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Effect of Activated Carbon Prepared from Leaflet of Date Palm Tree and Composite Nano silica/Activated Carbon on Growth and Productivity of Fenugreek Plant under Salinity Soil Conditions

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ABSTRACT
A field experiment was conducted with completely randomized design to assess the impact of the foliar application of using activated carbon from leaflet of date palm tree as by product and composite nano silica/activated carbon to alleviate salinity stress on fenugreek plants. The prepared samples AC and SiO_2/AC were characterized using zeta potentials, particle size distributions, EDX, FTIR, S_{BET} and morphology description were done using SEM and TEM. All techniques confirmed the good distribution of SiO_2 nanoparticles on surface of AC composite sample and particles size of SiO_2/AC were found to be in the size range of 70–80 nm. Characterization results showed that surface area of AC prepared from leaflet of date palm tree using KOH as activating agent and SiO_2/AC are 397.47m^2/g and 656.33m^2/g respectively. Through five foliar concentrations from sodium silicate, composite nano silica/activated carbon and activated carbon at (100, 300, 500, 700 and 1000 mgl^{-1}) compared with untreated plants as control. Using of SiO_2/AC could be a good way to deal with problem of soil salinity. As for, there were no significant effect among 100, 300, 500 mgl^{-1} SiO_2/AC for EL% and MSI% in plant leaves. Foliar spraying with 500 mgl^{-1} SiO_2/AC improved different aspects of growth parameters, nutrient elements, amino acids and protein content in seeds. Furthermore, 300 mgl^{-1} SiO_2/AC gave the highest weight of 100 seeds, weight of seeds yields ton fed^{-1} and improved quality of fixed oil. On other side, proline content through both seasons decreased by 46.02 and 38.78 % compared with control when 500 mgl^{-1} SiO_2/ AC applied.

Keywords: Activated carbon, Nano silica, Date palm tree, Salinity, Fenugreek.

Introduction
Fenugreek (*Trigonella foenum-graecum*. L) is an annual plant belonging family *Fabaceae*. It is one of the most important medicinal and spice plants in the world (Ahmad *et al.,* 2016). Fenugreek considers a rich source of nutritional benefits as well as biological and pharmacological properties for human as a result of containing some chemical constituents as carbohydrates, proteins, lipids, pyridine type alkaloids such as trigonelline, choline, flavonoids, amino acids, minerals, saponins, β-carotene, sitosterol, vitamins, nicotinic acid, diosgenin and volatile oils (Nathiya *et al.,* 2014 and Ahmad *et al.,* 2016). Moreover, Fenugreek seeds contain fixed oils. The major components of the oil, linolenic acid and oleic acid, pinene, palmitic acid, -Pentyl-1-(4-propylcyclohexyl)-1-cyclohexene, linoleic acid methyl ester (GU *et al.,* 2017). Thus, it improves hyperglycemia and has anticancer, antimicrobial and antioxidant effects. Moreover, fenugreek improves adipocyte differentiation, inhibition of inflammation

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in adipose tissues, decreasing pancreatic and renal damage (Al Mosawi, 2021). The production of fenugreek crop is affected by environmental stress such as: drought, salinity and heat.

Salinity stress is one of the main environmental problems affecting on crops production (Taha *et al.,* 2021). When a plant is exposed to salinity, its production decreases and effects on its physiology and biochemistry properties. The negative effect of salinity on plant growth is linked to the osmotic effect and/or the ionic effect. Both effects are harmful as they may cause changes in cell membrane characteristics, water status, enzymes, protein synthesis and gene expression to growing plants (Prakash *et al.,* 2011).

Silicon (Si) has beneficial roles in growth of plants, development and its metabolism (Arif *et al.,* 2021). Its absence results negative consequences in plant growth and yield (Rajput *et al.,* 2021). Also, Si can alleviate different biotic and abiotic stresses (Afshari *et al.,* 2021 and Bayoumi *et al.,* 2021). Furthermore, Si improves the toughness of cell walls in plants and accumulates in the gaps among cells and outer layers, resulting in larger, thicker, and heavier leaves (Son *et al.,* 2012).

Sodium silicate is the common name for Na_2Sio_3 and also called "glass water". Na_2Sio_3 had efficacy to relieve the salt stress and showed improvement in growth parameters of wheat plants grown under salt stress (Mushtaq *et al.,* 2021).

Nano materials and their applications are increasing in agricultural biotechnology fields. Nano materials may have special properties due to their small size. When contrasted to bulk materials, they have the ability to modify physico-chemical properties because their surface area is greater than bulk materials, their solubility and surface reactivity tend to be higher. Wherase, Nano silica is considered an important nano fertilizers or nanoparticles with highly reactive surface to volume ratios. The most important agro-application of nano silica is to facilitate plant growth (Al-Saeedi, 2021), stress tolerance (Mathur and Roy, 2020) such as drought and salinity (Bayoumi *et al.,* 2021). The use of nano silica improves pea plants in saline soils (Ismail *et al.,* 2022).

Nowadays many agricultural by-products have received attention in the scientific literature. Date palm tree consider as economic crop especially in the Middle East. These trees generate tons of leaves, rachis, pits and trunk as wastes; a lot of them are converted to compost and using for traditional art and craft or burning causing pollution to environment (Maha *et al.,* 2021). Many products can be extracted from different parts of date palm tree as cellulose fiber from leaves and rachis (Maha *et al.,* 2021) and activated carbon from date palm pits by using different chemical activating agent and used in removal of organic and inorganic pollutant from waste water. Also leaves of date palm tree is consider as by-products which is pruned annually to ensure the healthy growing of the date palm tree and the quality of date fruits, there is about 1562171 tons from leaflet which produced annually as each tree produces 13-20 Kg of leaves (Chandrasekaran and Bahkali, 2013).

Activated carbon produced from agricultural waste materials. Its availability, cheap cost and efficient production might make it a top priority to replace nonrenewable commercial activated carbon in a variety of applications. (Yahya *et al.,* 2018). Active carbon has direct effects on plants as it improves nutrient availability and pH (Kabouw *et al.,* 2010).

Thereupon, the aim of the work dealing with preparation, characterization and application in agriculture effects as:

1- Preparation and characterization of activated carbon from leaflet of date palm tree and composite nano silica/ activated carbon using various instrumentation techniques.
2- Evaluation of foliar application from different concentration of sodium silicate, active carbon and composite nano silica/activated carbon on alleviation of salinity stress on fenugreek plants.

2. Materials and Methods

2.1. Raw materials

Date palm tree leaves (*Phoenix dactylifera* L.) were gathered from Egypt (Agricultural research center). The leaves were separated from the stalk, washed with water to get rid of dust and shaded in sunlight for one week, then cut, mild and collected through a 3 mm diameter mesh before chemical analysis.

Potassium hydroxide, Tetra -ethyl ortho silicate (TEOS) $Si(C_2H_5O)_4$, formamide $HCONH_2$, ethanol C_2H_5OH, nitric acid HNO_3 and sodium silicate (Na_2SiO_3) were obtained from Sigma-Aldrich.

2.2. Preparation of Activated carbon (AC) from leaflet of date palm tree and composite nano silica/activated carbon (SiO_2/AC).

To prepare activated carbon, leaflet will be carbonized at 700 ºC for 3h, then the samples was impregnated in solution from KOH by ratio 1:2 (precursor: KOH) using appropriate amount of water for 2 days, then samples dried over night after that the samples fired at 550ºC for 3h, washed, dried and stored in bottle.

SiO_2 /AC was prepared as 228 ml from TEOS, 157 ml $HCONH_2$which called as dry additive agent, 60ml C_2H_5OH and 4ml HNO_3 (1N aq) after that activated carbon sample which prepared from leaflet was added to above solution and stirring the mixture for 2h at 50 ºC and aged for three days. The formed product was dried over night at 105ºC, after that the samples was fired at 550 ºC for 3h to calcined.

2.3. Characterization of prepared AC and SiO_2/AC

Zeta potential and particle size distribution of activated carbon from leaflet of date palm tree and composite nano silica activated carbon samples was done using Zetasizer nano series (NanoZS, Malvern, UK), while, EDX analyses of the samples were done using Oxford Link Isis instrument, UK., IR spectra were done using FT/IR - 4700 type A in the absorbance mode from 4000 to 400 cm^{-1}. The morphology and structure of AC were observed by SEM (Quanta 250 FEG) as AC sample were sputter coated with gold for 2 min and then observed under a working voltage of 15 kV. While SiO_2/AC were studied using TEM Image Tecnai G20, Super twin, double tilt, FEI, Netherland. Surface area were determined using gas sorption analyzer. The adsorption – desorption isotherm of nitrogen was determined at its boiling point -196 ºC by Quanta chrom 3000 instruments, the samples are degassed under vacuum at 200 ºC for 5 h before measurement.

2.4. Field experimental

Two field experiments were carried out at the Experimental Station of the Agricultural Research Center in Tag El- Ezz, Dakahlia Governorate, Egypt (30°57' 25" N latitude and 31°35' 54" E longitude) through winter seasons of 2020/2021 and 2021/2022 to study the impact of different foliar concentrations from sodium silicate (Na_2SiO_3), composite nano (SiO_2 /AC) and (AC) from leaflet on plant growth, yield and chemical contents of fenugreek plant grown under saline soil conditions. The Average properties of the experimental soil for the two seasons are presented in Table (1).

Table 1: Average physico-chemical properties of the experimental soil during two seasons.

Particle size distribution	**Coarse sand**	3.43	**Ions (meq/100g soil)**	**Ca^{++}**	1.88
	Fine sand	29.40		**Na^{+}**	2.88
	Silt	38.05		**K+**	0.47
	Clay	29.12		**Cl^{-}**	2.76
	Texture class	Sand clay loam		**Mg^{++}**	1.27
EC dS m^{-1}		5.69	**Available nutrients ($mg\ kg^{-1}$)**	**N**	49.93
pH (1:2.5)		8.04		**P**	4.43
Organic matter (g 100 g^{-1})		1.24		**K**	136.00

2.5. Layout of Experimental

The experimental design was arranged in a complete randomized blocks with sixteen treatments; each treatment was replicated three times.

Chemical fertilizers (NPK) were added as ammonium sulphate (20.5% N) at 200 kg fed^{-1}, superphosphate (15.5% P_2O_5) at 200 kg fed^{-1} and potassium sulphate (48% K_2O) at 100 kg fed^{-1}. Super phosphate was added during soil preparation, ammonium sulphate and potassium sulphate doses were applied in two equal splits, after 30 and 60 days from sowing. Organic manures (FYM) were added to the soil before sowing at the rate of 10 m^3 fed^{-1}. Chemical analyses of the organic manures used are presented in Table (2).

Table 2: Average chemical analysis of FYM used for two seasons

Properties	Value
pH (1:10)	6.18
EC (1:10)(dSm^{-1})	3.84
Organic matter (%)	31.89
Total Nitrogen (%)	1.14
Total Phosphorous (%)	0.39
Total Potassium (%)	0.51

2.6. The experiment treatments.

Foliar application of Na_2SiO_3, SiO_2/AC and AC each of them solely were done three times. The first dose was given 40 days after sowing and was repeated twice after 20 days interval, sixteen treatments were arranged as follow:

1) control (untreated plants); 2) Na_2SiO_3 at 100 mgl^{-1}; 3) Na_2SiO_3 at 300 mgl^{-1}; 4) Na_2SiO_3 at 500 mgl^{-1}; 5) Na_2SiO_3 at 700 mgl^{-1}; 6) Na_2SiO_3 at 1000 mgl^{-1}; 7) SiO_2 /AC at 100 mgl^{-1}; 8) SiO_2 /AC at 300 mgl^{-1}; 9) SiO_2 /AC at 500 mgl^{-1}; 10) SiO_2 /AC at 700 mgl^{-1}; 11) SiO_2 /AC at 1000 mgl^{-1}; 12) AC at 100mg^{-1}; 13) AC at 300mg^{-1}; 14) AC at 500 mg^{-1}; 15) AC at 700 mg^{-1}; 16) AC at 1000 mg^{-1}.

2.7. Cultivation Process

Fenugreek seeds (*Trigonella foenum-graecum* L.) were obtained from Medicinal and Aromatic Plants Research Department, Horticultural Research Institute, Agricultural research center, Egypt. Cultivation process was performed in the second week of October in 1st and 2nd season respectively. Each treatment was replicated three times, which contained three rows, 5m long and 60 cm width. The seeds were sown in hills on two sides of row and the distances between hills 20 cm. After 20 days from sowing, seedlings were thinned to be two plants / hill. Other field practices for fenugreek growing were followed according to the recommendation of the Ministry of Agriculture and Land Reclamation, Egypt.

2.8. Data recorded.

2.8.1. Plant growth parameters.

Plant height (cm), leaves number, branch number, fresh and dry weights of the shoot (g) per plant, length of root (cm), fresh and dry weights of the root (g) per plant were estimated and Leaf area plant^{-1} (cm^2) measured according to Alessi and Power (1975) using the following formula:

Leaf area (LA) = leaf length x maximum leaf width x 0.75. Leaf area in cm^2 of three plants was summed and the leaf area/plant was calculated.

2.8.2. Seed yield components.

Number of pods plant^{-1}, weight of seeds plant^{-1} (g) and seed yield fed^{-1} (ton) were determined. Also, weight of 100 seeds (g) was estimated.

2.8.3. Chemical analysis of fenugreek plant.

Electrolyte leakage: Ion leakage was estimated as electrical conductivity (EC%) (Hassanein *et al.,* 2012) by conductivity meter (Jenway 470 portable conductivity meter). The percentage of electrolyte leakage (EL %) was calculated as a formula:

EL (%) = (C1/C2) × 100.

Where C1 and C2 are the electrolyte conductivities determined before and after boiling, respectively.
Membrane stability index (MSI %): was determined by Rady (2011). The MSI (%) was calculated by the following equation according to Premchandra *et al.* (1990).

MSI (%) = [1 – (EC1/EC2)] x100.

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Where, EC1 = electrical conductivity value in leaf tissue sample solution after heating at 40 ˚C for 30 min, and EC2 = electrical conductivity value in another leaf tissue sample solution after heating at 100 ˚C for 10 min.

Chlorophyll content was estimated in the fresh leaves according to Gavrilenko and Zigalova (2003).

Fenugreek seeds samples (0.2 g) were taken to wet digestion using a mixture of sulphuric and perchloric acids (1:1) to determine the following nutrient elements**:**

Total Nitrogen (g. $100g^{-1}$) was determined by the modified microkjeldahl method as described by Jones *et al. (*1991)

Total phosphorus (g. $100g^{-1}$) was estimated using spectrophotometer by Milten Roy Spectronic 120 at wavelength 725 nm using stannous chloride reduced molybdosulphoric blue colour method in sulphoric system according to Peters *et al.* (2003).

Total potassium and sodium (mg. $100g^{-1}$) was determined using Flame-Photometer by Jenway PFP7 model according to Peters *et al.* (2003).

Calcium was determined by atomic absorption spectrophotometer using perkin Elmer Model 370A as described by Chapman and Pratt (1978).

2.8.4. Chemical composition

Crude protein in the plant seeds was calculated by multiplying N content by 6.25 (A.O.A.C. 2000).

Proline was assayed in fresh leaves according to the method of Marin *et al.* (2010). Two ml of the extract, 2.0 ml of acid ninhydrin and 2.0 ml of glacial acetic acid were added. After that, it incubated for 1 h in a boiling water bath followed by an ice bath. The absorbance was measured at 520 nm using spectrophotometer (Jasco, V-630, B163061148, Japan). Standard curve was determined by using a known concentration of pure proline**.**

Total carbohydrate was estimated in the plant seeds colorimetrical using spectrophotometer (Jasco, V-630, B163061148, Japan) as method given by (Shumaila and Safdar, 2009).

Total free amino acids in the plant seeds was determined using spectrophotometer (Jasco, V-630, B163061148, Japan) according to the method described by Jayaraman (1985).

Fixed oil of fenugreek seeds was extracted using n-hexane as a solvent in a Soxhlet system HT apparatus according to the methods of (AOAC, 1984). Then, fixed oil yield per plant and per fed. were calculated.

Fatty Acid Profiles in fixed oil of fenugreek seeds in the second season were performed in the Regional Center for Food and Feed, ARC, Egypt, using Gas chromatogram with FID detector according to the methods of (AOAC, 2000).

2.9. Statistical analysis

The statistical analysis software; CoStat version 6.4 (CoHort Software) was used for the analysis of variance (ANOVA) of the data, comparison among means was carried out using Duncan's new multiple range test at probability (*P*) level ≤ 0.05 (CoStat, 2005).

3. Results and Discussion

3.1. Zeta potential

Zeta potential analysis was carried out to spot the surface charges obtained by prepared samples in the colloidal state. Figure (1a and 1b) represented zeta potential of AC from leaflet and composite SiO_2/AC which showing negative zeta potential -21.8 for activated carbon due to using KOH as activating agent and-9.41for composite SiO_2/AC.

3.2. Dynamic light scattering

It is a broadly technique carried out to determine solid particles size in colloidal solution Figure (2a and 2b) represented particle size of AC from leaflet and composite nano SiO_2/AC. we found that the size in the range of 100-1000 in case of AC which approximately equal 425 nm, while in case of composite nano SiO_2/AC the particle size in rang of 10–100 nm and PDI = 0.256 which means that the sample is in range of nanomaterials and the particles is monodispersed.

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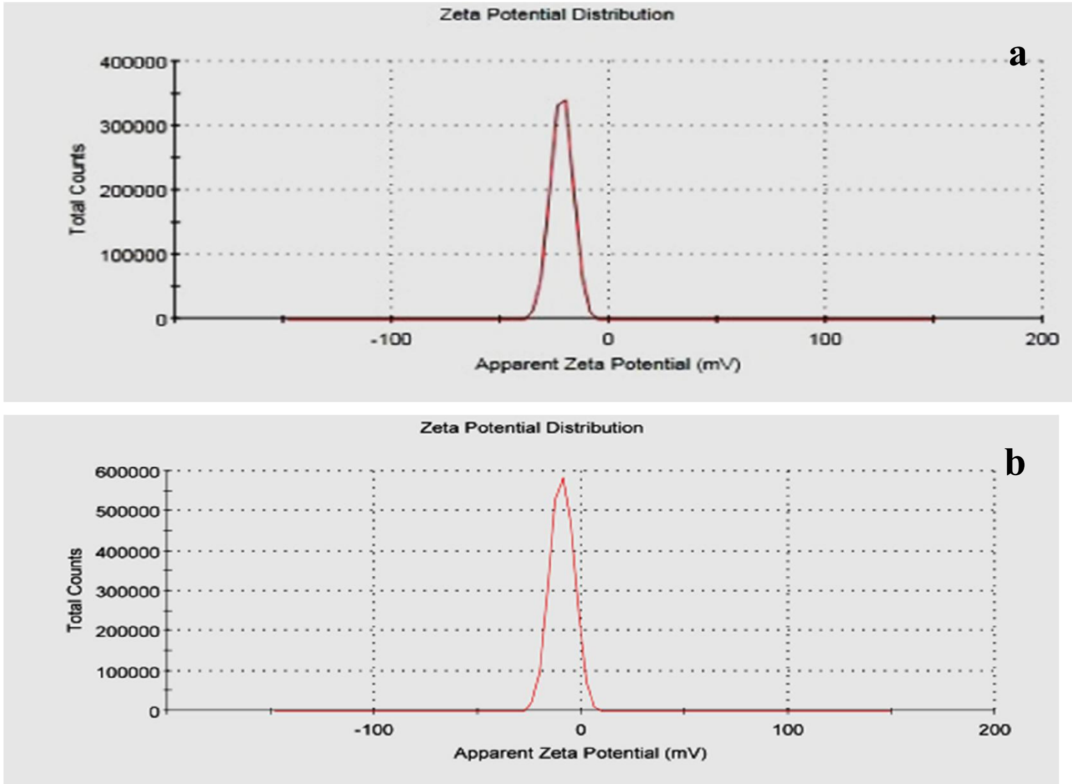

Fig. 1: Zeta potential of **(a)** activated carbon from leaflet, **(b)** composite nano silica/ activated carbon.

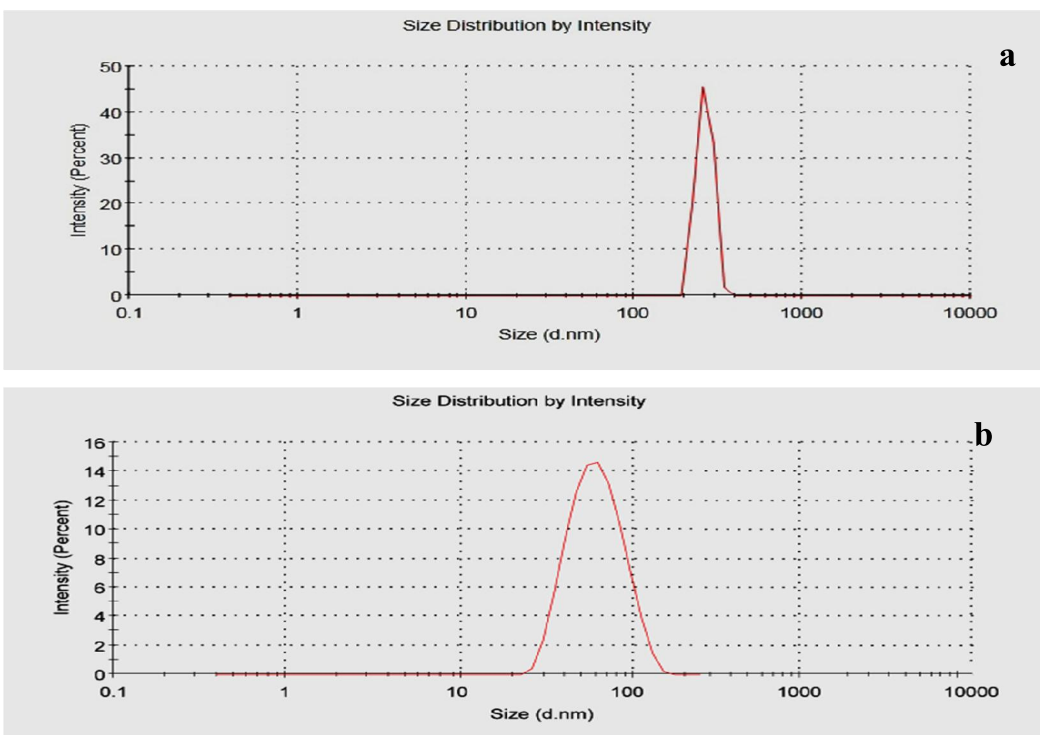

Fig. 2: Size distribution by number using Dynamic Light Scattering for (a) activated carbon from leaflet and (b) composite nano silica/ activated carbon.

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3.3. Energy dispersive x-ray

It is done to determine elemental analysis of all prepared samples from Figure (3a and 3b) we found that in case of AC sample there is only two peaks occur which corresponding to carbon and oxygen (70.31 wt % and 29.7 wt %) respectively, while in case of composite nano SiO_2/AC carbon there are three peaks appear which corresponding to carbon (48.05 wt %), silica (8.912 wt %) and oxygen (43.05 wt %). appearance of these peaks confirmed the formation of composite sample.

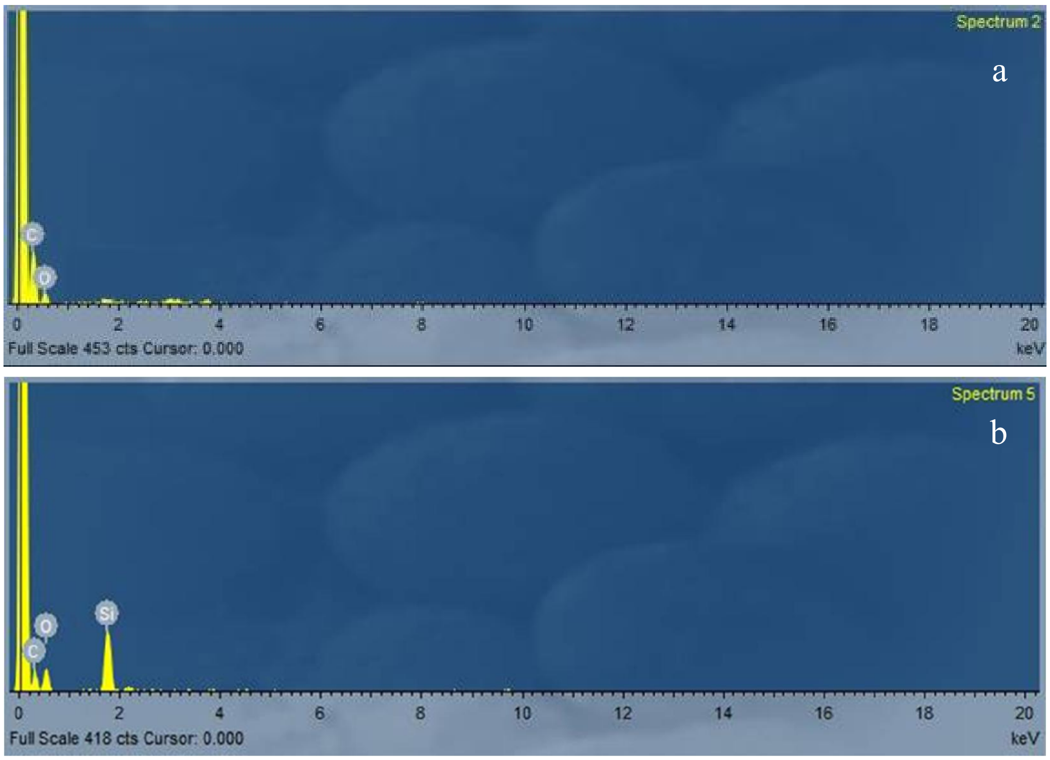

Fig. 3: EDX spectrum of (**a**) Activated carbon from leaflet, (**b)** Composite nano silica/activated carbon

3.4. FTIR spectroscopy analysis

FTIR spectroscopy is a simple technique that giving information about chemical changes which appears during chemical treatments (Ristolainen *et al.,* 2002). Figure (4) compares the FTIR spectra of AC from leaflet and SiO_2/ AC. The observation of absorption bands shows that there band around 3500 ─ 3400 $cm^{-}1$ is due to the –OH stretching vibration mode of hydroxyl functional groups and adsorbed water (Aguilar et *al* ., 2003). Small peak around 1520 cm^{-1} may due to the C=C stretching vibration in aromatic rings (Foo and Hameed 2009), due to the tars. While in case of nano composite SiO_2/ AC carbon there is peaks around 1050, 794 and 470 cm^{-1} refer to asymmetric, symmetric and the bending modes of SiO_2 (Günzler and Gremlich 2002&Duran *et al.,* 1986).

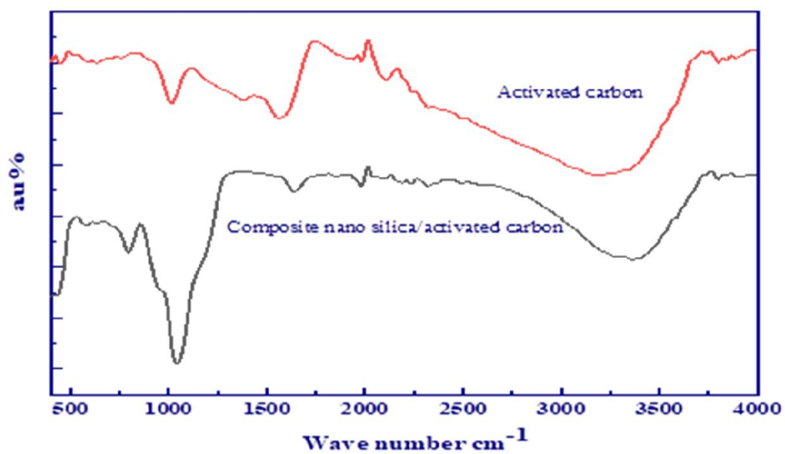

Fig. 4: FT-IR spectra of activated carbon from leaflet and composite nano silica /activated carbon.

3.5. Morphology of AC and SiO_2/AC samples.

SEM it is technique that used to detect the differences in surface morphologies while TEM is a major review measurement of the nano-particles size and morphology characterization Figure (5a) illustrated SEM image of AC sample and we found that activated carbon had randomly distributed pores. Such porosity was generated due to using potassium hydroxide as activating agent, pyrolytic decomposition of hemicelluloses and removal of byproducts from washing. Pores formation in an activated carbon is important as it is the active sites which playing the essential role in formation of composite nano SiO2/AC samples. From Figure (5b) it could be seen that silica particles had relatively better dispersion on the surface of activated carbon and tendency to form spherical silica particles in the average diameter 70 – 80 nm.

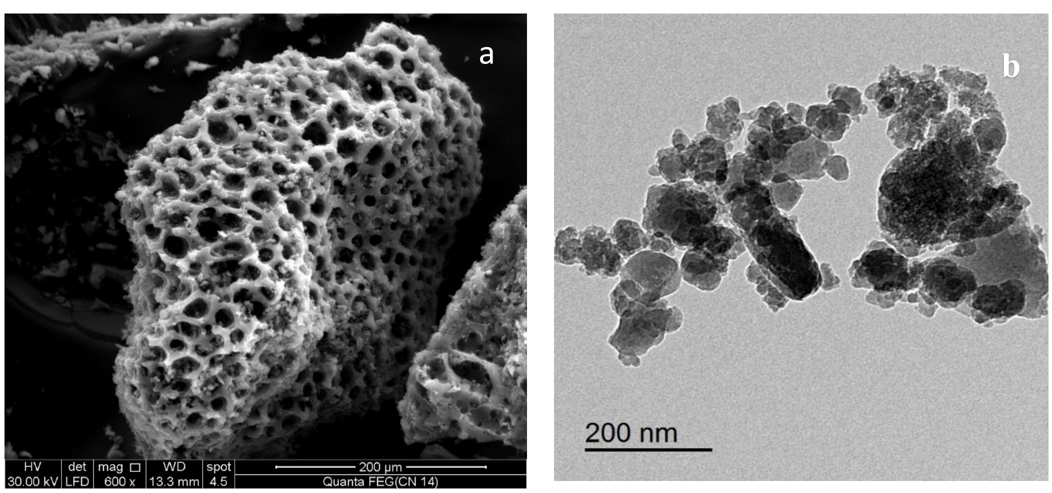

Fig. 5: (a) SEM of activated carbon from leaflet and (b) TEM of composite nano silica / activated carbon

3.6. Surface area and pore structure.

The BET surface area (S_{BET}), and the mean pore radius ($\bar{r}$) of the activated carbons were determined by application of Brunauer-Emmett-Teller (BET) analysis software available with the instrument equation and applied in the relative pressure range from 0.06 to 0.30 (Aroua *et al.,* 2008). The data are listed in Table (3).

Table 3: Textural properties of AC and SiO_2/AC as determined from nitrogen adsorption at -196°C

Adsorbents	S_{BET} (m²/g)	C_{BET}	Vp (cm³/g)	$\bar{r}$ (nm)
AC	397.46	3.071	0.1608	0.800
SiO_2/AC	656.33	2.75	0.2643	0.815

From Table (3) we can conclude that: the surface area for composite nano silica is higher than surface area of activated carbon from leaflets so this sample of nano silica will give good result with the plant that treated with it. Figure (6) presents the nitrogen adsorption/desorption isotherms at -196 °C for the investigated activated carbon sample. It is clear that all above sample give hysteresis loop, this hysteresis loop is usually attributed to thermodynamic or network effects or combination of two effects (Rouquerol *et al.,* 1999). Also, from Figure (7) we found Good straight line was obtained for points located in the relative pressure range (0.05-0.30). The second step when we applied BET theory is the determination of the surface area S_{BET}

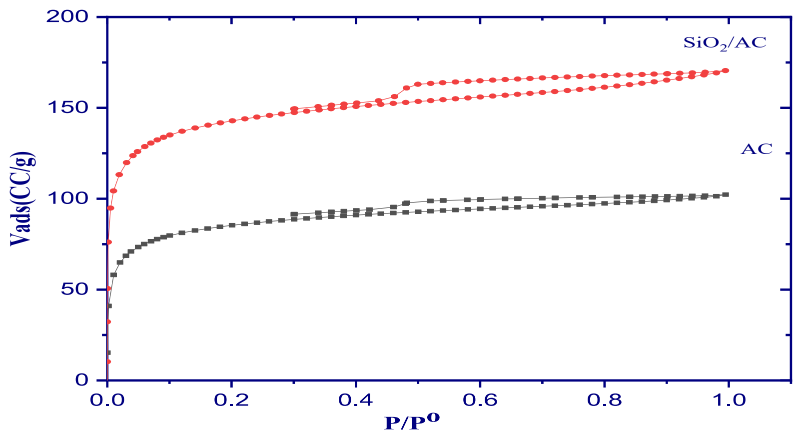

Fig. 6: Nitrogen adsorption / desorption isotherms at -196 oC for activated carbon from leaflet and composite nano silica / activated carbon

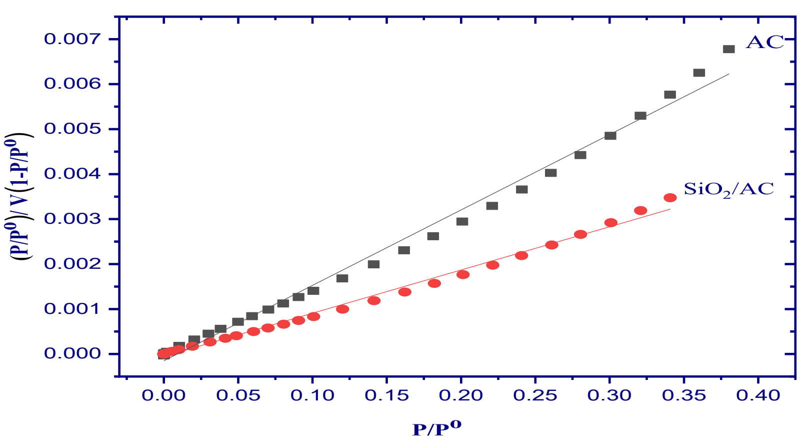

Fig. 7: The BET Linear plots of nitrogen adsorption isotherms at 77K for activated carbon from leaflet and composite nano silica / activated carbon

3.5. Electrode leakage (EL%) and membrane stability index (MSI%).

Data showed that (EL%) and (MSI%) of salt stressed fenugreek leaves showed various responses when treated with foliar spray of Na_2SiO_3, SiO_2/AC and AC at different concentrations. It was noted that the foliar spray of different concentrations caused a significant decrease in EL% and significantly increase MSI% in plant leaves comparing with control (Table 4). There was no significant effect among 100 mgl^{-1} AC, 100, 300, 500 mgl^{-1} SiO_2/ AC through 1st season. Application of SiO_2/ AC at 100 mgl^{-1} decreasing EL% by 31.10, 31.05 % and increasing MSI% by 14.13, 16.56% through two seasons, respectively when compared with control. Values of EL% and MSI% can be used to expect cell membrane damage that caused by salt stress (Ali *et al.,* 2008). The stimulation effect of saline on the EL % value might be attributed to injury the plasma membrane, that damage caused by reactive oxygen species (ROS) which could induce lipid peroxidation and consequently electrolyte leakage (Kassab *et al.,* 2012). Decreasing of EL% in response to various foliar application treatments may be due to stimulation of antioxidant responses that protect the plants from oxidative damage, increased membrane stability and tolerance of plants which in sequence enhanced scavenging of harmful free radicals (Rubinowska *et al.,* 2014) that keeps the plant from the oxidative damage by silicon treatments (Salwa *et al.,* 2013). Similar results were obtained by (Abdul Qados, 2015).

Table 4: Effects of Na_2SiO_3, SiO_2/AC and AC on electrode leakage and membrane stability index of fenugreek plants grown under salinity conditions during 2020/2021 and 2021/2022 seasons.

Treatments		Electrode leakage (EL %)		Membrane stability index (MSI %)	
		1st season	2nd season	1st season	2nd season
Control		31.25	34.78	68.75	65.22
Na_2SiO_3 (mgl^{-1})	**100**	28.84	31.37	71.16	68.63
	300	28.58	30.64	71.42	69.36
	500	27.64	28.56	72.36	71.44
	700	26.40	28.00	73.60	72.00
	1000	26.50	26.61	73.50	73.39
SiO_2/AC (mgl^{-1})	**100**	21.53	23.98	78.47	76.02
	300	21.79	23.40	78.21	76.60
	500	21.88	24.37	78.12	75.63
	700	25.29	25.63	74.71	74.37
	1000	26.43	27.50	73.57	72.5
AC (mgl^{-1})	**100**	21.97	23.66	78.03	76.34
	300	25.64	26.84	74.36	73.17
	500	27.43	28.68	72.57	71.32
	700	29.50	32.06	70.50	67.94
	1000	30.63	33.89	69.38	66.11
LSD at 5%		1.53	1.71	1.73	1.82

3.6. Plant growth characters.

It was observed that there were no significant differences between 100 mgl^{-1}SiO_2/ AC and 300 mgl^{-1} AC for shoot length comparison to the control. Foliar spray fenugreek plants with SiO_2/ AC at 100 mgl^{-1} induced shoot length by (22.68 and 32.54%); root dry weight by (113 and 157%) , respectively through two seasons. While, foliar spray with SiO_2/ AC at 500 mgl^{-1} revealed significant positive effects for branch number by (127.58 and 95%); leave number by (75.43 and 101%); fresh and dry weight of shoot by (136.18, 123.33 and 133, 130 %), leaf area by (73.62 and 77.01%) during 1st and 2nd seasons, respectively. concerning with root length, there were no significant difference among plants treated with 100 mgl^{-1} Na_2Sio_3, 1000 mgl^{-1} AC and untreated plants (Table 5).

To overcome salinity stress, plants have changed several systemic signals pathways as electricity, calcium, ROS, and hormones (Choudhury *et al.,* 2018), which enables plant tissues to alleviate stress (Fichman and Mittler, 2020). As discussed before the surface area for SiO_2/AC is 660.33 m^{2}g^{-1} as mentioned in Table (3). So, composite nano silica activated carbon can improve the plant tolerance to salt stress by decreased ROS production or hormones level changing (Wang *et al.,* 2022), increased antioxidant enzymes activities (Naguib and Abdalla, 2019), increased K^+ uptake and decreased Na^+ uptake by addition of Si were the main mechanisms responsible for improving growth of plants under salinity conditions (Shahzade, 2012). These results are in context with Badawy *et al.* (2021). It was found that foliar applications of SNPs improve saline tolerance, root improvement, growth efficiency of rice. Furthermore, activated carbon had randomly pores on the surface as observed in (Figure 5a).

(Chutipaijit and Sutjaritvorakul, 2018) who stated that activated carbon enhanced the callus induction and regeneration of plant in tissue culture medium of rice.

Table 5: Effects of Na_2SiO_3, SiO_2/AC and AC on plant growth characters of fenugreek plants grown under salinity conditions during 2020/2021 and 2021/2022 seasons.

Treatments		Shoot length (cm)		Branch (No.)		Leaves (No)		Root length (cm)		Leaf area (cm^2)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		35.50	40.23	7.25	10.00	57.00	64.00	16.50	18.00	2.54	2.48
Na_2SiO_3 (mgl^{-1})	**100**	36.00	44.50	8.50	10.00	73.00	77.00	16.50	17.00	3.89	4.01
	300	37.00	47.00	10.60	11.25	77.00	83.00	15.59	16.15	3.60	3.80
	500	38.00	47.50	12.00	14.00	86.50	80.00	13.50	15.75	3.49	3.56
	700	40.00	49.66	13.00	15.00	92.00	100.00	13.50	14.50	3.49	3.50
	1000	39.50	48.00	14.00	16.50	95.50	93.00	13.75	14.59	3.49	3.50
SiO_2/ AC (mgl^{-1})	**100**	43.76	53.32	13.50	17.75	94.00	107.50	13.00	12.00	3.90	4.13
	300	40.00	51.50	14.50	19.00	96.50	117.50	11.50	11.00	3.90	3.90
	500	39.15	50.45	16.50	19.50	100.0	129.5	10.50	10.00	4.41	4.39
	700	38.55	50.00	14.00	18.50	97.50	104.00	12.15	11.50	4.25	4.19
	1000	36.62	47.50	12.80	16.35	82.50	88.00	13.00	13.00	3.70	3.85
AC (mgl^{-1})	**100**	41.00	49.00	10.00	12.50	65.00	77.50	14.56	15.00	4.20	4.23
	300	43.50	52.50	10.75	12.50	74.00	89.75	12.75	13.50	3.38	3.44
	500	40.77	51.00	12.00	14.00	89.00	100.50	13.50	14.00	3.47	3.50
	700	37.79	43.45	8.50	11.00	70.00	75.00	15.50	16.50	3.04	2.92
	1000	33.00	41.00	7.00	9.50	63.00	65.00	16.50	18.00	2.70	2.61
LSD at 5%		1.25	1.47	1.45	1.33	5.90	7.42	1.50	1.81	0.21	0.18

Table 5: continued.

Treatments		Shoot fresh weight (g $plant^{-1}$)		shoot Dry weight (g $plant^{-1}$)		Root fresh weight (g $plant^{-1}$)		Root dry weight (g $plant^{-1}$)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		11.22	12.73	1.89	1.98	0.39	0.45	0.15	0.14
Na_2SiO_3 (mgl^{-1})	**100**	13.05	14.50	2.46	2.82	0.55	0.53	0.17	0.16
	300	16.50	19.13	2.83	2.43	0.69	0.74	0.21	0.23
	500	17.37	21.12	3.02	3.18	0.80	0.88	0.28	0.32
	700	20.02	22.00	3.28	3.69	0.85	0.92	0.26	0.26
	1000	23.18	25.50	3.51	3.52	0.77	0.81	0.24	0.26
SiO_2/AC (mgl^{-1})	**100**	22.57	25.00	3.24	3.73	0.81	0.88	0.32	0.36
	300	23.52	25.34	3.58	4.01	0.98	1.13	0.31	0.33
	500	26.50	28.43	4.40	4.57	0.86	1.01	0.28	0.30
	700	23.41	24.12	4.16	4.18	0.79	0.92	0.28	0.29
	1000	23.56	23.15	2.41	3.12	0.70	0.77	0.17	0.20
AC (mgl^{-1})	**100**	19.24	19.00	2.80	2.98	0.87	1.02	0.20	0.23
	300	20.92	23.43	4.16	3.96	0.75	0.98	0.30	0.33
	500	22.06	25.13	3.56	3.78	0.69	0.74	0.23	0.28
	700	16.57	15.97	2.02	2.17	0.52	0.60	0.18	0.20
	1000	11.00	12.45	1.75	1.84	0.49	0.46	0.15	0.15
LSD at 5%		1.37	1.92	0.22	0.16	0.12	0.12	0.021	0.027

3.7. Yield parameters.

It was obviously clear that the foliar application of SiO_2/ AC at 500 mgl^{-1} induce increasing the number of pods per plant by (89.9 and 102.88 %) comparing with the control through both seasons respectively. While, at concentration 300 mgl^{-1} SiO_2/ AC increased weight of seeds per plant by (34.13 and 37.05%) and weight of 100 seeds by (41.51 and 37.73 %) , through two seasons, respectively when compared with the control. However, 1000 mgl^{-1} AC gave poor data for the studied traits (Table 6). Salinity may cause damage to the ovary, and subsequently cause a reduction in the yield (Munns and Tester, 2008) due to harm effects of salinity on some metabolic processes in plant tissues (Al-Ashkar *et al.,* 2019), also plants close stomata to prevent water loss through transpiration. This mechanism limits CO_2 assimilation, which in turn slows down the photosynthesis process and limits the plant yield (El Moukhtari *et al.,* 2020). The present study showed treating with SiO_2/ AC were the most effective in alleviating the harmful effect of salinity on the plants. Where, Si treatments lead to increase K uptake and decrease Na uptake, hence increasing plant tolerance to salinity stress, as a result increasing productivity (Meena *et al.,* 2014). Moreover, SNPs improved the mechanical strength of plant tissues because of the amorphous solid Si accumulation on the cell wall layers (Yaghubi *et al.,* 2019), enhancing the activity of antioxidant enzymes (Abdul Qados, 2015). Beside nano silica, activated carbon enhanced the flowering in pineapple plants (van de Poel *et al.,* 2009). Our results agree with Ayman *et al.* (2020) who found that nano silica improves wheat yield under salinity stress and Taha *et al.* (2021) on lupine.

Table 6: Effects of Na_2SiO_3, SiO_2/AC and AC on yield characters of fenugreek plants grown under salinity conditions during 2020/2021 and 2021/2022 seasons.

Treatments		No of pods plant^{-1}		No of seeds pod^{-1}		Weight of seeds plant^{-1} (g)		Weight of 100 seeds (g)		Weight of seeds yield fed $^{-1}$ (ton)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		20.80	20.43	15.00	14.50	2.90	2.78	1.06	1.06	0.406	0.389
Na_2SiO_3 (mgl^{-1})	**100**	25.17	24.00	15.75	17.15	3.09	2.99	1.09	1.11	0.433	0.419
	300	27.75	24.00	16.00	17.75	3.31	3.41	1.17	1.19	0.463	0.477
	500	29.50	30.75	17.00	19.00	3.09	3.15	1.13	1.12	0.433	0.441
	700	31.25	30.66	17.00	17.50	3.01	3.02	1.13	1.14	0.421	0.423
	1000	33.50	33.50	15.50	16.00	3.01	2.94	1.07	1.09	0.421	0.412
SiO_2/ AC (mgl^{-1})	**100**	34.50	32.50	18.50	19.85	3.57	3.52	1.17	1.13	0.500	0.493
	300	36.25	37.00	16.50	20.45	3.89	3.81	1.50	1.46	0.545	0.533
	500	39.50	41.45	16.50	23.00	3.78	3.78	1.23	1.30	0.529	0.529
	700	38.00	38.86	20.00	18.60	3.60	3.65	1.13	1.27	0.504	0.511
	1000	37.05	38.50	15.50	17.00	3.58	3.57	1.20	1.23	0.501	0.500
AC (mgl^{-1})	**100**	37.50	39.75	22.00	18.50	3.76	3.70	1.17	1.17	0.526	0.518
	300	31.55	33.00	16.25	17.00	3.57	3.57	1.11	1.14	0.500	0.500
	500	28.50	29.18	17.00	20.00	3.49	3.57	1.07	1.12	0.489	0.500
	700	20.00	22.00	23.50	19.50	3.06	3.20	1.09	1.12	0.428	0.448
	1000	18.00	20.00	18.25	17.88	2.80	2.96	1.00	1.07	0.392	0.414
LSD at 5%		2.38	1.80	2.20	2.44	0.24	0.19	0.059	0.098	0.034	0.026

3.8. Photosynthetic pigments.

In our present study, the data registered in (Table7) cleared that there were non-significant effect between application of 300 and 500 mgl^{-1} SiO_2/ AC for Chl a and total chlorophyll through both seasons. While, at 300 mgl^{-1} SiO_2/ AC, Chl b increased by 44.4 and 37.56% when compared with the control, respectively through two seasons. Treated plants with 700 mgl^{-1} SiO_2/ AC increased carotenoid content by (24.29 and 27.85%) over control during 1st and 2nd seasons, respectively. Salinity induces the activity of some enzymes that degrade chlorophylls (Banakar *et al.,* 2022). Different foliar application from Na_2SiO_3, SiO_2/AC and AC reduced the side effects of salinity stress on photosynthetic pigments through reduction EL% and rising MSI % as displayed before. Furthermore, the decreasing the ROS and elevating the antioxidant systems stabilize the chloroplast membrane and protect the chloroplasts from salt stress and stopped degradation of leaf chlorophyll (Sevengor *et al.,* 2011 & Siddiqui and Al-Whaibi, 2014). Our results were matched with El- Emary and Amer (2018) on faba bean and maize plants.

3.9. Nutrient elements.

Data in Table (8) cleared that foliar application with 500 mgl^{-1} SiO_2/ AC significantly increased the N by (21.26, 19.35%), P by (37.27, 42.39%), K by (9.71, 9.22%) and Ca content by (28.49, 20.57%) in fenugreek seeds respectively, comparing with control plants. On other hand, Na content decreased with the same treatment by (38.75, 34.15%) through two seasons respectively. It was noticed that there was no significant effect for P content among 500 mgl^{-1} SiO_2/ AC and 100 mgl^{-1} AC through 1st season. N, P, K and Ca are very important elements for membrane structure, cell division, stomatal function, and plant growth cell wall synthesis, involved in plant defence and repair the damage from biotic and abiotic stress (Hu and Schmidhalter, 2005). Also, high potassium content improves water potential and sustainability of plant finally ameliorates the Na^+ ion toxicity. Hence, it is concluded that foliar application of 500 mgl^{-1} SiO_2/ AC increases potassium uptake and alleviates Na^+ toxicity. It may be due to the effect of nano silica on the uptake of the minerals and the reduction in the absorption of Na. These results were on line with reported by (Abdul Qados, 2015) on faba bean, Sadak and Ahmed (2016) on wheat plant and Banakar *et al.* (2022) on fenugreek.

Table 7: Effects of Na_2SiO_3, SiO_2/AC and AC on photosynthetic pigments of fenugreek plants grown under salinity conditions during 2020/2021 and 2021/2022 seasons.

Treatments		Ch l a (mg g^{-1} f. wt)		Chl b (mg g^{-1} f. wt)		Total chlorophyll (mg g^{-1} f. wt)		Carotenoid (mg g^{-1} f. wt)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		0.958	0.923	0.389	0.426	1.347	1.349	1.066	1.034
Na_2SiO_3 (mgl^{-1})	**100**	1.107	1.321	0.540	0.532	1.647	1.853	1.217	1.210
	300	1.102	1.333	0.536	0.551	1.638	1.884	1.268	1.243
	500	1.180	1.352	0.530	0.543	1.71	1.895	1.231	1.228
	700	1.195	1.386	0.520	0.519	1.715	1.905	1.235	1.237
	1000	1.212	1.402	0.499	0.505	1.711	1.907	1.241	1.249
SiO_2/ AC (mgl^{-1})	**100**	1.265	1.385	0.541	0.558	1.806	1.943	1.283	1.274
	300	1.300	1.432	0.562	0.586	1.862	2.018	1.291	1.288
	500	1.308	1.428	0.551	0.574	1.859	2.002	1.296	1.303
	700	1.264	1.390	0.503	0.532	1.767	1.922	1.325	1.322
	1000	1.229	1.336	0.471	0.499	1.700	1.835	1.252	1.273
AC (mgl^{-1})	**100**	1.121	1.227	0.481	0.512	1.602	1.739	1.271	1.278
	300	1.133	1.235	0.494	0.507	1.627	1.742	1.274	1.282
	500	1.157	1.210	0.514	0.536	1.671	1.746	1.294	1.299
	700	1.190	1.249	0.551	0.549	1.741	1.798	1.311	1.311
	1000	0.973	0.953	0.431	0.455	1.404	1.408	1.225	1.242
LSD at 5%		0.0259	0.0286	0.0306	0.029	0.048	0.0365	0.0215	0.0262

Table 8: Effects of Na_2SiO_3, SiO_2/AC and AC on nutrient contents of fenugreek plants grown under salinity conditions during 2020/2021 and 2021/2022 seasons.

Treatments		N (g. 100g^{-1})		P (g. 100g^{-1})		K (mg. 100g^{-1})		Na (mg. 100g^{-1})		Ca (mg. 100g^{-1})	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		3.34	3.41	0.220	0.217	752	748	111	110	172	175
Na_2SiO_3 (mgl^{-1})	**100**	3.38	3.53	0.214	0.219	744	753	104	108	174	172
	300	3.50	3.58	0.237	0.242	755	765	100	102	186	181
	500	3.72	3.80	0.270	0.264	785	773	95	94	201	196
	700	3.74	3.81	0.277	0.270	787	775	95	93	204	198
	1000	3.90	3.90	0.282	0.288	793	779	93	93	210	200
SiO_2/AC (mgl^{-1})	**100**	3.66	3.74	0.276	0.285	786	776	94	90	199	197
	300	3.97	3.96	0.293	0.300	813	803	83	85	216	206
	500	4.05	4.07	0.302	0.309	825	817	80	82	221	211
	700	3.88	3.90	0.289	0.289	791	786	91	89	212	199
	1000	3.76	3.83	0.280	0.278	780	780	96	92	191	196
AC (mgl^{-1})	**100**	3.93	3.98	0.300	0.293	810	800	82	83	209	209
	300	3.86	3.75	0.287	0.282	790	780	88	87	198	193
	500	3.75	3.72	0.270	0.267	781	768	93	90	189	189
	700	3.63	3.57	0.254	0.257	769	761	93	93	187	178
	1000	3.57	3.52	0.231	0.242	760	757	91	94	179	177
LSD at 5%		0.084	0.078	0.010	0.009	6.48	4.90	2.70	2.00	2.18	1.86

3.10. Chemical composition.

Different foliar treatments decreased proline accumulation particularly when plants sprayed with SiO_2/ AC. There were non-significant difference between 100, 300 and 500 mgl^{-1} SiO_2/ AC for proline through two seasons. Proline content through both seasons decreased by (46.02 and 38.78%) compared with control when 500 mgl^{-1} SiO_2/ AC treated with. Furthermore, treated with 500 mgl^{-1} SiO_2/ AC gave significant value of amino acids and protein through two seasons where the increasing by (73.03, 79.13% and 21.21, 19.38%) over the control, respectively. Concerning with total carbohydrate there were no significant differences between 1000 mgl^{-1} SiO_2/ AC and 100 mgl^{-1} AC through both seasons (Table 9).

Proline plays an important role in plant osmotic regulation, where it accumulates under stress conditions (Nayyar and Walia, 2003). The accumulation of proline and amino acids permits plants to keep cell turgor pressure for cell expansion under salinity stress conditions; act as osmo-protectants (Ruiz-Carrasco *et al.,* 2011). Proline has the ability to scavenge ROS and other free radical compounds, preventing protein denaturation during stress (Szabados and Savouré, 2010). Proline content increasing consistent with the suggestion that nitrogen forwarded to the synthesis of proline instead of chlorophyll. Improvement of protein and carbohydrate content might be due to the role of Si-NPs in the activation of various enzymes associated with protein and amino acids biosynthesis beside carbohydrate metabolism (Ma and Yamaji, 2008; Wang *et al.,* 2013 and Mahmoud *et al.,* 2020). Beside the role of activated carbon that randomly distributed pores on the surface as observed from (Figure 5a) The results of our study are in line with those obtained by Rahimi *et al.* (2012) on fennel; Kalteh *et al.* (2014) on basil and Ayman *et al.* (2020) on wheat.

Table 9: Effects of Na_2SiO_3, SiO_2/AC and AC on chemical compositions of fenugreek plants grown under salinity conditions during 2020/2021 and 2021/2022 seasons.

Treatments		Proline content (µmol g^{-1}).		Amino acid (%)		Protein content (g. 100g^{-1})		Total carbohydrates (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		2.89	2.63	0.152	0.139	20.88	21.31	54.72	55.32
Na_2SiO_3 (mgl^{-1})	**100**	2.33	2.35	0.154	0.144	21.13	22.06	55.85	57.50
	300	2.26	2.29	0.157	0.148	21.88	22.38	57.35	58.00
	500	2.15	2.24	0.159	0.153	23.25	23.75	59.22	60.07
	700	2.13	2.18	0.159	0.157	23.38	23.81	59.47	60.39
	1000	2.07	2.11	0.161	0.166	24.38	24.38	62.50	63.50
SiO_2/AC (mgl^{-1})	**100**	1.64	1.77	0.224	0.203	22.88	23.38	62.37	64.00
	300	1.58	1.68	0.237	0.218	24.79	24.75	62.37	64.18
	500	1.56	1.61	0.263	0.249	25.31	25.44	61.04	65.43
	700	1.94	1.95	0.191	0.200	24.25	24.38	61.65	66.32
	1000	2.11	2.14	0.152	0.194	23.50	23.94	67.80	67.00
AC (mgl^{-1})	**100**	2.23	2.18	0.147	0.140	24.56	24.88	67.77	66.67
	300	2.17	2.03	0.153	0.151	24.13	23.44	63.70	61.50
	500	2.54	2.21	0.151	0.149	23.44	23.25	56.79	57.37
	700	2.78	2.29	0.149	0.140	22.69	22.31	54.22	53.20
	1000	2.88	2.50	0.138	0.130	22.31	22.00	52.55	51.08
LSD at 5%		0.18	0.17	0.015	0.011	0.53	0.48	2.10	2.02

3.11. Fixed oil content.

Foliar spraying with Na_2SiO_3 and SiO_2/AC improve the fixed oil percentage. It was noted that, no significant effect among 1000 mgl^{-1} Na_2SiO_3 and 300 mgl^{-1} SiO_2/ AC. Fixed oil percentage was increased At 300 mgl^{-1} SiO_2/ AC by (100.4 and 97.87%) over the control, respectively during the two seasons (Table 10). Oil yield influenced by salinity (Farouk and Omar, 2020). Si might be act as an important factor in elicitor accelerated secondary metabolite production that might improve various transcriptional modifications. Si may be enhance oil yield by enhancing cell development and ion uptake (Esmaeilzadeh and Rezaei, 2018). This result is matched with previous studies that showed using of Si enhanced oil accumulation and possibly served as an effective stimulant to increase the production of secondary metabolites (Farouk and Omar, 2020). Our results agree with El-Leithy *et al.* (2019) on black cumin and Farouk *et al.* (2020) on sweet basil.

3.12-Fixed oil constituents.

The analysis of fenugreek seeds oil illustrates that, the oil composed of 12 well known fatty acids (Table 11). The results declared that foliar spray of 300 mgl^{-1} SiO_2/ AC resulted in decrement in palmitic acid, heptadecanoic acid, stearic acid, vaccinic acid and gondoic acid by 5.34, 24.4, 2.1, 20 and 16.67%, respectively compared to the control. Myristic acid disappeared in SiO_2/ AC treated plants. On the other hand, SiO_2/ AC treatment increased arachidic and behenic saturated fatty acids. Moreover, foliar spray with 300 mgl^{-1} SiO_2/ AC increased the palmitoleic and linoleic omega-6 unsaturated fatty acids by 88.8 and 5.91%, receptively compared to untreated plants but declined oleic and linolenic unsaturated fatty acids by 0.45 and 2.84%, respectively compared with untreated plants. So, according to the present results, 300 mgl $^{-1}$ SiO_2/AC improve the oil quality of the studied fenugreek plants, that it reduces the concentration of saturated fatty acids by 4.64% and increasing the unsaturated fatty acids by 1.12% compared to control. The oil was rich with unsaturated fatty acids, chiefly linoleic, linolenic and oleic fatty acids acids, which have therapeutic importance. The major compounds fenugreek oil is linoleic acid omega-6 (Akbari *et al.,* 2019). The occurrence of saturated acids (18.1 and 17.26%) in fenugreek seeds oil in control and SiO_2/ AC at (300 mgl $^{-1}$), respectively represent a chief quantitative variation against marketable oils. Our results agree with Sulieman *et al.* (2008) on fenugreek seed oil and Farouk *et al.* (2022) on borage seeds oil. Such positive role may be achieved by silicate that lead to increase unsaturation fatty acids (Wang and Galletta, 1998).

Table 10: Effects of Na_2SiO_3, SiO_2/AC and AC on fixed oil content of fenugreek plants grown under salinity conditions during seasons of 2020/2021 and 2021/2022.

Treatments		Fixed oil percentage (%)		Fixed oil content plant^{-1} (g)		Fixed oil content fed^{-1} (Kg)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		6.95	7.03	0.20	0.19	28.32	27.20
Na_2SiO_3 (mgl^{-1})	**100**	10.50	10.37	0.32	0.31	45.39	43.42
	300	11.07	11.13	0.37	0.38	51.23	53.09
	500	11.51	11.49	0.36	0.36	49.72	50.69
	700	12.32	12.51	0.37	0.38	51.81	52.86
	1000	13.71	13.80	0.41	0.41	57.74	56.88
SiO_2/ AC (mgl^{-1})	**100**	13.26	13.32	0.47	0.47	66.31	65.59
	300	13.93	13.91	0.54	0.53	75.92	74.11
	500	10.98	11.07	0.42	0.42	57.99	58.52
	700	9.5	9.62	0.34	0.35	47.88	49.16
	1000	9.37	9.41	0.34	0.34	46.99	46.98
AC (mgl^{-1})	**100**	9.87	9.93	0.37	0.37	51.95	51.36
	300	8.41	8.62	0.30	0.31	42.03	42.99
	500	8.01	8.00	0.28	0.29	39.07	39.96
	700	7.39	7.47	0.23	0.24	31.62	33.55
	1000	6.35	6.89	0.18	0.20	24.83	28.62
LSD at 5%		1.09	1.05	n.s	n.s	5.02	4.62

Table 11: Fixed oil constituents of the selected treatments in the second season.

Fatty acids	Relative distribution (%)	
	Control	SiO_2/ AC (300mgl $^{-1}$)
Myristic acid (C14:0)	0.19	--
Palmitic acid (C16:0)	11.43	10.82
Heptadecanoic acid (C17:0)	0.41	0.31
Stearic acid (C18:0)	4.29	4.20
Arachidic acid (C20:0)	1.33	1.41
Behenic acid (C22:0)	0.45	0.52
Palmitoleic acid (C16:1)	0.27	0.51
Vaccinic acid (C18:1) omega-7	0.40	0.32
Oleic acid (C 18:1) omega-9	15.67	15.60
Linoleic acid (C18:2) omega-6	31.16	33.0
Linolenic acid (C18:3) omega-3	34.17	33.20
Gondoic acid (C20:1)	0.24	0.20
No. of fatty acids	12	11
Total saturated%	18.1	17.26
Total unsaturated%	81.91	82.83

Conclusion

Activated carbon were prepared from date palm tree leaflet using KOH as activating agent and composite SiO_2/ AC. S_{BET} ranged between 397.46 and 656.33 m^2/g. It is obvious that the use of SiO_2/ AC enhanced fenugreek crop productivity under salinity soil conditions. Thus, in this context, the usage of 500mgl^{-1} SiO_2/ AC could be more effective for growth parameters and chemical composition while 300mgl^{-1} SiO_2/ AC improved yield characters and fixed oil percentage. On other hand, the application of higher concentration from activated carbon had poor effects for different aspects compared with other treatments. Also, the preparation of activated carbon from leaflet of date palm tree and its application in agriculture field consider a new way to get rid of leaflet of palm tree as waste causing problem in environment.

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