15.33 | 15.78 |
| NSi (2) at 2 mM | 17.67 | 17.54 | 17.12 | 15.99 | 17.08 | 16.83 | 17.03 | 16.73 | 15.50 | 16.52 |
| Gypsum at 20 g/plant | 18.77 | 17.11 | 16.52 | 15.89 | 17.07 | 19.49 | 17.57 | 16.72 | 16.21 | 17.50 |
| NSi (1) + Gypsum | 21.79 | 18.74 | 17.81 | 17.63 | 18.99 | 20.21 | 18.20 | 17.33 | 17.59 | 18.33 |
| NSi (2) + Gypsum | 23.07 | 19.81 | 19.44 | 17.13 | 19.86 | 21.41 | 20.35 | 19.59 | 17.62 | 19.74 |
| Mean (S) | 18.95 | 17.35 | 16.70 | 15.52 | ---- | 17.90 | 17.00 | 16.49 | 15.67 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | 0.69 | | | | | 0.66 | | |
| AT | | | 0.84 | | | | | 0.80 | | |
| SX AT | | | 1.69 | | | | | 1.61 | | |
| N (% dry matter) | | | | | | | | | | |
| Control | 1.92 | 1.74 | 1.59 | 1.45 | 1.67 | 1.85 | 1.80 | 1.66 | 1.59 | 1.72 |
| NSi (1) at 1 mM | 1.98 | 1.88 | 1.84 | 1.84 | 1.88 | 1.95 | 1.87 | 1.85 | 1.83 | 1.87 |
| NSi (2) at 2 mM | 1.96 | 1.95 | 1.90 | 1.84 | 1.91 | 1.99 | 1.88 | 1.86 | 1.80 | 1.88 |
| Gypsum at 20 g/plant | 1.99 | 1.96 | 1.91 | 1.85 | 1.93 | 2.16 | 1.93 | 1.89 | 1.81 | 1.95 |
| NSi (1) + Gypsum | 2.39 | 2.03 | 1.99 | 1.92 | 2.08 | 2.33 | 2.23 | 1.97 | 1.87 | 2.10 |
| NSi (2) + Gypsum | 3.11 | 2.72 | 2.55 | 2.02 | 2.60 | 3.57 | 2.41 | 2.28 | 2.10 | 2.59 |
| Mean (S) | 2.22 | 2.05 | 1.96 | 1.82 | ---- | 2.31 | 2.02 | 1.92 | 1.83 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | 0.11 | | | | | 0.14 | | |
| AT | | | 0.14 | | | | | 0.18 | | |
| SX AT | | | 0.28 | | | | | 0.35 | | |
| K (% dry matter) | | | | | | | | | | |
| Control | 1.57 | 1.52 | 1.27 | 1.23 | 1.40 | 1.60 | 1.40 | 1.24 | 1.21 | 1.36 |
| NSi (1) at 1 mM | 1.70 | 1.71 | 1.56 | 1.52 | 1.62 | 1.62 | 1.67 | 1.50 | 1.48 | 1.57 |
| NSi (2) at 2 mM | 1.71 | 1.67 | 1.55 | 1.58 | 1.63 | 1.79 | 1.73 | 1.58 | 1.63 | 1.68 |
| Gypsum at 20 g/plant | 1.72 | 1.69 | 1.66 | 1.60 | 1.67 | 1.73 | 1.71 | 1.63 | 1.62 | 1.67 |
| NSi (1) + Gypsum | 1.81 | 1.80 | 1.77 | 1.75 | 1.78 | 1.86 | 1.78 | 1.79 | 1.77 | 1.80 |
| NSi (2) + Gypsum | 1.96 | 1.81 | 1.80 | 1.77 | 1.84 | 1.87 | 1.83 | 1.78 | 1.75 | 1.81 |
| Mean (S) | 1.75 | 1.70 | 1.60 | 1.57 | ---- | 1.74 | 1.69 | 1.59 | 1.58 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | 0.07 | | | | | 0.06 | | |
| AT | | | 0.08 | | | | | 0.07 | | |
| SX AT | | | 0.17 | | | | | 0.14 | | |
| Proline content (μ moles/g fresh matter) | | | | | | | | | | |
| Control | 2.69 | 3.65 | 4.37 | 4.17 | 3.72 | 2.33 | 3.02 | 3.95 | 3.54 | 3.21 |
| NSi (1) at 1 mM | 3.66 | 4.80 | 4.22 | 5.10 | 4.44 | 3.15 | 4.20 | 4.24 | 4.44 | 4.01 |
| NSi (2) at 2 mM | 5.90 | 4.28 | 5.98 | 5.44 | 5.40 | 4.71 | 4.30 | 5.36 | 4.09 | 4.61 |
| Gypsum at 20 g/plant | 4.61 | 5.52 | 6.03 | 5.69 | 5.46 | 4.54 | 5.06 | 5.35 | 5.82 | 5.19 |
| NSi (1) + Gypsum | 6.40 | 7.67 | 6.54 | 7.12 | 6.93 | 5.93 | 6.94 | 6.92 | 8.18 | 6.99 |
| NSi (2) + Gypsum | 8.11 | 6.80 | 7.64 | 8.41 | 7.74 | 8.82 | 8.43 | 9.06 | 9.98 | 9.07 |
| Mean (S) | 5.23 | 5.45 | 5.79 | 5.99 | ---- | 4.91 | 5.33 | 5.81 | 6.01 | ---- |
| L.S.D. (0.05) | | | | | | | | | | |
| S | | | 0.56 | | | | | 0.64 | | |
| AT | | | 0.69 | | | | | 0.78 | | |
| SX AT | | | 1.38 | | | | | 1.57 | | |

Table 6: Effect of irrigation water salinity, nano silicon (NSi) and gypsum treatments on Ca, Na, Cl (% dry matter) as well as total phenolic and total flavonoids content in leaves of *Jatropha integerrima* during the 2015 and 2016 seasons.

| Additive Treatments (AT) | First season (2015) | | | | | Second season (2016) | | | | | |
|--------------------------|--|------|------|------|----------|-----------------------------|------|------|------|----------|--|
| | Salt concentration (S), ppm | | | | | Salt concentration (S), ppm | | | | | |
| | Control | 1000 | 2000 | 4000 | Mean (T) | Control | 1000 | 2000 | 4000 | Mean (T) | |
| | Ca (% dry matter) | | | | | | | | | | |
| Control | 0.28 | 0.31 | 0.35 | 0.41 | 0.34 | 0.30 | 0.36 | 0.39 | 0.40 | 0.36 | |
| NSi (1) at 1 mM | 0.36 | 0.44 | 0.42 | 0.45 | 0.41 | 0.43 | 0.46 | 0.47 | 0.52 | 0.47 | |
| NSi (2) at 2 mM | 0.49 | 0.52 | 0.53 | 0.48 | 0.51 | 0.51 | 0.56 | 0.55 | 0.53 | 0.54 | |
| Gypsum at 20 g/plant | 0.59 | 0.59 | 0.76 | 0.74 | 0.67 | 0.48 | 0.56 | 0.63 | 0.73 | 0.60 | |
| NSi (1) + Gypsum | 0.64 | 0.73 | 0.71 | 0.75 | 0.71 | 0.74 | 0.76 | 0.80 | 0.75 | 0.76 | |
| NSi (2) + Gypsum | 0.76 | 0.78 | 0.86 | 0.89 | 0.82 | 0.73 | 0.78 | 0.83 | 0.86 | 0.80 | |
| Mean (S) | 0.52 | 0.56 | 0.61 | 0.62 | ---- | 0.53 | 0.58 | 0.61 | 0.63 | ---- | |
| L.S.D. (0.05) | | | | | | | | | | | |
| S | | | | 0.05 | | | | 0.05 | | | |
| AT | | | | 0.06 | | | | 0.06 | | | |
| SX AT | | | | 0.12 | | | | 0.11 | | | |
| | Na (% dry matter) | | | | | | | | | | |
| Control | 0.67 | 0.73 | 0.77 | 0.84 | 0.75 | 0.65 | 0.66 | 0.65 | 0.74 | 0.67 | |
| NSi (1) at 1 mM | 0.63 | 0.65 | 0.63 | 0.64 | 0.64 | 0.55 | 0.59 | 0.57 | 0.58 | 0.57 | |
| NSi (2) at 2 mM | 0.45 | 0.40 | 0.45 | 0.45 | 0.44 | 0.39 | 0.44 | 0.47 | 0.47 | 0.44 | |
| Gypsum at 20 g/plant | 0.32 | 0.31 | 0.37 | 0.45 | 0.36 | 0.33 | 0.39 | 0.40 | 0.45 | 0.39 | |
| NSi (1) + Gypsum | 0.29 | 0.33 | 0.34 | 0.38 | 0.33 | 0.31 | 0.34 | 0.36 | 0.40 | 0.35 | |
| NSi (2) + Gypsum | 0.26 | 0.31 | 0.34 | 0.37 | 0.32 | 0.29 | 0.33 | 0.35 | 0.37 | 0.34 | |
| Mean (S) | 0.43 | 0.45 | 0.48 | 0.52 | ---- | 0.42 | 0.46 | 0.46 | 0.50 | ---- | |
| L.S.D. (0.05) | | | | | | | | | | | |
| S | | | | 0.02 | | | | 0.03 | | | |
| AT | | | | 0.03 | | | | 0.04 | | | |
| SX AT | | | | 0.06 | | | | 0.08 | | | |
| | Cl (% dry matter) | | | | | | | | | | |
| Control | 0.61 | 0.57 | 0.60 | 0.72 | 0.62 | 0.50 | 0.50 | 0.57 | 0.61 | 0.55 | |
| NSi (1) at 1 mM | 0.46 | 0.51 | 0.51 | 0.52 | 0.50 | 0.43 | 0.44 | 0.43 | 0.43 | 0.43 | |
| NSi (2) at 2 mM | 0.35 | 0.37 | 0.36 | 0.41 | 0.37 | 0.33 | 0.36 | 0.33 | 0.34 | 0.34 | |
| Gypsum at 20 g/plant | 0.23 | 0.30 | 0.30 | 0.40 | 0.31 | 0.25 | 0.26 | 0.30 | 0.38 | 0.30 | |
| NSi (1) + Gypsum | 0.20 | 0.26 | 0.28 | 0.35 | 0.27 | 0.23 | 0.23 | 0.26 | 0.30 | 0.25 | |
| NSi (2) + Gypsum | 0.19 | 0.26 | 0.27 | 0.32 | 0.26 | 0.22 | 0.24 | 0.25 | 0.30 | 0.25 | |
| Mean (S) | 0.34 | 0.38 | 0.38 | 0.45 | ---- | 0.32 | 0.34 | 0.35 | 0.39 | ---- | |
| L.S.D. (0.05) | | | | | | | | | | | |
| S | | | | 0.04 | | | | 0.03 | | | |
| AT | | | | 0.05 | | | | 0.04 | | | |
| SX AT | | | | 0.09 | | | | 0.07 | | | |
| | Total phenolic (mg GAE/g DW) | | | | | | | | | | |
| Control | 2.63 | 2.69 | 2.72 | 2.97 | 2.75 | 2.59 | 2.63 | 2.66 | 2.79 | 2.67 | |
| NSi (1) at 1 mM | 2.21 | 2.48 | 2.26 | 2.67 | 2.40 | 2.47 | 2.48 | 2.54 | 2.60 | 2.52 | |
| NSi (2) at 2 mM | 2.10 | 2.12 | 2.18 | 2.28 | 2.17 | 2.21 | 2.39 | 2.35 | 2.41 | 2.34 | |
| Gypsum at 20 g/plant | 1.98 | 2.05 | 2.23 | 2.15 | 2.10 | 2.08 | 2.13 | 2.31 | 2.48 | 2.25 | |
| NSi (1) + Gypsum | 1.72 | 1.76 | 2.03 | 2.10 | 1.90 | 1.69 | 1.91 | 2.22 | 2.37 | 2.05 | |
| NSi (2) + Gypsum | 0.75 | 1.26 | 1.97 | 2.07 | 1.51 | 0.88 | 1.75 | 2.03 | 2.11 | 1.69 | |
| Mean (S) | 1.90 | 2.06 | 2.23 | 2.37 | ---- | 1.99 | 2.21 | 2.35 | 2.46 | ---- | |
| L.S.D. (0.05) | | | | | | | | | | | |
| S | | | | 0.13 | | | | 0.11 | | | |
| AT | | | | 0.16 | | | | 0.13 | | | |
| SX AT | | | | 0.33 | | | | 0.26 | | | |
| | Total flavonoids (mg rutin /g DW) | | | | | | | | | | |
| Control | 2.14 | 2.23 | 2.32 | 2.34 | 2.26 | 2.08 | 2.11 | 2.19 | 2.28 | 2.16 | |
| NSi (1) at 1 mM | 2.13 | 2.15 | 2.18 | 2.21 | 2.17 | 2.05 | 2.06 | 2.13 | 2.15 | 2.09 | |
| NSi (2) at 2 mM | 1.95 | 1.93 | 1.95 | 1.96 | 1.95 | 1.79 | 1.96 | 1.97 | 1.99 | 1.93 | |
| Gypsum at 20 g/plant | 1.86 | 1.86 | 1.87 | 1.94 | 1.88 | 1.89 | 1.91 | 1.92 | 1.97 | 1.92 | |
| NSi (1) + Gypsum | 1.82 | 1.83 | 1.84 | 1.88 | 1.84 | 1.79 | 1.87 | 1.88 | 1.92 | 1.86 | |
| NSi (2) + Gypsum | 1.66 | 1.78 | 1.81 | 1.80 | 1.76 | 1.69 | 1.80 | 1.88 | 1.92 | 1.82 | |
| Mean (S) | 1.92 | 1.96 | 1.99 | 2.02 | ---- | 1.88 | 1.95 | 1.99 | 2.04 | ---- | |
| L.S.D. (0.05) | | | | | | | | | | | |
| S | | | | 0.07 | | | | 0.06 | | | |
| AT | | | | 0.08 | | | | 0.07 | | | |
| SX AT | | | | 0.16 | | | | 0.15 | | | |

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