



## Effect of nanosilicon and phosphorus levels added to saline soil on phosphorus availability and growth and yield of cauliflower (*Brassica oleracea* L. var. botrytis)

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### Abstract:

A field experiment was carried out at the Agricultural Research Station College of Agriculture, University of Basrah, southern Iraq during the growing season of 2023, to study the effect of adding nanosilicon on the available and uptake of phosphorus added at three levels to in saline soil (EC, 29.22 dSm<sup>-1</sup>) planted with cauliflower plants. The experiment was designed in a Completely Randomized Block Design with three replications and two factors: the first was nano silicon levels (0, 100, and 200 kg Si ha<sup>-1</sup>) and the second was phosphorus levels (0, 30, and 60 kg P ha<sup>-1</sup>). Cauliflower (*Brassica oleracea* L. var botrytis) seedlings were transplanted to field at a rate of 5 plants per plot (2 x 0.5 m), and irrigated with Shatt al-Arab water through a drip irrigation system. Results indicated that silicon supply decreased the concentration of soluble Ca+Mg in soil solution compared to the control treatment, which resulted in an increase in available phosphorus in the soil, reaching a maximum value of 65.94 mg kg<sup>-1</sup> soil at the level of 200kg Siha<sup>-1</sup>. Addition of nanosilicon at level of 100 kg Si ha<sup>-1</sup> improved growth parameters and yield of cauliflower (P leaves, number of leaves, leaf area, curds yield) and quality of leaves and curd (TSS, chlorophyll, and carotene). However, increasing silicon supply to 200 kg Si ha<sup>-1</sup> led to a decrease in all parameters. The results also indicated that addition phosphorus resulted an increase in Ca+Mg concentration soil

solution. Increasing the phosphorus levels improved growth parameters and yield of cauliflower plants. The highest value for curds yield( 69.27 Mg ha<sup>-1</sup>) was obtained in plant received 100 Kg Si ha<sup>-1</sup> along with 60 Kg p ha<sup>-1</sup>.

*Keywords: nanosilicon, available-p, cauliflower, soluble calcium and magnesium, leaf area, curd yield.*

## INTRODUCTION:

Agriculture provides food for more than 7 billion people, and this is expected to increase by 50% in 2050 (Molotoks *et al.*, 2021), which will confirmed the global need for food production, especially in developing countries where population growth rate is 90%. Therefore, the increase in crop production must range between 70% and 100% in 2050 (World Bank. 2008). This increase of production requires organic and inorganic fertilizers to achieve the desired yield. However the excessive addition of chemical fertilizers cause soil degradation and lose its fertility and biodiversity, in addition to being polluted and increasing the cost of the agricultural processes and exacerbated the phenomena of salinization and desertification, making soil unsuitable for sowing (Acquaah.2007).

Phosphorus is one of the major nutrients benefit for plant growth, as it plays an important role in many vital processes in the cell. It helps in cell division, enzyme activation, and seed formation. It is an sole in energy turnover, as well as the genetic information(DNA and RNA) in plants (Barker and Pilbeam, 2006). phosphorus founs in soils in small available quantities due to its exposure to sorption and precipitation in acidic and alkaline soils. One of the most serious factor affecting phosphorus availability is soil salinity which phosphorus interacts with salinity by reacting with excess dissolved calcium and magnesium in calcareous soils, forming unavailable forms precipitated over time. Hence, the relationship of inorganic phosphorus with Ca and Mg in such soils highly dependent on soil pH in combination with mineral composition. Prasad and power (1997) also stated that OH<sup>-</sup> ,

$\text{SO}_4^{=}$  and  $\text{MgO}_4^{=}$  will compete with orthophosphate for available reaction sites. Researchers have worked hard to implement many strategies to increase the availability of this element and increase the fertilizer use efficiency. Such strategies are controlling the method of addition, dividing the fertilizer dose, using organic or biological fertilization, integrated nutrient management, and adding soil amendments.

Silicon is the second most abundant element in earth crust and is included in the composition of silicate minerals, which release into the solution after weathering. Silicon is known to be beneficial nutrient for plants, and the plant absorbs this element in the form of monosilicic acid (Haynes, 2004). This element plays an important role for plants because of its beneficial effects on the soil and plants, especially for enhance tolerance to biotic or abiotic stresses such as salinity. Many studies have confirmed the positive role of silicon in increasing the availability of nutrients, including phosphorus.

Silicon plays an important role in phosphorus availability in soil, but there is little information about how silicon in

soil interacted with phosphorus availability especially in saline calcareous soils. Many studies such as Kostic *et al.*, (2017) and Neu *et al.*, (2017) on wheat and Owino-Gerroh and Gascho, 2004; Al-rubaie and Abdulkareem.2024 on corn, have confirmed the benefit effect of Si to cover phosphorus deficiency. Silicon can change the pH of the soil and increasing the possibility of orthophosphate availability (Owino Gerroh and Gascho, 2004), reducing the adsorption of phosphorus by soil minerals due to competition between P and silicic acid (Matichenkov and Bocharinkov, 2001), improving the microbial activity in the soil and increasing phosphorus mineralization (Liang *et al.*, 2021), displacing p-anion by Si-anion from slightly phosphates (Fe, Al, Mn, Ca, Mg-p) through increasing Si adsorption chance and then desorption of p-anion (matichenkove and Ammosova, 1996) and the ability of silicon to alter plant metabolism by modifying the expression of genes related to stresses (Kostic *et al.*, 2017). Based on the above, this study aimed to demonstrate the role of nanosilicon in the availability

of phosphorus in saline soil with subsequent effect on growth and yield

## MATERIALS AND METHODS

The experiment was conducted in saline soil at the Agricultural Research Station / College of Agriculture / University of Basra, located in the Karma Ali region ( $47^{\circ} 44'40''E$  and  $30^{\circ} 33'44''N$ ) of 3 m above sea level and 9.78 km away from Basrah center during the growing season of 2023. A composite soil sample (0-30cm) was taken from the field, air-dried, ground and pass through 2mm sieve to measure the initial soil properties (Table 1). The experiment included two factors:

1- Silicon level: silicon was added at levels of 0, 100, and 200 kg Si ha<sup>-1</sup> in form of Nano-silicon (98% SiO<sub>2</sub>)(FADAK complex new technology, IRAN)

2- Phosphate fertilizer level : Phosphorus was added at levels of 0, 30, and 60 kg P ha<sup>-1</sup> in form of concentrated superphosphate (20%P) (General fertilizer Co., HOMS. Syria).

The experiment was designed as a factorial experiment with a randomized complete block design (R.C.B.D) with three replications of total number of experimental plots. Field was plowed

of cauliflower plants.

perpendicularly at a depth of 0.35 m, and smoothed after carrying out the adjustment and leveling operations. Rows were opened with a distance between one and other 1m, the width of the row was 0.5m. Cow manure was added at level of 5 tons ha<sup>-1</sup> mixing with the depth of 0.2m. Each plots (2×0.5m) contains 5 plants with a distance of 0.4m. plants are irrigated using a drip irrigation system using Shatt al-Arab water (≈20 dSm<sup>-1</sup>). White flake cauliflower seedlings were grown in plastic dishes and then transplanted to the field after reached the stage of three leaves. Each plot fertilized with urea (46% N) at 250 kg N ha<sup>-1</sup> and potassium sulphate (43% K) at 160 kg K<sub>2</sub>O ha<sup>-1</sup>.

Nanosilicon was added to the soil in rows near the plants line at two doses at planting and after 15 days from the first dose. As for concentrated superphosphate fertilizer, it was added in rows along the line of the plants with one dose at planting stage. Nitrogen and potassium fertilizers, were added in the same method of phosphorus.

Nitrogen was added in three doses during a season, while potassium in a single dose at planting stage. All agricultural practices adopted in the region were carried out until the end of the season and harvesting.

Randomize soil samples were taken at a depth of (0-30) cm for each plot, mixed to obtain a composite sample, air-dried, and passed through 2mm sieve. The soil pH was measured in a soil suspension (1:1), then the suspension was filtered, and soluble  $Ca^{++}+Mg^{++}$  were determined by titration with  $Na_2$ -EDTA (Page *et al.*,1982). Available phosphorus was extracted by 0.5M  $NaHCO_3$  solution(Olsen) and developing

the color with ammonium molybdate and ascorbic acid, and phosphorus was assay spectrophotometrically (Murphy and Riley ,1962). Average number of leaves were calculated for three Plants for each plot. leaf area was calculated according to the method described by Sadik *et al.* (2011) using the scanner and the Image program.

Leaves were washed, dried at 70°C, and then digested using solution (4% $HClO_4+H_2SO_4$ ) (Cresser and Parsons ,1979). phosphorus concentration in the digest solution was estimated using a spectrophotometer (Murphy and Riley,1962).

Table 1 : some chemical and physical properties of soil

property		Value	unit
pH (1:1)		7.80	-
Electrical conductivity (EC)		29.22	$dSm^{-1}$
Available phosphorus		18.30	$mg\ kg^{-1}$
Available silicon		20.20	
Available nitrogen		18.00	
Available potassium		120.60	
$Ca^{++}$		33.30	$mmol\ L^{-1}$
$Mg^{++}$		19.16	
$Na^+$		81.30	
$CO_3^-$		0.00	
$HCO_3^-$		6.01	
$SO_4^-$		7.50	
$Cl^-$		195.00	
Total carbonates		332.31	$gkg^{-1}$
Soil particles Size	sand	38.80	%
	loam	40.00	
	clay	21.20	
Soil texture		loam	

Chlorophyll in the leaves also estimated according to the method described by Abbas and Abbas(1992) by extracted with 80% acetone and using a spectrophotometer. The pigment chlorophyll A was measured at a wavelength of 663 nm and chlorophyll B was measured at a wavelength of 645 nm. Carotene pigment was also measured in plants curd at a wavelength of 480 nm, and the concentration of each pigment was calculated as in the following equations:

$$\text{Chlorophyll A (mg L}^{-1}\text{)} = 12.7 \times (663) D - 2.69 \times (645) D.$$

$$\text{Chlorophyll B (mg L}^{-1}\text{)} = 22.9 \times (645) D - 4.68 \times (663) D.$$

$$\text{Total chlorophyll (mg L}^{-1}\text{)} = 20.2 \times (645) D + 8.02 \times (663) D. \text{ Then expressed as (mg 100g}^{-1}\text{).}$$

Where D : represents the optical density reading of the extracted chlorophyll.

The concentration of carotene in the curd was calculated through the following equation:

$$1000X = \frac{E Y}{e 100}$$

Where :

X : milligrams of carotene in one cm<sup>3</sup> of solution.

Y : final solution volume after dilution with acetone.

E : device reads at a wavelength of 480 nm.

e : carotene constant equal to 2300.

Total soluble solids (TSS) were estimated by placing a small piece of the curd in a hand press, then taking some drops and placing in a Hand Refractor Meter. A total yield the weight of all curd or each plot was recorded.

The treatments were subjected to statistical analysis as a factorial experiment with two factors (nano-silicon levels and phosphorus levels). The data of all parameters were included in the ANOVA table using the SPSS program, and the means were compared using the adjusted least significant difference (RLSD) at level of 0.05 of significance .

## RESULTS AND DISCUSSION

Table 2 indicated that the addition of nanosilicon led to a significant decrease in the concentration of soluble calcium and magnesium(Ca+Mg) in the soil

solution. They decreased from 121.80 MeqL<sup>-1</sup> in control treatment to 27.92 and 36.25 MeqL<sup>-1</sup> for the level of 100 and 200 kg Si ha<sup>-1</sup>, respectively (average of P

levels). Bosnic *et al.* (2019) obtained similar results with regard to calcium, explaining this by formation of silicon-calcium complexes, while Kaya *et al.* (2006) explained the decrease in calcium concentration to improved plant growth in the presence of silicon and increased uptake of ions, including calcium. Similar results were obtained by Mathur and Roy (2020) and Alsaeedi (2021) regarding magnesium ion. Table (2) indicated an increase in the concentration of calcium and magnesium with increasing phosphorus level, with a mean values of 57.49, 67.40, and 61.08 MeqL<sup>-1</sup> for the

levels of 0, 30, and 60 kg P ha<sup>-1</sup>, respectively (average of Si levels). This increase may be due to the presence of calcium in concentrated superphosphate fertilizer(12-14%) (Prasad and Power. 1997). The highest value of Ca+Mg in a soil solution was 132.46 MeqL<sup>-1</sup> when silicon was not added along with highest phosphorus level 30 kg pha<sup>-1</sup>, which was significantly superior to the rest values. That means the behavior of silicon did not differ according to the levels of phosphorus, and the concentration of Ca+Mg still increased with increasing phosphorus levels at all levels of silicon.

**Table 2: Effect of nano silicon and phosphorus fertilizer on soluble (Ca+Mg) , pH and available phosphorus in soil.**

	<u>S1</u>			<u>S2</u>			<u>S3</u>			<u>LSD</u>		<u>S × P</u>
	<u>P<sub>1</sub></u>	<u>P<sub>2</sub></u>	<u>P<sub>3</sub></u>	<u>P<sub>1</sub></u>	<u>P<sub>2</sub></u>	<u>P<sub>3</sub></u>	<u>P<sub>1</sub></u>	<u>P<sub>2</sub></u>	<u>P<sub>3</sub></u>	<u>S</u>	<u>P</u>	
<b>Ca+Mg</b> (MeqL <sup>-1</sup> )	108.28	124.66	132.46	28.80	31.78	23.20	35.40	45.78	27.58	1.66	1.66	2.93
<b>pH</b>	7.89	7.97	7.68	7.69	7.59	7.76	7.90	7.75	7.71	NS	NS	NS
<b>P available</b> (mgkg <sup>-1</sup> )	24.19	46.03	52.28	24.95	47.01	81.55	34.59	80.01	83.24	4.09	4.09	5.60

S<sub>1</sub>:0 kg Si ha<sup>-1</sup>; S<sub>2</sub>:100 kg Si ha<sup>-1</sup>; S<sub>3</sub>:200 kg Si ha<sup>-1</sup>;P<sub>1</sub>:0 kg P ha<sup>-1</sup>; P<sub>2</sub>:30 kg P ha<sup>-1</sup>; P<sub>3</sub>:60 kg P ha<sup>-1</sup>; NS: Non-significant

Neither nanosilicon nor phosphorus levels affected the soil pH, and the values ranged between 7.59 and 7.97 (Table 2). This may be due to the high content of calcium carbonate in the soil (Table 1), which plays a buffer materials

increases the resistance against to changes soil pH in alkali ranges (Helyar and Porter, 1989).

The addition of nanosilicon had a significant effect (p≤0.05) in increasing available phosphorus in soil (table 2).

The highest value of available phosphorus ( $65.94 \text{ mg kg}^{-1}$ ) was obtained at level  $200 \text{ kg Si ha}^{-1}$  compared to levels 0 and  $100 \text{ kg Si ha}^{-1}$ , which reaching  $40.83$  and  $51.17 \text{ mg kg}^{-1}$ , respectively. It is consistent with the results of Liao *et al.* (2020); Jabal and Abdulkareem (2023) and Al-rubaie and Abdulkareem (2024). The effect of silicon on enhancing soil phosphorus availability involved several mechanisms. Matichencov and Bocharnikova (2001) attributed to the adsorption of silicon with phosphorus complexes of Ca, Mg, Fe, or Al which leads to silicon replacing the phosphate ion and releasing phosphate into the soil solution. Sadgrove (2006) pointed out that the highly porous structure of silicon nanoparticles helps in preserving phosphate from loss. Silicon acid competes with phosphate for binding minerals, so leading a high mobilization of phosphate from the minerals (Schaller *et al.*, 2019). Enhancing microbial activity by silicon addition will accelerate the mineralization of organic phosphorus (Laing *et al.*, 2021). Moreover, Kostic *et al.* (2017) confirmed the beneficial role of silicon on phosphorus availability to the ability of silicon to alter plant metabolism by

modifying the expression of genes responsible for stress resistance.

It can be noted from table (2) that the effect of silicon on the available phosphorus was opposite to its effect on the concentration of Ca+ Mg, which indicates that the availability of phosphorus increased with decreasing Ca+ Mg concentration, so decreasing the possibility of forming phosphate complexes (Dishon *et al.*, 2011). This means that addition of silicon will eliminate the negative effect of salinity on phosphorus availability in soil resulting from the presence of excess amounts of Ca and Mg. Buehrer (2001) explained that the presence of more calcium ions contributes to the acceleration of phosphorus immobilization.

Adding phosphate fertilizer increased available phosphorus in soil, with values of  $27.91$ ,  $57.68$ , and  $72.35 \text{ mg kg}^{-1}$  for the levels of 0, 30, and  $60 \text{ kg P ha}^{-1}$ , respectively. It agrees with the results of Amruth *et al.* (2017) and Mustafa and Abdulkareem (2019).

The results also showed that there were a significant differences of the interaction, that availability phosphorus increased with increasing levels of silicon

at all phosphorus levels, and it also increased with increased phosphorus at all levels of silicon, confirming the positive interaction between the two nutrients and ensuring the benefit role of silicon in increasing the available phosphorus under the conditions of the experiment of saline soil. This finding support using of silicon in saline soils to reduce the harm effect of salinity in phosphorus availability . The highest value was 83.24 mg kg<sup>-1</sup> in treatment S3P3, while the lowest value was 44.19 mg kg<sup>-1</sup> in treatment S1P1 with an increase percent of 88.36%.

Table 3 showed the parameters of growth and yield of cauliflower as a result of the addition of silicon and phosphate fertilization. Phosphorus in leaves significantly increased by increasing the level of silicon from 0 to 100 kg Si ha<sup>-1</sup> then decreased at level of 200 kg Si ha<sup>-1</sup>, but with no significant differences and still higher than control. Increasing the amount of available phosphorus in soil will increase the phosphorus uptake by plant, since the uptake in plant is a function to the available amount in soil

(Cooper,2008). Ma and Takahashi (1990) concluded that the phosphorus absorbed by rice is not affected by soil silicon additions, and that the amount of silicon benefit depends on the phosphorus content in soil and the affinity between phosphorus and the cations (Fe, Mn, and Ca). Similar result was obtained by Liao *et al.*(2020) who found a decrease in phosphorus uptake by rice at high level of silicon (31.2kgSiha<sup>-1</sup>) attributing that to the less accumulation of nutrients at the high silicon level. The results of table(3) indicated no significant effects of phosphorus level and the interaction between silicon and phosphorus on phosphorus concentration in leaves. No significant effect of phosphorus levels inspite of the increasing in available phosphorus in the soil (Table 2) may be attributed to the date of the plant sample at end of the season which lead to low concentration of phosphorus at this stage because of translocation of phosphorus to the plants sink(curd) and /or because of dilution effect .

**Table 3: Effect of Nano silicon and phosphorus fertilizer on some growth parameters of plant and yield**

P	S1			S2			S3			S	LSD	
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>		P	S × P
leaf	1.00	1.03	1.12	1.14	1.16	1.18	1.12	1.13	1.15	0.09	NS	NS

	(gmkg <sup>-1</sup> plant)											
<b>Leaf number</b> (plant <sup>-1</sup> )	16.66	17.00	17.00	19.66	20.00	20.66	16.66	17.00	17.66	1.45	NS	NS
<b>Leaf area</b> (dm <sup>2</sup> )	36.29	36.02	44.84	46.49	47.08	48.39	41.13	42.86	48.12	2.55	2.55	3.01
<b>Yield</b> (Mg ha <sup>-1</sup> )	39.96	43.31	44.79	48.29	51.56	69.27	41.25	50.37	67.46	8.76	8.76	10.14

S<sub>1</sub>:0 kg Si ha<sup>-1</sup>; S<sub>2</sub>:100 kg Si ha<sup>-1</sup>; S<sub>3</sub>:200 kg Si ha<sup>-1</sup>; P<sub>1</sub>:0 kg P ha<sup>-1</sup>; P<sub>2</sub>:30 kg P ha<sup>-1</sup>; P<sub>3</sub>:60 kg P ha<sup>-1</sup>; NS: Non-significant

Data of table 3 indicated that adding nanosilicon significantly affected the number of leaves of cauliflower plants. Increasing level of silicon from 0 to 100 kgSiha<sup>-1</sup> lead to significant increase in the number of leaves, while increasing dosage to 200kgSiha<sup>-1</sup> significantly decreased the number of leaves, but still in bar with control. This was similar to phosphorus concentration in leaves. Similar results were obtained by Yassen *et al.* (2017), who added nanosilicon at levels of 15, 30, 60 and 120 mg L<sup>-1</sup> to cucumber and found that 60 mg L<sup>-1</sup> had a positive effect on cucumber plant growth indicators, including the number of leaves. Neu *et al.* (2017) showed that a appropriate Si level promotes growth and yield of plant, however high level induce a negative effect on the parameters due to that the high supply might lead to a stress response with negative impact on plant growth and utilization of nutrients such as C,N and P by negative effect on nutrient accumulation and biomass production of plant. Furthermore, Liang

*et al.*(2021)found a negative effect of high level of silicon on microbial activity in soil related to N and P mineralization. Bloodnick(2014) found a distortion of flowers at high levels of silicon. The positive effect of silicon could be through the increasing water content of the plant (Romero-Aranada *et al.*, 2006), in addition to the role of silicon in improving the efficiency of photosynthesis and the synthesis of organs in plant leaf (Saud *et al.*.,2014). Epstein (2001) attributed the increase in plant height and number of leaves to the role of silicon in increasing the absorption of water and nutrients and thus accelerating the growth process.

The results also indicated that inspite of the increasing in the number of leaves with increasing phosphorus levels, it did not reach the significance. Also, the interaction of nanosilicon and phosphate fertilizer did not have a significant effect on the number of leaves of cauliflower plants. These results were similar to the results obtained from phosphorus in leave.

The results of Table 3 showed that adding nanosilicon up to the level of 100 kg Si ha<sup>-1</sup> led to a significant increase in the leaf area, with the average value of 47.32 dm<sup>2</sup>, but increasing the level to 200 kg Si ha<sup>-1</sup> led to a significant decrease to 44.03 dm<sup>2</sup>. These results were similar to the results for the phosphorus concentration in the leaves and the number of leaves. This result was in line with the results of Al-Subaie (2021), which can be attributed to the essential role of silicon in stimulating many enzymes and improving the efficiency of the photosynthesis process (Saud *et al.*, 2014). Abdelazim *et al.* (2017) stated that silicon works to increase the biological activities of plant cells, which is reflected in the materials and compounds resulting from the photosynthesis process, thus achieving an increase in plant growth and improving the characteristics of vegetative growth. Al-Ameri (2024) attributed the increase in leaf area after adding silicon to an increase in the swelling pressure exerted on the cell wall, thus increasing the elongation of the leaves and increasing their areas.

Table 3 indicated an increase in leaf area with increasing phosphate levels,

with values of 41.84, 41.98, and 47.11 dm<sup>2</sup> at 0, 30, and 60 kg p ha<sup>-1</sup>, respectively, with no significant difference between 0 and 30 kg p ha<sup>-1</sup>. Phosphorus is considered one of the essential nutrients for plants. It is a necessary component of many organic compounds that are important for metabolic processes and root growth. It is benefit for energy transfer compounds in the living cell such as ATP, DNA, and RNA, which is responsible for protein synthesis in plants. A sufficient amount of phosphorus enhances many aspects of plant physiology, such as photosynthesis and respiration (Arif *et al.*, 2005). The results indicated that the highest leaf area was recorded in plant received 100kgSiha<sup>-1</sup> along with 60kgpha<sup>-1</sup> reaching 48.39dm<sup>2</sup> and caused an increase percents of 33.34% over control treatment.

Nanosilicon levels to 100kgSiha<sup>-1</sup> significantly increased the curd total yield of cauliflower plants then decreased insignificantly at 200kgSiha<sup>-1</sup>, following the same trend as the effect observed in the previous growth parameters. The value were 42.52, 56.37 and 53.02 Mgha<sup>-1</sup> for levels of 0, 100 and 200 kgSiha<sup>-1</sup>, respectively. Similar findings

were recorded by Al-Subaie (2021) on cauliflower. This was attributed to the positive effect of silicon on growth parameters (leave number and leaf area) and nutrients uptake (phosphorus concentration) and consequently the positive effect on biomass production resulting in enhancing resource allocation towards reproductive organs (Neu *et al.*, 2017).

The results indicated that increasing phosphate fertilizer led to a significant increase in the total yield of cauliflower, with a significant superiority of the 60 kg p ha<sup>-1</sup> level compared with other levels. Al-Ziadi and Aloosy (2011) found that adding phosphorus led to a significant increase in the yield of curd of cauliflower plants with percents of 45% and 73% at 45 and 90 kg Pha<sup>-1</sup> over control treatments, and they attributed this to the role of phosphorus in increasing plant growth through nutritional status and its role in many vital plant processes. For interference values of yield in Table (3),

the level of 100 kg Si ha<sup>-1</sup> is superior to the level of 200 kg Si ha<sup>-1</sup> at all levels of phosphorus, which indicates that it is the appropriate level for plant grown under experimental conditions. The highest curd yield (69.27 Mg ha<sup>-1</sup>) was obtained with interaction of 100kgSiha<sup>-1</sup> with 60kgpha<sup>-1</sup>.

Table 4 showed the quality of cauliflower leaves and curd. Addition of silicon significantly increased TSS up to the level of 100 kg Si ha<sup>-1</sup> (5.08%), then decreased at level of 200 kg Si ha<sup>-1</sup>. This is consistent with the results of Al-Subaie (2021) who noted an increased in TSS the concentration of 1 ml Si L<sup>-1</sup> and 1.5 ml Si L<sup>-1</sup> due to the positive effect of silicon in increasing the carbohydrates and vitamins in the curd. Toresano *et al.* (2012) also found that spraying silicon at a concentration of 250 ml Si L<sup>-1</sup> on cherry tomato grown under greenhouse conditions led to a significant increase in TSS in the fruits.

**Table 4: Effect of Nano silicon and phosphorus fertilizer on some chemical quality of leaves and curd of plant**

	<u>S1</u>			<u>S2</u>			<u>S3</u>			<u>LSD</u>		
	<u>P<sub>1</sub></u>	<u>P<sub>2</sub></u>	<u>P<sub>3</sub></u>	<u>P<sub>1</sub></u>	<u>P<sub>2</sub></u>	<u>P<sub>3</sub></u>	<u>P<sub>1</sub></u>	<u>P<sub>2</sub></u>	<u>P<sub>3</sub></u>	<u>S</u>	<u>P</u>	<u>S × P</u>
<b>TSS (%)</b>	4.06	4.40	6.00	4.36	4.60	6.30	4.20	4.45	5.36	0.69	0.69	NS
<b>Chlorophyll</b> (mg100gm <sup>-1</sup> FW)	7.08	7.43	7.79	5.87	7.12	7.79	5.52	7.00	8.06	NS	1.10	NS
<b>Carotene</b> (mg100gm <sup>-1</sup> FW)	81.00	101.33	132.66	96.00	119.00	136.33	90.66	109.00	126.33	19.92	19.92	NS

Table 4 showed that adding phosphate fertilizer caused an increase in TSS with the highest value(5.88%) at the level of 60 kg p ha<sup>-1</sup>, Arif *et al.*(2005) stated that phosphorus is an essential nutrient that contributes to photosynthesis potential and increases the amount of metabolites food which translocate towards flowers and fruits. The interaction effect of nanosilicon and phosphate fertilizer was not significant on TSS values (Table 4).

In regard to chlorophyll content, table 4 showed that addition silicon did not have a significant effect on the amount of chlorophyll in the leaves, while adding phosphate fertilizer led to a significant increase in chlorophyll with increasing phosphorus levels. The mean values were 6.15 ,7.18 and 7.88mg100g<sup>-1</sup> FW for level 0,30 and 60 kgpha<sup>-1</sup>, respectively. This increase can be attributed to the fact that the phosphorus absorbed by the plants improves the vegetative growth of the cauliflower plant, which in turn produces the maximum leaf area and leaves number(table 3), and consequently increases photosynthesis process (Metwaly, 2017). The interaction

between silicon and phosphate fertilizer did not have a significant effect on chlorophyll in cauliflower leaves.

Carotenes are the most important biochemical indicator of salinity tolerance , since it produced to minimize the harmful effect of oxidative stress (free radicals) in plant against chlorophyll degradation , so it regard as the first defence mechanism of plant (Ashraf and Harris.2004).

Table 4 indicated that increasing of nanosilicon up to 100 kg Si ha<sup>-1</sup> led to a significant increase of carotene in the curd of cauliflower .However, increasing nanosilicon supply to 200 kg Si ha<sup>-1</sup> decreased the carotene content insignificantly but still higher than control, with the values of 104.99,117.11and 108.66 mg100g<sup>-1</sup>FW respectively. Khan and Huang(2021) found that application of Si resulted in a significant increase in carotene by 39% in tomato fruits. This was explained by the fact that Si can improved the synthesis of chlorophyll A, B, and carotene. This result clearly indicated that presence of silicon induced the production of carotenes against the

negative effect of salinity. The results also indicated that increasing phosphorus levels led to a significant increase in the concentration of carotene in cauliflower curds, with values of 89.22, 109.77 and 131.77 mg 100 g<sup>-1</sup> FW for the levels of 0, 30, and 60 kg p ha<sup>-1</sup>, respectively. Al- Khalidi (2024) found that treating cauliflower with 2 mg L<sup>-1</sup> nanophosphorus significantly rise the content of carotene. Metwaly (2017) attributed that to the role of phosphorus in formation of many organics, in addition to being an essential element for adenosine synthesis such as ATP as well as creation of DNA and RNA. It can be seen from the results of the traits listed in Table (4) that they were affected by the addition of phosphorus or silicon in the same direction as the effect on plant growth and yield parameters (Table 3).

We concluded from this study that addition of silicon increased phosphorus availability in saline soil by decreasing Ca and Mg in soil solution, and consequently enhanced plant performance, as well as improved plant defence mechanism against the harmful effect of salinity. Increasing in the addition of nanosilicon beyond the level of 100 kg Si ha<sup>-1</sup> led to a decrease in the

growth and yield parameters of cauliflower plants inspite of increasing available phosphorus in soil. This result leads us to suggest that cauliflower plants grown under experimental conditions are classified as not accumulating silicon in the context of plant classification in this regard, and that implementing additional studies on other silicon sources and other phosphate levels is important to complete the recommendations under saline soil conditions.

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