Benha Journal of Applied Sciences (BJAS) print: ISSN 2356–9751
Vol. (8) Issue (5) (2023), (43-53) online: ISSN 2356–976x
http://bjas.journals.ekb.eg

Chlorophyll content and yield responses for withholding irrigation and Si foliar spray at normal and Nano source under different critical growth stages of wheat

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Abstract

To determine the most important stages for skipping (withholding) irrigation, Investigate the role of silicon and irrigation rates in alleviating water stress effect on improving wheat production in the much critical stages, and Investigation the effect of K-silicate as an anti-stress substance on wheat under drought stress has been investigated, a field factorial experiment on wheat was carried out during the 2021–2022 growing season. Six treatments make up the first factor. The following treatments were used: I_0 no skipping; I_1 skipping at tillering (20 days after seeding "AS"); and I_2 skipping at the vegetative stage (45 days AS). I_3 skips flowering (60 days AS), I_4 skips milk (90 days AS), and I_5 skips the dough stage (110 days AS). Two Si treatments were performed: S_1 normal Si and S_2 Nano dose (2, 4, and 6 $mLSiL^{-1}$) spray solutions of D_1, D_2, and D_3. Plants treated with K silicate produced yields ranging from 6.116 from $S_1D_1I_1$ to 8.615 from $S_2D_3I_0$, representing increases of 3.6 to 45.9%, respectively, over the non-Si treatments' average yield. Plants not getting silicates produced grain yields of I_1 (withholding irrigation during tillering) and I_0 (without withholding), which ranged in size from 5.045 to 6.175 Mgha-1, respectively. Plants that received silicates produced grain yields that ranged from 5.413 from $S_1C_1I_1$ to 8.279 from $S_2C_3I_0$, a growth of 52.95%. The main consequence of the Nano application is a rise of 5.04%. I_1 (skipping at tillering) had the lowest yield of all the irrigation methods, producing 5.958 Mgha-1. The greatest was I_0, which produced 7.926 $Mgha^{-1}$, an increase of 33.03%, with no irrigation being withheld. Following is a list of the main effects of irrigation $I_1 > I_5 > I_6 > I_4 > I_3 > I_2$. It can be concluded that S_2 Nano dose at 6 $mLSiL^{-1}$ might be used as an anti-stress substance otherwise regardless of the critical wheat growth stages without any further effects on the yield. Moreover, tillering is the most critical wheat growth stage, so it is not recommended to withhold irrigation, especially in this stage.

Keywords: S_2 nano - withholding irrigation- Chlorophyll content - skipping (withholding) irrigation.

1- Introduction

The most significant strategic cereal crop worldwide and in Egypt is wheat. The lack of irrigation water in Egypt affects the production of the grain industry. Egypt now faces a water shortage of more than 1,000 m3/person/year. Egypt will experience a severe shortage of 500 m3/per capita/per year by 2025 **[18].** As a result, the issues with agricultural water distribution will get worse. Egypt's task is to figure out how to produce more food while utilizing less water. As a result, reducing the amount of irrigation water used will help to solve the issue while also maximizing the advantages of the current irrigation water. One of the most crucial strategies for water conservation in irrigated agriculture is irrigation scheduling. Water resource management to satisfy crop needs can be aided by water management during the growth stages **[13].**

Wheat's moisture-sensitive stages include tillering, elongation, booting, and grain development **[1]**. Numerous variables, such as the stage of growth, the severity of the water stress, the length of the stress period, and cultivars, have an impact on how the plant responds to water stress **[10]**. By selecting the maximal grain output and its stability under water-stress conditions, plant breeders may typically find drought resistance mechanisms **[17] [29] [15]**. High grain yields from wheat must be produced by cultivars under a variety of stress and non-stress conditions **[28].** Despite being the second-most common element in soil, silicon (Si) is not necessary for plant growth **[37]**.

Higher plants, however, profit from this component, especially under stress **[35]**. The development stage, the degree of the water stress, the length of the stress period, and cultivars are only a few of the variables that affect how the plant reacts to water stress **[10]**. By choosing the maximum grain production and stability under water-stress circumstances, plant breeders can frequently discover drought resistance mechanisms **[17] [29] [15]**. High grain yields from wheat must be possible in a variety of stress- and non-stressful situations **[28]**. Despite being the second-most common element in soil, silicon (Si) is not necessary for plant growth **[37]**. Conversely, higher plants gain from this element, especially in difficult circumstances. Several studies have shown that si has a positive impact on drought-stressed plants, especially in terms of water relations, photosynthesis, and other crucial physiological characteristics **[27] [36]**. But it's still not known how Si decreases the negative impacts of drought on plants. In plants under drought stress, silica may be involved in several physiological processes **[26]**. It's capable of improving light absorption effectiveness. Having light pass through the mesophyll tissue may increase the effectiveness of light absorption **[37]**.

The advantageous effects are thought to be brought on by Si deposition in the cell walls of roots, leaves, culms, and hulls. Excessive transpiration is encouraged by heat stress or drought, and vessel compression is prevented by silicon deposits in the cell walls of xylem vessels. The silicon cellulose barrier in epidermal tissue prevents plants from losing too much water through transpiration, and its deposition in roots reduces metal binding sites, resulting in less salt and harmful metal absorption and translocation from roots to shoots **[16]**. The benefits of silicon nanoparticles over their bulk material have not been extensively studied. Because silicon nanoparticles have unique physiological characteristics, they can enter plants and alter their metabolic processes. Mesoporous silicon nanoparticles have the potential to be interesting developments for agriculture. A wide range of fields could benefit greatly from nanotechnology **[9]**.

The morphology, physiology, and biochemistry of plants are altered by drought, and some of these effects are discussed in this paper. Due to decreased stomatal conductance, drought stress gradually alters CO_2 absorption rates. Along with hindering.

plant growth, it also reduces stem extension, root multiplication, and leaf size. The relative chlorophyll content has a substantial impact on photosynthesis since chlorophyll is a crucial component of chloroplasts. The rate of photosynthetic activity is correlated positively. A common sign of oxidative stress due to drought stress is a decrease in chlorophyll concentration. Pigment photo-oxidation may be to blame for this. decomposition of chlorophyll For light absorption and the development of decreasing abilities, photosynthetic pigments are extremely important to plants. Chlorophyll b. b and an are both sensitive to soil dehydration **[19].**

The main objective of the present investigation was to:

1- Study the sensitivity of different stages of the wheat plant to water stress.
2- Identify the much critical stages to the maximum duration of withholding irrigation.
3- Reducing the effect of drought stress and its effects on growth and increasing yield.
4- Investigate the role of silicon and irrigation rates in alleviating water stress effect on improving wheat production in the much critical stages.
5- Investigation the effect of K-silicate as an anti-stress substance on wheat under drought stress has been investigated.
6- Evaluate the performance of K-silicate foliar spray to mitigate water-deficit stress on wheat yield.

1- Materials And Methods

A factorial field experiment was conducted in 2021–2022, to determine the most important phases for the longest time of irrigation withholding for particular wheat cultivars throughout Middle Egypt. The plot area was 15.0 m^2 (3 x 5 m). The primary plots were for irrigation practices (factor A), while the secondary plots were for silicate source (factor B), and the tertiary sub-sub plots were for K-silicate and Nano Silica foliar spray concentrations (factor C). Six irrigation regimes, one cultivar (Sakha-95), two sources of silicate as K-silicate and Nano Silica, and three foliar spray doses (2, 4, and 6 ml/ L) were among the 36 treatments that made up the experiment. These treatments represented various combinations of the study's components. When the number of replicates is taken into consideration, the experiment exhibits a 108 plot. On November 20th, seeds were sown, and on May 1st, the plants were harvested. The crop that was planted before wheat was maize. All of the suggested agronomic procedures for growing wheat in the Giza region were followed. In both seasons, maize was the crop planted before wheat. The second irrigation marked the beginning of the irrigation regime's treatments. The K-silicate and Nano Silica foliar spray quantities were administered from the second irrigation (**Tillering stage**).

1- Soil physical and chemical properties: -

The soil at the research site was sampled at several depths (0-15 cm), (15-30 cm), (30-45 cm), and (45-60 cm). **[31]** determined soil-water constants such as soil field capacity (F.C) and wilting point, and **[32]** calculated bulk density. The international technique was used to determine particle size distribution and soil texture **[33]**. The statistics in Table 2 show that the soil has a clayey texture. Total soluble salts (Soil Ec, dS m-1), soil reaction (pH), and soluble cations and anions were measured using the methods outlined by **[32]**. So_4^2 was calculated using the difference between soluble cations ($mmolc^{-1}$) and anions ($mmolc^{-1}$), as shown in Table 2.

2- Agricultural practices: -

Wheat known as **Shaka 95** was grown (***Triticum aestivum*** L.). All agronomic practices for wheat crops in the evaluated region, except for the examined treatments (irrigation treatments and sowing dates), were carried out in accordance with the Agricultural Research Center's requirements (ARC). The experimental design was a split-split plot with three replicates, with the main plots denoting irrigation treatments, the subplots denoting silica source, and sub-sub plots amounts of foliar spray, as shown below:

Factor A:(main plots): irrigation regime (withholding irrigation):

I_1: no withholding of irrigation (without withholding irrigation).

I_2: Withholding irrigation on the 20th day after sowing (tillering stage).

I_3: Withholding irrigation at the 45th day after sowing (Vegetative growth stage).

I_4: Withholding irrigation on the 60th day after sowing (Flowering stage).

I_5: Withholding irrigation on the 90th day after sowing (Milk stage).

I_6: Withholding irrigation on the 110th day after sowing (dough stage).

Factor B (subplots): silicate source:

S_1: K-Silicate

S_2: Nano-Silica

Factor C (sub-subplots): K-silicate and Nano Silica foliar spray concentrations:

R_0: Water sprinkling (control).

R_1: Apply Nano-Silica to the plants at a rate of 2 ml/l of water.

R_2: Apply Nano-Silica to the plants at a rate of 4 ml/l of water.

R_3: Apply Nano-Silica to the plants at a rate of 6 ml/l of water.

The photosynthetic pigments (chlorophyll a and chlorophyll b) were extracted from fresh plant leaf samples, and at the flowering stage, ten plants from each subplot were sampled. These pigments were homogenized in N-N-dimethylformamide and quantified using the spectrophotometric method in accordance with the following formulas **[40]:**

Chlorophyll a = 12.64 A664 – 2.99 A647

Chlorophyll b = - 5.6 A647 – 23.26 A664.

The ammonia of 34 % concentration, H_2SO_4, and HCl is manufactured by Al Nasr Company, Egypt. Sodium silicate is manufactured by El Nile Company, Egypt.

2- Synthesis of silica nanoparticles: -

Silica nanoparticles synthesis by sol-gel method in which hydrolyses of sodium silicate have been done using H_2SO_4. However, in typical synthesis, 10 ml of sodium silicate was put in a 100 ml glass beaker and added drop by drop H_2 SO_4 of 68% concentration until the PH of the mixture become 2 then stir for 1 hour until thick gel formation. Finally, the gel was heated in the oven for 2 hours at 500°C to obtain silica nanoparticles **[2].**

Characterization techniques for Nano Potassium Silicate:

Characterization was performed to confirm the formation of a K- Nano Silicate and no unwanted chemicals from the synthesis method, as well as to provide information on the shape, size, surface area, roughness profile, and pore size of the Nano K- Silicate. Conformed the composition of Nano K- Silicate carried out by XRD (D8 Discovery-Bruker Company) at the condition of 40 KV and 40 AM (1600W) at speed scan 0.02 and 2theta (θ) range from 10 to 80 degrees. The transmission electronic microscope (TEM) model EM-2100 was used to examine 2D and 3D shape, agglomeration, concentration, and size. Jol 2000, Japan, performed high-resolution imaging at a magnification 25X and voltage 200 kV, as well as scanning electron microscopy (SEM).

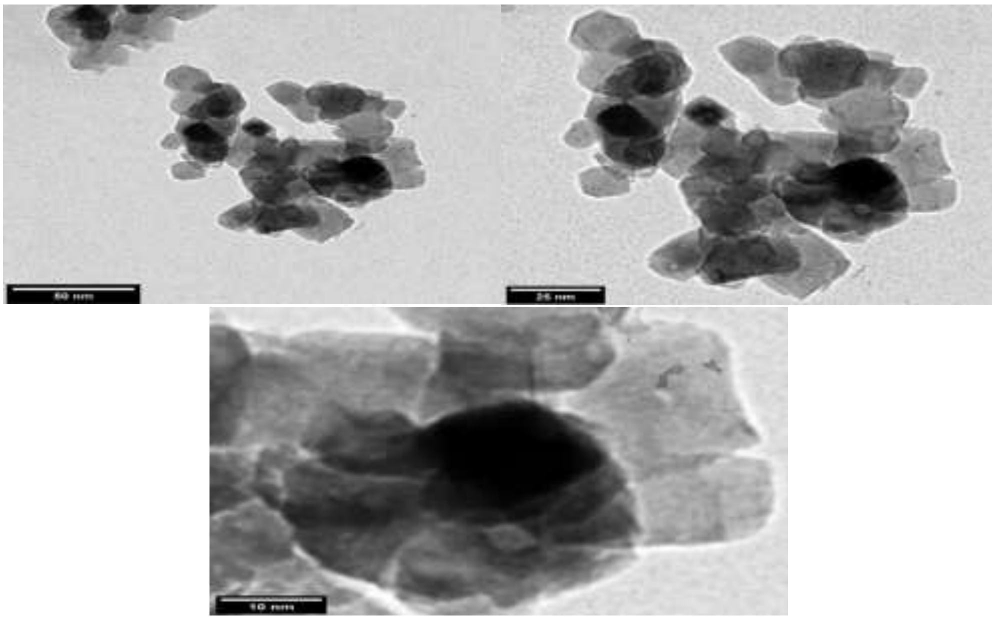

Fig.(1) TEM images of Nano K- Silicate

Fig. (2) SEM images of Nano K- Silicate

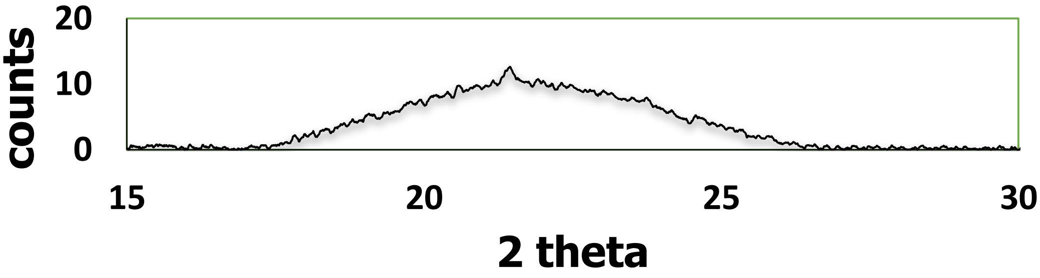

Fig. (3) XRD pattern of Nano K- Silicate

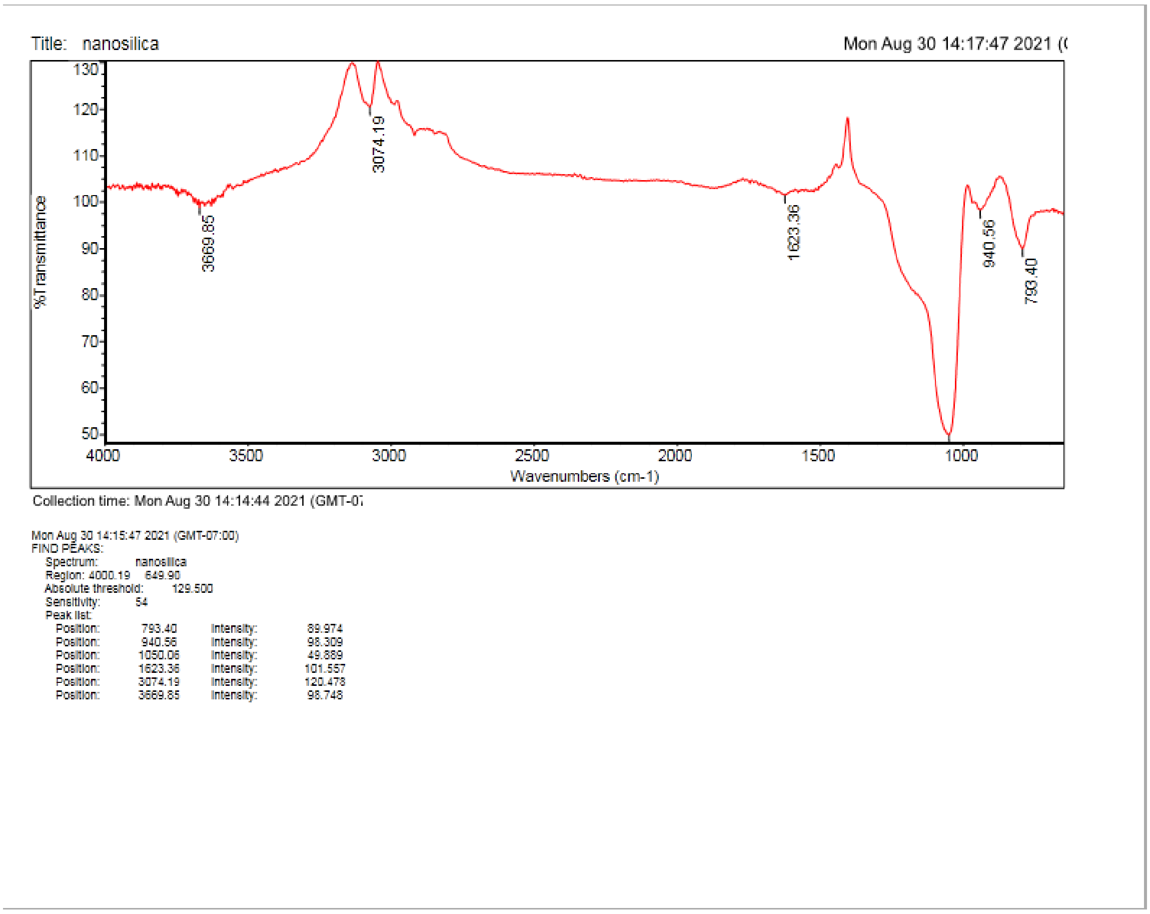

Table (1) Physical and chemical parameters of the soil at the experiment site in Giza.

	Parameter	Value: Sampling depth (cm) 0-15	15-30	30-45	45-60
	Particle-size distribution				
	Clay %	25.08	25.80	9.81	16.51
	Silt %	45.25	41.06	28.40	69.79
	Fine sand %	27.76	30.56	61.07	12.00
	Coarse sand %	1.91	2.58	0.72	1.70
	Textural class	**CLAY**	**CLAY**	**S.C.L**	**CLAY**
	Soil chemical analyses				
		Sampling depth (cm) 0-15	**15-30**	**30-45**	**45-60**
	PH	7.52	7.56	7.66	7.71
	EC dS/m^{-1}	1.31	2.07	1.84	1.37
	Cations and anions in soil paste extract (mmol$_c$L^{-1})				
Cations (mmol$_c$L^{-1})	**Na^+**	5.11	10.44	10.42	6.20
	K^+	0.08	0.04	0.02	0.19
	Ca^{2+}	4.29	5.71	4.29	4.29
	Mg^{2+}	5.04	5.30	5.04	2.49
Anions (mmol$_c$L^{-1})	**CO_3^{2-}**	0.00	0.00	0.00	0.00
	HCO_3^-	0.94	1.89	2.83	2.36
	Cl^-	6.78	7.63	6.78	5.93
	SO_4^{2-}	6.80	11.97	10.16	4.88

***S.C.L (Silt Clay Loamy)**

Table (2) Soil field capacity, wilting point, accessible water, and bulk density at different depths.

Depth cm	Field capacity (FC) % by weight	mm	Wilting Point (WP) % by weight	mm	Available water (AW) % by weight	mm	Bulk density (BD) Mg/m^3
0-15	40.6	69.4	18.5	31.6	22.1	37.8	1.14
15-30	38.3	67.1	17.7	31.9	19.6	35.3	1.2
30-45	37.1	63.1	16.8	31.2	17.1	31.8	1.24
45-60	36.5	66.2	17.7	33.5	17.3	32.7	1.26
Total		**265.8**		**128.2**		**137.6**	

Where: - F.C % = Soil field capacity, W.P % = wilting point, AW % = Available water, and BD, Mg/m³ = Soil bulk density, N.D. means not detected
FC: moisture at a moisture tension of 33 kPa.
WP: moisture at a moisture tension of 1.5 MPa.
FC-WP = AW

Table (3) shows the chemical analysis of irrigation water.

Water quality	PH	EC	Soluble ions (mmol$_c$/ L): Cations Ca^{2+}	Mg^{2+}	Na^+	K^+	Anions HCO_3^-	Cl^-	SO_4^{2-}	RSC	SAR	Adj.SAR
Tap water (T W)	8.0	1.18	4.85	3.20	4.43	0.39	3.30	1.86	7.71	0.00	2.21	5.75

Note RSC, residual sodium carbonate; SAR, sodium adsorption ratio; Adj, adjusted

3- Results And Discussion

The yield of Wheat grain and Straw

Results in table 4 show that grain yields ranged from 5.045 to 6.175 Mgha^{-1} for plants that did not receive silicates, as measured by I_1(withholding irrigation at tillering) and I_0 (without withholding). Plants given silicates increased grain yield by 52.95%, from 5.413 given by $S_1D_1I_1$ to 8.279 given by $S_2D_3I_0$. The primary effect of Nano application is a 5.04% increase. I_1 (skipping at tillering) produced the lowest yield of 5.958 Mgha-1. The highest was I_0(no irrigation withholding), which gave 7.926 Mgha^{-1}, a 33.03% increase. Irrigation's primary effect can be summarized as follows: $I_1 > I_5 > I_6 > I_4 > I_3 > I_2$.

Results table 5 shows straw yields ranged from 7.756 to 9.541 Mgha^{-1} for plants that did not receive silicates, according to I_1 (withholding irrigation at tillering) and I_0 (without withholding). Plants given silicates produced straw yields ranging from 8.396 given by $S_1D_1I_1$ to 12.844 given by $S_2D_3I_0$, a 52.98% increase. The main effect of the Nano application is an increase of 5.38%. I_1 (skipping tillering) produced the lowest yield of 9.172 $Mgha^{-1}$. The highest was I_0 (no irrigation withholding), which yielded 12.253 $Mgha^{-1}$, a 33.59% increase. $I_1 > I_5 > I_6 > I_4 > I_3 > I_2$ are the main effects of irrigation.

Photosynthetic pigments

Results table 6 shows plants that did not receive silicates produced chlorophyll ranging from 7.940 to 10.039 mg/g, as measured by I_1 (withholding irrigation at tillering) and I_0 (without withholding). Plants given silicates increased Chlorophyll by 40.59%, ranging from 9.017 given by $S_1D_1I_1$ to 12.677 given by $S_2D_3I_0$. The main effect of the Nano application is a 10.69% increase. I_1 (skipping at tillering) had the lowest chlorophyll content of any irrigation, with 9.704 mg/g. The highest was I_0 (no irrigation withholding), which gave 11.739 mg/g, a 20.97% increase. Irrigation's main effect can be summarized as follows: $I_0 > I_4 > I_5 > I_3 > I_2 > I_1$.

Results Table 7 shows Plants that did not receive Silicates produced Chlorophyll b ranging from 1.724 to 3.353 mg/g, as measured by I_1 (withholding irrigation at tillering) and I_0 (without withholding). Plants given silicates produced chlorophyll b ranging from 2.162 produced by $S_1D_1I_1$ to 5.170 produced by $S_2D_3I_0$, representing a 39.13% increase. The main impact of the Nano application is a 22.21% increase. The irrigation with the lowest Chlorophyll b content was I_1 (skipping at tillering), with 2.586 mg/g. The highest was I_0 (no irrigation withholding), which gave 4.730 mg/g, an increase of 82.91%. $I_0 > I_4 > I_5 > I_3 > I_2 > I_1$ is the main effect of irrigation.

The current findings are consistent with those reported by **[13] [1]**, who indicated that tillering, elongation, booting, and grain production are all moisture-sensitive.

[26] [37] Silicon is thought to be involved in several physiological processes in drought-stressed plants.

The current findings are consistent with those obtained by **[21], [25]**, **[23]**, **[24], [4]**, **[5], [8], [41]**, **[38]**, **[22],** and **[42]** discovered that in a field experiment, wheat crops that received five irrigations at crown root, tillering, booting, earing, and milking stages produced the highest grain yield.

According to **[3],** irrigation increased agricultural output while decreasing water usage efficiency as the irrigation rate increased. Severe water stress from seedling to maturity reduced dry matter, harvest index, and all yield components while increasing the number of viable spikes/m2 and grains/spike by 60 and 48%, respectively.

When compared to the control treatment, **[21]** found that wheat yield and total biomass production were statistically significant in T3, T4, and T5. With the control treatment, plant height, flag leaf width, and length, the number of fertile tillers, panicle length, number of grains per panicle, and weight of 1000 grains were all statistically significant. Protein percentages varied markedly between irrigation treatments.

[25] investigated the effect of different irrigation regimes on wheat growth, yield, and yield components in Bangladesh. They discovered that irrigation regimes had a significant impact on panicle development, resulting in the lowest panicle weight in all four types in both seasons. The 10 mm irrigation produced the most grain weight per panicle, followed by the 20 mm irrigation. Water stress has a significant impact on grain production and several yield components. Grain yield per plant, grain weight per plant, and commercial yield were all higher in the well-irrigated 20 mm irrigation plants.

According to **[23]** water stress has a significant impact on wheat biological yield, grain production, and its components. When compared to full irrigation, wheat grain output was reduced by 36.7, 22.8, and 45.6% when irrigation was stopped from early stem elongation to flag leaf emergence, flag leaf emergence to anthesis, and anthesis to late grain filling, respectively. Furthermore, water stress reduced wheat yield at all developmental stages. The grain filling and stem elongation phases were the most important under water stress conditions. Lower moisture stress treatments improved WUE while severe moisture stress treatments lowered WUE.

According to **[24],** deficit irrigation is an optimal method in which water is provided during drought-sensitive growth phases, whereas irrigation water is administered sparingly, if at all if rainfall provides a minimal supply of water to the crops. **[14]** subjected wheat plants to drought by skipping irrigation at various stages of plant age, namely tillering, spike initiation, heading, flowering, and dough stage. The findings revealed that water requirements can vary depending on the amount and frequency of irrigation water.

[43] discovered that wheat crops that received five irrigations during the crown root, tillering, booting, earing, and milking phases produced the highest grain yield in a field trial. According to **[4],** water scarcity had a significant impact on the number of spikes/m^2, number of kernels/spike, 1000-grain weight, plant height, days to maturity, maturity length, harvest index, and grain yield of wheat.

According to **[5],** crops that were completely watered produced the most spike length and the most grains per spike (10% more than plants that were subjected to water stress during the anthesis stage). Maximum biological yield (10% higher than water stress during stem elongation and water stress during stem elongation and anthesis, respectively), maximum grain yield (18% and 22% higher than water stress during stem elongation and water stress during stem elongation and anthesis, respectively), higher 1000 grain weight (18.29% higher than all other water stress treatments, water stress during stem elongation exhibited significantly higher 1000 grain weight).

According to **[8],** increasing irrigation and nitrogen application levels improved wheat crop growth rate (g m^{-2} day^{-1}), leaf area index, number of fertile tiller m^{-2}, number of grains $spike^{-1}$, and harvest index. Four irrigations of 150 kg N ha^{-1} at the tillering, booting, anthesis, milking, and dough phases resulted in the highest harvest index.

[41] conducted a field study in Pakistan to investigate the impact of irrigation timing. According to the data, the irrigation treatments had a significant impact on grain production, biological yield, grains per spike, and 1000-grain weight. Irrigation at the crown root stage + tillering stage + booting stage + earing stage + milking stage + dough stage (I_5) and Irrigation at the crown root stage + booting + anthesis + grain development (I_4) yielded larger grain yield (6159.16 kg ha^{-1}) than all other irrigation treatments. Irrigation at crown root stage + booting (I_1) had the highest TDM (15801 kg ha^{-1}) and the lowest (I_5) (9284 kg ha^{-1}).

[38] stated that skipping one watering during the tillering, elongation, or heading phases reduced all parameters except spike length and seed index. During the tillering, elongation, and heading phases, skipping one irrigation reduced plant height, spikes per m^2, 1000-grain weight, grain yield, and straw yield, in that order.

In Egypt, **[39]** investigated the impact of five irrigation regimes. Regular irrigation increased the number of spikes m^2, 1000-grain weight, and grain yield in both seasons. Skipping irrigation at all development stages reduced 1000-grain weight, grain yield, straw production, and biological yield when compared to full irrigation in both seasons.

According to **[20]**, water stress significantly reduced area due to decreased cell division. Water stress also affected specific weight and grain output. Following anthesis, water scarcity reduced grain filling duration, grain weight, and crop productivity.

[45] conducted research in Turkey to develop wheat deficit irrigation solutions. Water deficits had varying effects on wheat yield, quality, and water-use efficiency depending on the plant-growth phases in which they were administered, according to the findings. Water shortages during the stem elongation and heading phases significantly reduced wheat yield. A 35% deficiency applied solely during the stem elongation stage, on the other hand, resulted in the highest thousand-grain weight.

Silicon (Si) and its compounds, according to **[11]**, have beneficial effects on a wide range of plant species, particularly when faced with biotic and abiotic challenges. Their effects on drought-stressed wheat (***Triticum aestivum L***.) plants, however, are unknown. Wheat seeds were individually seeded in pots to see how SiO_2 Nanoparticles (NPs) affected drought stress. The SiO_2 NPs were then applied to the plants via soil and foliar spray over three stages of development.

[6] demonstrated that Si-foliar and Si-soil treatments outperformed the control treatment in yield metrics.

According to **[7],** drought stress reduced chlorophyll-a (1.07), chlorophyll-b (0.49), total chlorophyll contents (1.62), plant height (100.17 cm), 1000-grain weight (36.66 g), total dry weight per plant (309.75 g), biological yield (23,424 kg/ha), and grain yield (4564.2 kg/ha). By increasing chlorophyll-a (1.21), chlorophyll-b (0.64), total chlorophyll contents (1.92), 1000-grain weight (44.33 g), total dry weight per plant (385.00 g), biological yield (24,000 kg/ha), and grain yield (5074.8 kg/ha), foliar application of 2% $K_2Si_2O_5$ significantly reduced drought-induced damages. These findings suggest that exogenous $K_2Si_2O_5$ application could be used as a quick, simple, and effective method of reducing drought-induced damage to wheat production.

[30] Studied that Withholding the last one or two watering significantly reduced the overall examined wheat traits in both seasons. Sprinkling wheat plants with potassium silicate sol at a rate of 4 Cm^3 per L outperformed other studied foliar application transactions and produced the highest amounts of growing characters, yield and its ingredients, and grain excellence traits in both times years.

According to **[12]**, When irrigation was skipped during the anthesis stage (I_2), plants of chakwal-50 performed very well, with the highest GY (5.20 **Mg ha^{-1}**) as compared to sehar-06. Sehar-06 gained more GY (5.13 **Mg ha^{-1}**) under normal irrigation (I_0) with Si tillering, whereas Chakwal-50 is a drought-tolerant genotype and gave more GY (4.91 **Mg ha^{-1}**) at anthesis through Si seed priming. Chakwal-50 produced more grain yield with exogenous Si application during tillering, followed by seed priming.

Conclusion

Form the aforementioned outcomes. It can be concluded that the use of Nano k- Silicate at a concentration of 6 $mLSiL^{-1}$ is the most effective for delaying irrigation during most wheat growth stages. Furthermore, because tillering is the most critical stage of wheat growth, it is not recommended to withhold irrigation during this stage. Nanoparticles have been shown to play an important role in the agricultural system. In this study, Nano Silica demonstrated its importance for chlorophyll, wheat grain, and straw. All measured yield parameters, such as grain and straw, were positively affected by Nano Silica, with higher values compared to when Nano Silica was not applied under water stress. The application of 6 $mLSiL^{-1}$ Nano Silica is the ideal concentration that wheat plants should be treated with withholding irrigation to achieve the highest values of biochemical characteristics and yield. The findings revealed that using Nano Silica can improve wheat grain yield in arid regions and can be used as a beneficial fertilizer for foliar application.

Table (4) Effect of withholding irrigation regimes on grain Yield (Mg ha^{-1}) as affected by irrigation regime.

Si source (S)	Si dose (D)	Irrigation skipping (I) I_0	I_1	I_2	I_3	I_4	I_5	Mean
	D_1	7.579	5.413	6.135	6.332	6.853	6.485	**6.466**
S_1	**D_2**	7.936	5.800	6.478	6.499	7.192	6.843	**6.791**
	D_3	8.275	6.102	6.881	6.856	7.565	7.199	**7.146**
Mean		**7.930**	**5.772**	**6.498**	**6.562**	**7.203**	**6.842**	**6.801**
	D_1	7.569	5.783	6.489	6.840	7.195	6.851	**6.788**
S_2	**D_2**	7.918	6.140	6.826	7.208	7.552	7.196	**7.140**
	D_3	8.279	6.512	7.194	7.564	7.911	7.562	**7.504**
Mean		**7.922**	**6.145**	**6.836**	**7.204**	**7.553**	**7.203**	**7.144**
Grand mean		**7.926**	**5.958**	**6.667**	**6.883**	**7.378**	**7.023**	
Means of D treatments								
D_1		7.574	5.598	6.312	6.586	7.024	6.668	**6.627**
D_2		7.927	5.970	6.652	6.853	7.372	7.019	**6.966**
D_3		8.277	6.307	7.037	7.210	7.738	7.380	**7.325**
L.S.D at 0.05		**I= 0.026 ; S = 0.010; C = 0.010 ; I. S= 2.475 ; I.C= 2.449 ; S.C = 1.414 ; I.S.C = 3.463**						
Treatments receiving no silicates (sprayed with water)								
		I_0	**I_1**	**I_2**	**I_3**	**I_4**	**I_5**	
		6.175	5.045	5.414	5.784	6.136	5.764	**5.720**

Notes :

I_0: No irrigation skipping (no irrigation withholding).

I_1: Skipping irrigation at tillering.
I_2: irrigation at Vegetative Growth.
I_3: irrigation at Flowering.
I_4: irrigation at the Milk stage.
I_5: irrigation at the dough stage.

D_1, D2 and D_3 are 2, 4 and 6$mLSiL^{-1}$respectively

S_1 and S_2 are normal and nano silicate,

Table (5) Effect of withholding irrigation regimes on straw yield (Mg ha^{-1}) as affected by irrigation regime.

Si source (S)	Si dose (D)	Irrigation skipping (I) I_0	I_1	I_2	I_3	I_4	I_5	Mean
	D_1	11.74	8.40	9.57	10.16	10.95	9.89	**10.12**
S_1	**D_2**	12.26	9.02	9.97	9.95	11.51	10.47	**10.53**
	D_3	12.72	9.29	10.64	10.95	12.12	11.66	**11.23**
Mean		**12.24**	**8.90**	**10.06**	**10.35**	**11.53**	**10.67**	**10.63**
	D_1	11.66	9.01	9.97	11.11	11.44	11.16	**10.73**
S_2	**D_2**	12.29	9.44	10.89	11.28	12.17	11.25	**11.22**
	D_3	12.84	9.88	11.09	11.64	12.90	11.66	**11.67**
Mean		**12.26**	**9.44**	**10.65**	**11.34**	**12.17**	**11.36**	**11.21**
Grand mean		**12.25**	**9.17**	**10.36**	**10.85**	**11.85**	**11.02**	
Means of D treatments								
D_1		11.70	8.70	9.77	10.64	11.20	10.53	**10.42**
D_2		12.28	9.23	10.43	10.61	11.84	10.86	**10.87**
D_3		12.78	9.58	10.87	11.29	12.51	11.66	**11.45**
L.S.D at 0.05		**I= 0.096 ; S = 0.054 ; C = 0.042 ; I. S= 0.132 ; I.C= 0.102 ; S.C = 0.059 ; I.S.C = 0.144**						
Treatments receiving no silicates (sprayed with water)								
		I_0	**I_1**	**I_2**	**I_3**	**I_4**	**I_5**	
		9.541	7.756	8.610	9.353	9.371	9.280	**8.985**

- **See notes of the table for treatment designations.**

Table (6) Contents of chlorophyll (a) in fresh wheat foliage (mg g^{-1}) as affected by irrigation regime.

Si source (S)	Si dose (D)	Irrigation skipping (I) I_0	I_1	I_2	I_3	I_4	I_5	Mean
	D_1	11.31	9.02	9.09	9.42	10.16	9.27	**9.71**
S_1	**D_2**	11.44	9.06	9.21	10.15	10.88	9.89	**10.10**
	D_3	11.55	9.95	10.43	10.47	11.73	10.96	**10.85**
Mean		**11.433**	**9.341**	**9.576**	**10.012**	**10.920**	**10.038**	**10.220**
	D_1	11.28	9.78	9.88	10.03	10.51	10.35	**10.30**
S_2	**D_2**	12.18	10.05	10.42	10.42	11.33	10.88	**10.88**
	D_3	12.68	10.37	10.97	11.09	11.44	11.30	**11.31**
Mean		**12.04**	**10.07**	**10.42**	**10.52**	**11.09**	**10.84**	**10.83**
Grand mean		**11.74**	**9.70**	**10.00**	**10.26**	**11.01**	**10.44**	
		Means of D treatments						
D_1		11.30	9.40	9.48	9.73	10.33	9.81	**10.01**
D_2		11.81	9.56	9.82	10.29	11.10	10.39	**10.49**
D_3		12.12	10.16	10.70	10.78	11.58	11.13	**11.08**
L.S.D at 0.05		**I= 0.135 ; S = 0.056 ; C = 0.036 ; I. S= 0.138 ; I.C= 0.088 ; S.C = 0.051 ; I.S.C = 0.124**						
		Treatments receiving no silicates (sprayed with water)						
		I_0	**I_1**	**I_2**	**I_3**	**I_4**	**I_5**	
		10.04	7.94	8.62	9.33	9.36	9.10	**9.07**

***See notes of the table for treatment designations.**

Table (7) Contents of chlorophyll (b) in fresh wheat foliage (mg g^{-1}) as affected by irrigation regime.

Si source (S)	Si dose (D)	Irrigation skipping (I) I_0	I_1	I_2	I_3	I_4	I_5	Mean
	D_1	3.817	2.162	2.186	2.204	3.604	2.402	**2.729**
S_1	**D_2**	4.071	2.315	2.577	2.692	3.806	2.665	**3.021**
	D_3	4.541	2.576	2.842	3.108	4.039	3.769	**3.479**
Mean		**4.143**	**2.351**	**2.535**	**2.668**	**3.816**	**2.945**	**3.076**
	D_1	4.729	2.427	2.862	3.134	4.370	2.956	**3.413**
S_2	**D_2**	5.514	2.762	2.943	3.285	4.774	3.341	**3.770**
	D_3	5.710	3.273	3.355	3.428	4.977	3.412	**4.026**
Mean		**5.318**	**2.821**	**3.053**	**3.282**	**4.707**	**3.236**	**3.736**
Grand mean		**4.730**	**2.586**	**2.794**	**2.975**	**4.262**	**3.091**	
		Means of D treatments						
D_1		4.273	2.295	2.524	2.669	3.987	2.679	**3.071**
D_2		4.793	2.539	2.760	2.989	4.290	3.003	**3.396**
D_3		5.126	2.925	3.098	3.268	4.508	3.590	**3.753**
L.S.D at 0.05		**I= 0.188; S = 0.032 ; C = 0.025 ; I. S= 0.079 ; I.C= 0.062 ; S.C = 0.036 ; I.S.C = 0.088**						
		Treatments receiving no silicates (sprayed with water)						
		I_0	**I_1**	**I_2**	**I_3**	**I_4**	**I_5**	
		3.353	1.724	2.082	2.373	3.237	2.260	**2.505**

***See notes of the table for treatment designations.**

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