Asian Journal of Research in Biology

Volume 8, Issue 1, Page 42-53, 2025; Article no.AJRIB.12738

Application of Nano-silicon and Nano-selenium Enhances Barley Photosynthetic Parameters and Yield Productivity under Saline Irrigation Water in Egypt

Samah A. Mariey [a*], Megahed M. Amer [b], Karima R. Ahmed [a], Aans.H. Ahmed [a] and K.A.EAlfky [c]

[a] Barley Research Department, Field Crops Research Institute, Agricultural Research Center, 12619, Egypt.
[b] Soil Improvement and Conservation Research Department, Soil, Water and Environment Research Institute (SWERI), Agriculture Research Center (ARC), Giza 12112, Egypt.
[c] Crop Physiology, Field Crops Research Institute, Agricultural Research Center, 12619, Egypt.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/ajrib/2025/v8i146

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.ikprress.org/review-history/12738

Original Research Article

Received: 22/11/2024
Accepted: 25/01/2025
Published: 30/01/2025

ABSTRACT

Freshwater sources for agriculture irrigation system are not accessible in all countries also not enough to increase food production thus using saline water for agriculture will be possible explanation for limiting water resources_Egypt is on these countries that surfing of limiting

**Corresponding author: E-mail: samahmariey1@yahoo.com, samahmariey@arc.sci.eg;*

Cite as: *Mariey, Samah A., Megahed M. Amer, Karima R. Ahmed, Aans.H. Ahmed, and K.A.EAlfky. 2025. "Application of Nano-Silicon and Nano-Selenium Enhances Barley Photosynthetic Parameters and Yield Productivity under Saline Irrigation Water in Egypt". Asian Journal of Research in Biology 8 (1):42-53. https://doi.org/10.56557/ajrib/2025/v8i146.*

conventional water resources for agriculture in Western deserts, Sinai, North Coast. Nonetheless Salinity stress is a vital abiotic stress that affect harmfully on crop production consequently using micronutrients elements could help the growth and yield of crops by increasing plant hydration situation, stimulation plant defense mechanisms for salinity stress. Thus in this study , lysimeter experiments during two growing seasons 2020/2021 and 2021/2022 were carried out to investigate the responses of four different concentration saline irrigation water using sea water mixing with well water (S1= 2.35, S2= 4.0 ,S3=S= 8.0, and 12.0 dSm^{-1}) salinities levels stress and using two nutritional micronutrients Nano silica SiO2 NPs and Nano selenium Se NPs to investigated their effects on some photosynthetic and grain yield compounds traits characters of three Egyptian barley cultivars (Giza 132, Giza 137 and Giza 137). The results showed that increasing saline water irrigations caused a significant decreasing all of photosynthetic parameters by an average reduction (43.51, 4.62 and7.88 %) for maximal photochemical efficiency of PSII (*Fv/Fm* ratio), total chlorophyll content (SPAD) and leaf temperature under S4 level. Likewise increasing saline water irrigations caused a significant decreasing in yield and its yield compounds characters by average reduction 23.47% for grain yield (GY) while persuaded all barley cultivar to early flowering by an average 4.56 % under S4 treatment. Giza 137 was the saline water tolerance cultivars while Giza 132 was the salinity sensitive cultivars. Despite the fact, the results clearly indicate that using of SiO2 NPs and Se NPs caused significantly increased all of the photosynthetic parameters and yield and its compounds under saline water levels over than without using Nano elements of the three Egyptian cultivars. Analogous, the results clearly indicate that treatment of SiO2 NPs was more efficient than Se NPs, that GY was increasing by (24.95%) more than applicated by Se NPs was (14.8%) compere without using SiO2 NPs and under irrigated by saline water S4 for all cultivars, which GY showed significantly positive correlated with SiO_2 NPs and Se NPs. The principal components analysis PCA described 100 % of both PCA1and PCA2 of the total changeability. Hence, the application of using SiO2 NPs and Se NPs will be more efficient in improving Barely Photosynthetic parameters and grain yield Productivity under using saline irrigation water in Egypt.

Keywords: Barley; sea water; SiO2 NPs; Se NPs; photosynthetic parameters; grain yield; PCA.

1. INTRODUCTION

“Barley (*Hordeum vulgare L.*) is a foremost cereal crop that has fit changed to several abiotic stresses in dry areas, which ranking fourth universally in production after maize, wheat and rice), also used as a nutritional source of human food by using it with wheat flour in the bread industry, stock feed and malt production for the brewing industry” (Finocchiaro et al., 2023). “In Egypt, barley is a major winter crop cultivated in old and newly reclaimed lands that suffer from a lack of irrigation, low soil fertility, and salinity of both soil and water. However, there is a lack of awareness of the nutritional role of barley for both humans and animals” (Mansour et al., 2021; Mariey et al., 2023).

“Salinity stress is an vital abiotic stress that affect harmfully on crop production, it’s one of the most substantial abiotic stresses manipulating the metabolic happenings, causes yield loss from year to year and causing plant cuts which are controlled by a large number of genes” (Mariey et al., 2023; Abdelrady et al., 2024). “In Egypt, the salt- affected soils area cover about 56% of cultivated land, ranged from low soil salinity of 44% of the salinized cultivated land, moderate soil salinity of 27% of salinized cultivated land, high soil salinity of 29% of the salinized cultivated land, and extreme soil salinity of 1% of the salinized cultivated land” (Aboelsoud et al., 2022).

“Using micronutrients could help the growth and yield of crops by increasing plant hydration position, activation plant defense mechanisms for stress” (Taha et al., 2021; Mahlooji et al., 2018). “Silicon (Si) consider as a nutritional elements which its application has been standard as a recent biological approach for overcoming the negative effects of high soil salinity and attractive salinity stress responses in plants” (Falouti et al., 2024). “Nanoparticles (NPs) have involved the courtesy of researchers unpaid to its diverse physicochemical possessions when compared to majority particles” (Seleiman et al., 2021; Mariey et al., 2019; Mariey et al., 2022). “Silica nanoparticles (SiO_2 NPs), exhibit higher absorption and utilization efficiency with in plants compared with traditional Si fertilizers, moreover, improve the stress resistance by adaptable hormonal balance and indorsing nutrient absorption and operation in the plants" (Alharbi et al., 2022; Ismail et al., 2022).

"Selenium (Se) is observed as one of the most vital micronutrients in human and animal diet, but its importance for higher plants remnants unverified, also has numerous applications in food and feed via various biofortification methods" (Szarka et al., 2020). "Nnanoparticles of selenium (NPs-Se), can enhance plant growth by activating the antioxidant system under nutrient deficiency in the sandy soils, as well as improve the crop yield and quality in arid zones" (El-Ramady et al., 2018, Hussein et al., 2019; Badawy et al., 2021).

Although many studies about salt-tolerance mechanisms in barley have been explored, there has been limited investigate about using SiO2 NPs and Se NPs in improving barley growth and yield under saline environments. Therefore, the current study aimed to assess the effects of the application of SiO2 NPs and Se NPs on the Photosynthetic parameters and grain yield, of barley cultivars under saline water conditions.

2. MATERIALS AND METHODS

2.1 Barley Plant Materials

The grains of three barley cultivars were kindly provided by Sakha Barley Dep., Sakha Agricultural Research Station, Field Crops Research Institute, ARC, Egypt, were used in this study their names and pedigree shown in (Table 1).

2.2 Lysimeter Experiments Growth Conditions

Lysimeter experiment was conducted during the two consecutive barley-growing seasons of 2020/2021 and 2021/2022, in the soil improvement and conservation Research department at Sakha Agricultural Research Station, Kafer El-Sheikh Governorate. The site is located in the middle North of Nile Delta area of Egypt with 30°-57/ N latitude, 31°-07/E longitude with an elevation of about 6 meters above mean sea level

The experiment was conducted using three factors completely randomized design (CRD) with three replications. first factor included four irrigation salinity levels, S1 (EC=2.33dsm^{-1}equal 1491.2 ppm), S2(EC= 4dsm^{-1} equal 2560 ppm), S3 (EC=8dsm^{-1} equal 6400 ppm), and S4(EC=12dsm^{-1} equal 9600 ppm)

Second factor included four barley cultivars (Table 1), were grown at 22th and 25th Nov. 2020 and 2021 respectively, and harvested on 28th and 30th April 2021 and 2022 respectively, all local recommendation was uniformly followed to grow barley plants without any stress expects irrigation treatments.

Table 1. Name of the four barley cultivars and their pedigree, salinity response, released year and reference which used in the studied experiment

Name	Description of agro-morphological characters, Pedigree and released year	Salinity response	References
Giza 137	Six rows, Egyptian barley variety, early heading, tallest height, high yield ability precocious, high productive, newly reclaimed and moderate resistance to fungi diseases. It has been selected from the crosses (Giza 118 /4/Rhn-03/3/Mr25-//Att//Mari/Aths*3-02) ARC- Egypt, released 2017	Tolerance	Amer et al., 2017; Mariey et al., 2022a & 2022b
Giza 132	Six rows, Egyptian barley variety, late heading, short height, tolerant to drought and fungi diseases, sensitive to salinity. It is issued from the cross of (Rihane-05//AS 46/Aths*2Athe/ Lignee 686) ARC- Egypt, released 2006.	Sensitive	Noaman et al., 2006; Mariey et al. 2016
Giza 138	Six rows, Egyptian barley variety early heading, tallest height, precocious, high yield ability high productive in newly reclaimed and moderated tolerance to salinity and moderate resistance fungi diseases. It has been selected from the cross Acsad1164/3/Mari/Aths*2//M-Att-73-337-1/5/Aths/ lignee686 /3/Deir Alla 106//Sv.Asa/ Attiki /4/Cen/Bglo."S") ARC- Egypt, released 2017	Moderated Tolerance	Amer et al., 2017; Mariey et al., 2022a & 2022b

Table 2. Average values of some physical and chemical properties of the experimental Soil during the two growing seasons 2020/2021 and 2021/2022

Soil depth (cm)	Soil physical properties							
	Soil moisture characteristics				Particle size distribution (g kg^{-1})			
	F.C (%)	W.P. (%)	A.W. (%)	B.D. (kg m^{-3})	Sand	Silt	Clay	Soil texture
0-20	44.11	22.18	21.93	1.28	173.0	255.0	572.0	clay
20-40	40.52	20.29	20.23	1.30	188.3	247.8	563.9	clay
40-60	38.03	19.13	19.90	1.31	190.3	251.5	558.2	clay

Soil chemical properties						
Soil depth (cm)	**pH**	**EC (dSm^{-1})**	**SAR**	**CEC (cmole kg^{-1})**	**OM (g kg^{-1})**	**$CaCO_3$ (g kg^{-1})**
0-20	7.98	2.70	9.75	37.36	17.1	24.2
20-40	8.05	3.61	10.01	36.45	16.0	25.3
40-60	8.10	3.89	10.98	35.42	13.2	23.1

F.C.: *Field Capacity**;** **W.P.:** Wilting Point; **A.W.**: Available Water; **B.D.**: Bulk Density; **pH**: was determined in soil water suspension (1:2.5); **EC**: was determined in saturated soil paste extract; **SAR:** Sodium adsorption ratio; **CEC:** Cation Exchange Capacity; **OM**: Organic Matter*

Third factor consist of two nanoparticle (NP) nutrients of silicon (NPs-Si) and selenium (NPs-Se), plant leaves were fully treated with NPs-Si (300 ppm) according to Amer and El- Emary (2018) and NPs-Se (100 ppm) according to Amer et al. (2023) at twice at 25- and 40-days growth stages of barley.

The size of Se-NPs was further confirmed by transmission electron microscopy (TEM)imaging, which demonstrated that the Se particles possessed an average diameter of 40–80 nm. The zeta potential measurements indicated a high negative charge (−45.16 mV). Se-nanoparticles were prepared biologically using Bacillus cereus strain culture as the bacte-ria strain from the Agricultural Microbiology Department, Soils, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC), according to (Ghazi et al, 2022). Used nano-silica was provided by National Research Center (NRC), and have characterized by specific surface area (300-330m2g-1), pH (4.0-4.5), and mean diameter(10nm).

2.3 Soil Samples

Soil samples were collected from all plots before experiment and after the first and second seasons in three consecutive depths of 0-20, 20-40 and 40-60 cm to monitor some physical and chemical characteristics. were analyzed. Particle size distribution was determined according to **Piper (1950)**. Soil moisture characteristics were monitored using (a Time Domain Reflect meter (TDR) probe) as presented in Table 2.

2.4 Measured Characteristics

Photosynthetic parameters: At the heading stage, the maximal photochemical efficiency of PSII was estimated by measuring the chlorophyll fluorescence as Fv/Fm ratio using an Optiscan OS-30P fluorometer (Opti-Science, Hudson, NH, USA). Total chlorophyll content was measured as a SPAD value determined using a chlorophyll meter (SPAD-502) Minolta Camera Co. ltd., Japan) and leaf temperature were recorded using a portable porometer (steady-state porometer, LICOR, LI-1600, and Lincoln, NE, USA.

Agronomical parameters: At the heading stage days to heading HD were recorded and at the harvest stage ten guarded plants were randomly taken from each plot to measure plant height PH cm, number of grains spike^{-1} NGS, thousand Karnal weight TKW and grain yield GY was determined using the full plot area (1.0 m^{-2}).

2.5 Data Analysis

2.5.1 Phenotypic data analysis

The results from the two seasons were homogeneity and statistically analyzed as the completely randomized design (RCD) model using the SPSS software. There is no significant interaction was found between year and treatment, thus, results were pooled across years (Bartlett, 1937). Fischer's protected least significant difference (LSD) at the 5% level of significance was used for treatment means.

Pearson's correlation test was performed using SPSS 22.0 version (SPPS Inc., Chicago, IL) to determine the relationship between each two studied traits. Principal Component Analysis (PCA) were performed using Minitab 18.1 statistical software (Minitab Inc., Coventry, UK).

3. RESULTS AND DISCUTION

3.1 Effect of Different Saline Water and Nano Treatments

3.1.1 Effect on studied traits

3.1.1.1 Analysis of variance (ANOVA)

The combined analysis of variance (ANOVA) of The maximal photochemical efficiency of PSII (Fv/Fm), Total chlorophyll content (SPAD value), leaf temperature (LT), days to heading (HD), plant height (PH), number of grains spike^{-1} (NGS), thousand Karnal weight (TKW g) and grain yield (GY) indicated a significant statistical effect ($P < 0.01$) by saline water irrigation treatments (S) , cultivars (C) and nano treatments (N) as showing in (Table 3).

A significant two-way interaction between saline water irrigation levels and cultivars (S X C) was observed for all studied traits. A significant two-way interaction between irrigation levels and genotypes (C X N) were observed for all studied traits expect except the LT and PH (NGS^{-1}) was non-significant. Similarly, significant two-way interaction between nano x saline irrigation levels (N X S) were detected for all studied traits expect except the LT and PH was non-significant. Likewise, the combined ANOVA indicated a significant effect for three-ways interaction (C X S X N) across all traits, expect for LT and PH was non-significant. Theses results were in agreement with (Mariey et al., 2022 a,b & 2023; Falouti et al., 2024; Abdelrady et al., 2024) they suggested that the effect of salinity, cultivars, nano and their interaction was significant for all physiological and agnomical traits .

Table 3. The effect of different saline water irrigation treatments stress and different Nano treatments on phenotypic traits of three barley cultivar Combined data of two years)

Parameters	Photosynthetic parameters			Agronomical traits				
	Fv/Fm	SPAD	LT	HD	PH	NGS^{-1}	TKW	GY
Saline Irrigation treatments								
S1	0.390 a	42.322 a	26.367 a	80.222 a	94.111 a	11.986 a	1.477 a	473.323 a
S2	0.298 b	41.811 b	26.000 b	79 .444 b	92.121 b	11.667 b	1.433 b	444.484 b
S3	0.213 c	41.067 c	25.367 c	77.000 c	86.115 c	10.111 c	1.334 c	383.339 c
S4	0.120 d	40.367 d	24.289 d	76.778 d	84.444 d	9.333 d	1.221 d	362.272 d
F Test	*	**	**	**	**	**	**	**
Barley cultivars								
Giza132	0.200 c	39.517 c	20.658 c	84.750 c	82.333 c	9.500 c	1.290 c	309.167 c
Giza138	0.321 b	41.150 b	26.292 b	77.583 b	93.167 b	10.917 b	1.356 b	423.353 b
Giza137	0.326 c	43.925 a	26.678 b	74.917 a	93.750 a	10.927 a	1.397 a	498.343 a
F Test	*	**	*	**	**	**	**	**
Nano treatments								
Without	0.240 c	40.708 c	20.975 c	70.000 c	87.500 c	10.250 c	1.225 c	315.833 c
Naon-Si (SiO2 NPs)	0.316 a	42.608 a	26.300 a	79.500 a	91.083 a	10.667 a	1.368 a	420.833 a
Nano-Se (Se NPs)	0.290 b	41.275 b	26.333 b	78.750 b	90.667 b	10.417 b	1.352 b	414.167 b
F Test	*	**	**	**	**	**	**	**
Interaction								
C X S	**	**	**	**	**	**	**	**
C X N	**	**	**	**	**	**	**	**
S X N	**	**	NS	**	NS	**	**	**
C XS X N	**	**	NS	**	NS	**	**	**

*Which Ns, * and ** non-significant and significant at the 0.05 and 0.01 levels of probability, respectively, Fv/Fm: Chlorophyll fluorescence, SPAD: Total chlorophyll content, LT: leaf temperature, HD: days to heading, PH: plant height, NGS^{-1}, no. of grain spike, TWK: GY: grain yield.*

3.2 The Phenotypic Mean Performances

The average of mean performances and relative changes of all measured characters under four saline water irrigation treatments (S_1, S_2 S3and S4) and using two nano treatments (nano silica and nano selenium) during two growing seasons, were calculated to investigate the phenotypic diversity of three barely cultivars in order to define their response to saline water stress tolerance and define the best nano treatments to enhancement their ability to saline water tolerance were presented in (Table 3).

3.2.1 Effects of different irrigation saline water on the studied traits

Increasing of saline water irrigations up to (S2=4, S3=8 and S4 =12 dSm^{-1}) caused a significant decreasing all of photosynthetic parameters such as the maximal photochemical efficiency of PSII with an average reduction (19.82, 23.72, 43.51 % *Fv/Fm* ratio) , total chlorophyll content by average reduction (1.9 1.08, 4.62% SPAD values) and leaf temperature with an average reduction (1.39, 3.79 and 7.88 % degrees) as compared with S1=2.33 $dSm\text{-}^{1}$, as showed in (Table 3 & Fig. 1). This result agree with the studies by (Shah et al., 2020; Akhter et al., 2021; Mariey et al. 2022 a, b & , 2021; Abdelrady et al., 2024), they revealed a decreased in total chlorophyll content (SPAD value) and Fv/Fm ratio in barley plant leaves due to irrigating by saline water which salinity had a negative effect of the of photosynthetic parameters . In the same trend increasing of saline water irrigations caused a significant decrease in agronomical traits PH, NGS-1, TKW and GY with average reduction of 10.94,20.00,15.59 and 23.47%) under 12dSm-1 level (S4) treatment as compared with S1=2.33 $dSm\text{-}^{1}$ (Table 3 & Fig. 1).

Whereas, increasing saline water irrigation levels persuaded all barley cultivar to early flowering by an average 1.52,1.80, 4.56 % under (S2, S3 and S4) treatments, respectively as compared with (S1). respectively. Significant differences were found among all the three barley cultivars, in which Giza 137 was more affected by salinity stress than the other two cultivars as recognized as tolerance Egyptian barley cultivar of most of the measured traits (Table 3). The results were recognized by (Zeeshan et al., 2020; Mariey et al., 2022 a, & 2023) they reported that the salinity decreasing all the agronomical traits while earlier flowering in Barley.

3.2.2 Effects of SiO2 NPs and Se NPs treatments on the studied traits

SiO2 NPs and Se NPs treatments significantly increased all of the photosynthetic parameters and agronomic studied characters values (Table 3 & Fig. 2)**,** the results clearly indicate that treatment of nano silica SiO2 NPs was more efficient which gave the maximum values of *Fv/Fm ratio*, SPAD value, LT, HD PH, NGS, TKW and GY over without nano treatment with significantly increased by average values 23.99, 4.46, 20.25, 11.95, 3.93, 3.91, 10.48 and 24.95% respectively. Regarding the nano selenium Se NPs treatments, the results showed that Se gave higher values of *Fv/Fm* ratio, SPAD value, LT, HD PH, NGS, TKW and GY over without treatment by average increasing 17.08, 1.37, 20.35, 11.11,3.49, 1.60 9.37, 23.74 and 14.8% respectively as shown in (Fig. 2). these results were agree with (Hussein et al.,2019; Badawy et al., 2021; Alharbi et al., 2022; Ismail et al., 2022; Falouti et al., 2024) they reported that the addition of NPs-Si or NPs-Se treatments as foliar application showed a significant improvement increasing in photosynthetic parameters and yield traits under salinity, also foliar application of SiO2 NPs was more efficient to enhance yield components more than foliar application of NPs-Se.

3.2.3 Effect of the interaction between saline water irrigation and, SiO2 NPs and Se NPs treatments on the studied traits of three cultivars

Regarding, the effect of the interaction between SiO2 NPs and Se NPs treatments and different saline irrigations water, the results clearly display that using nano Si and nano Se treatments significantly increased all of studied characters values as presented in (Table 3). Additionally, the interaction between using nano Si and nano Se treatments and cultivars caused the high increases in the grain yield and all studied traits of all cultivars under irrigation by different salinity levels of saline water as showed in Table 3. Nano silica SiO2 NPs and Nano selenium Se NPs increased significant grain yield in all cultivars as compared with the without using nano treatments at different salinity levels was shown in Fig. 3. The highest grain yield (Fig. 3) was gotten by Giza 137 cultivar when irrigated by salinity level 12dSm^{-1} with using nano silica and nano selenium (360.0 and 350.0 g/plot). On the other hand, the lowest gain yield was recorded for Giza 132 from all nano treatment irrigations under the four salinity (Fig. 3). This results were in good harmony with (Badawy et al., 2021; Alharbi et al., 2022; Ismail et al., 2022; Falouti et al., 2024) which they informed that the adding NPs-Si or NPs-Se as foliar application will caused a significant improvement increasing in grain yield under salinity stress, similarly application of SiO2 NPs will be more efficient to enhance yield components more than foliar application of NPs-Se.

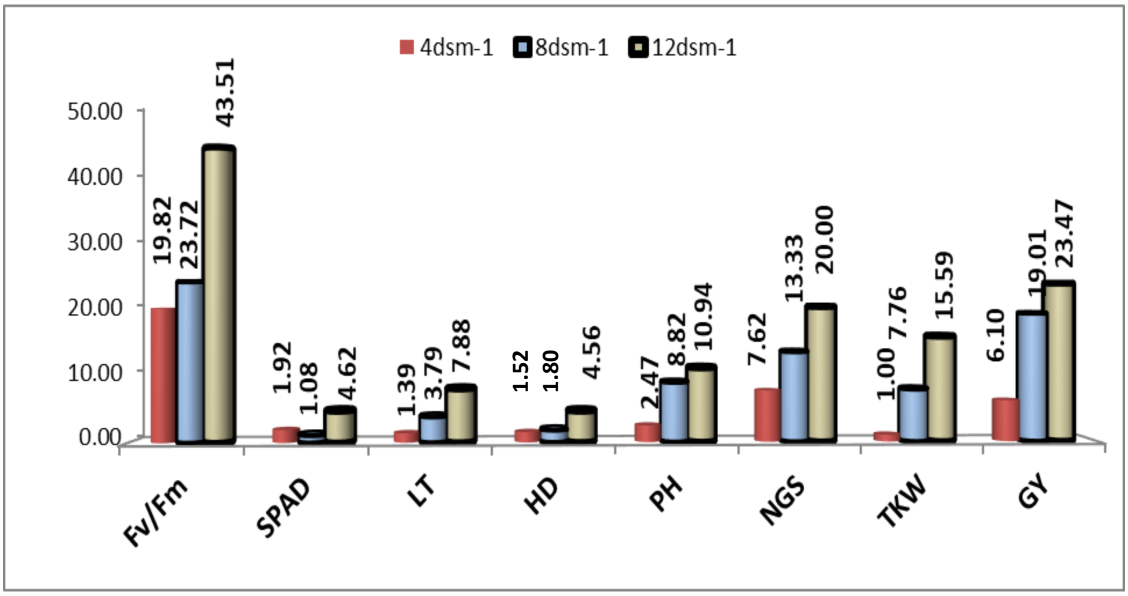

Fig. 1. The average reduction of the studied traits due to salinity stress 4, 8and 12 dsm^{-1} salinity levels as compere by 2.33 dsm^{-1} level

Fv/Fm: Chlorophyll fluorescence, SPAD: Total chlorophyll content, LT: leaf temperature:, HD: days to heading , PH : plant height, , NGS^{-1}, no. of grain spike , TWK : thousand Karnal weight and GY : grain yield,

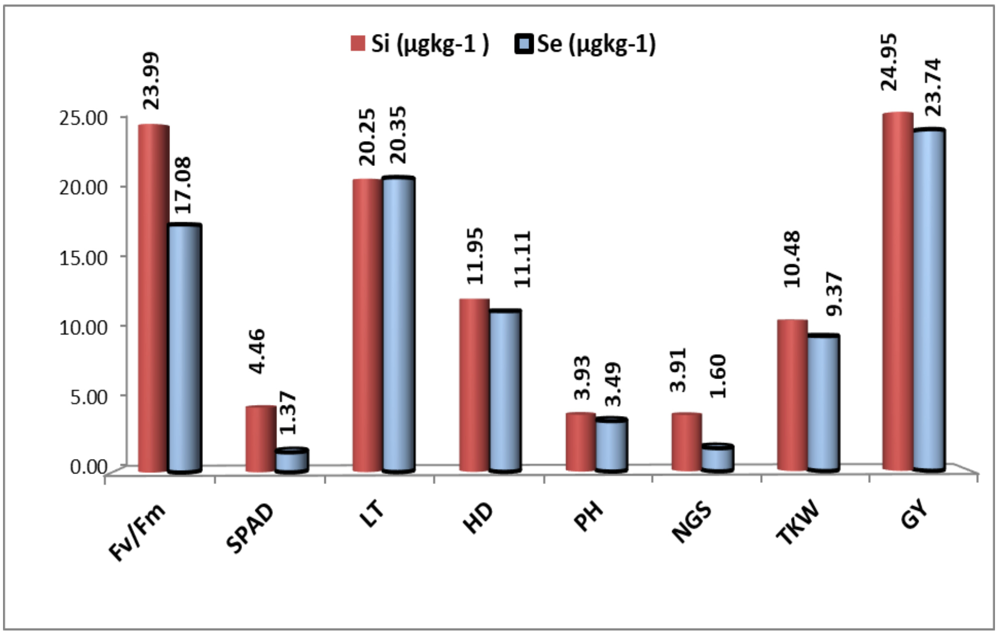

Fig. 2. The average increasing of the studied traits due to using nano si and nano as compere by without nano treatments

Fv/Fm: Chlorophyll fluorescence, SPAD: Total chlorophyll content, LT: leaf temperature, HD: days to heading, PH: plant height, NGS^{-1}, no. of grain spike, TWK: thousand Karnal weight and GY: grain yield

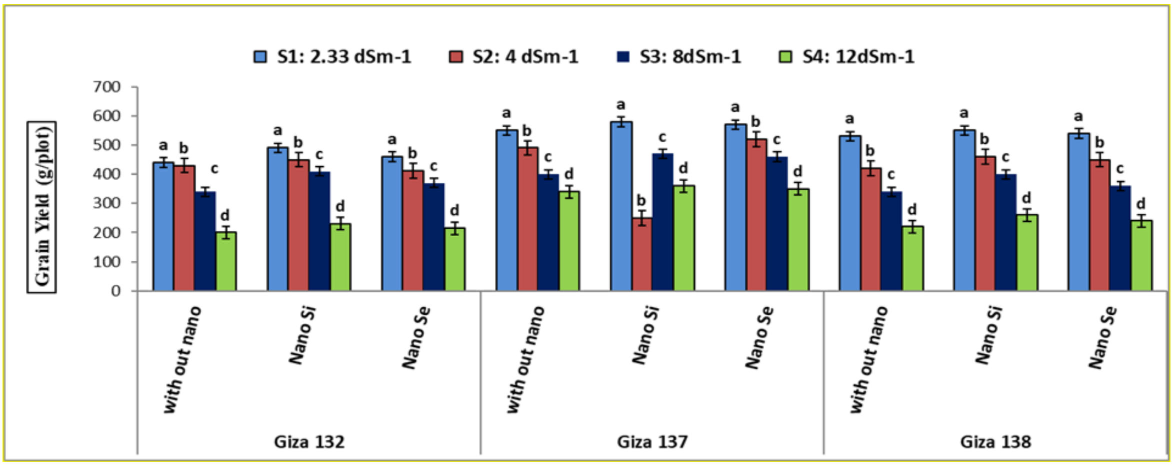

Fig. 3. Effects of interaction between salinity levels and nano treatments on grain yield of Giza 132m Giza 137 and Giza 138 (Combined data of two years)

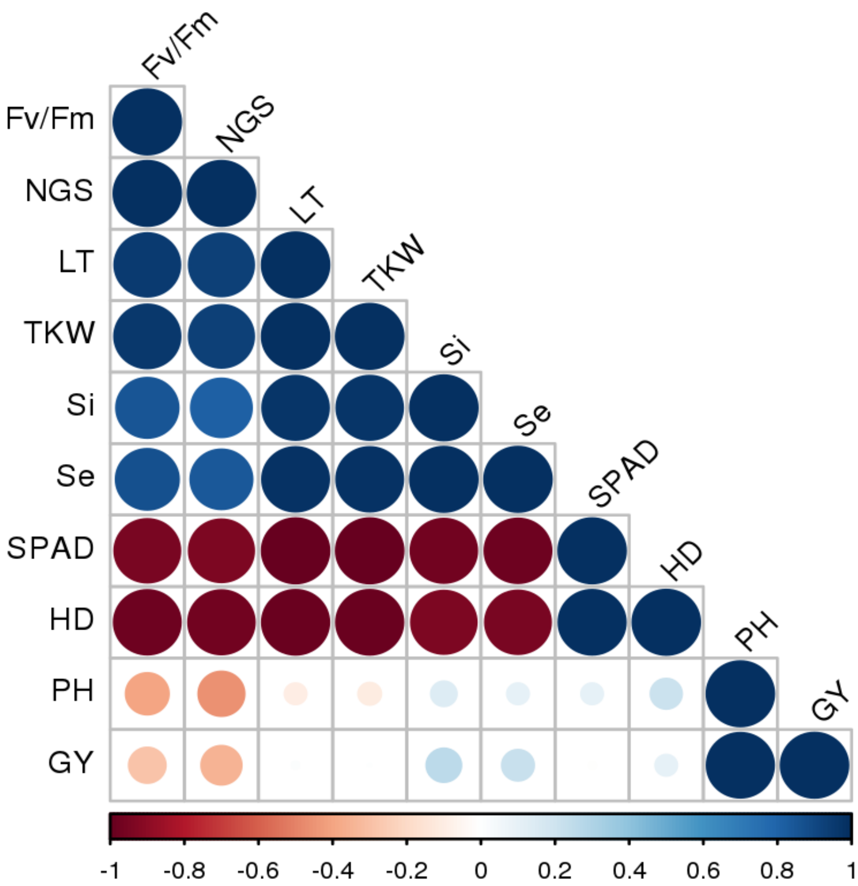

Fig. 4. Pearson correlation coefficient heatmap among grain yield (GY)

Fv/Fm: Chlorophyll fluorescence, SPAD: Total chlorophyll content, LT: leaf temperature, HD: days to heading, PH: plant height, NGS^{-1}, no. of grain spike, TWK: Thousand Karnal weight, Se: nanoselenium concentrate and Si: nano silica. Correlation key and the scale reads, red circle indicted negative correlation, blue circle indicted positive correlation, white circle mean no correlation smaller circle indicted lesser significance; bigger circle indicted greater significance. The color intensity and the size of the circle are relative to the correlation coefficient

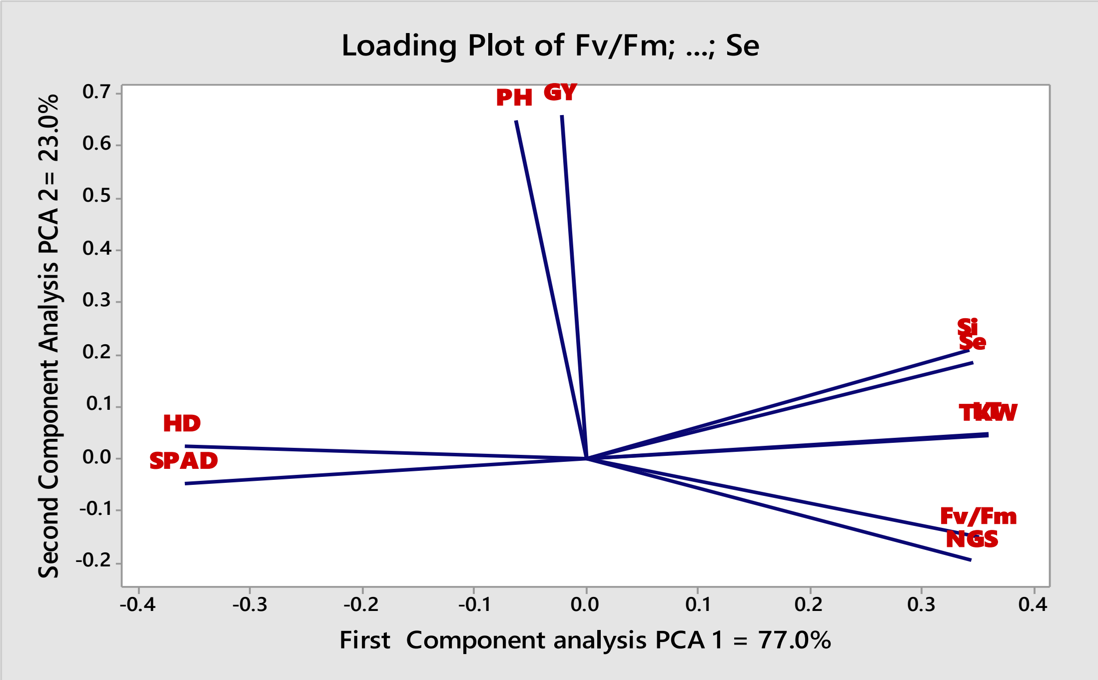

Fig. 5. Loading plot graph, showing the first two principal components (PCA) of the correlation matrix among the studied traits

Fv/Fm: Chlorophyll fluorescence, SPAD: Total chlorophyll content, LT: leaf temperature, HD: days to heading, PH: plant height, NGS^{-1}, no. of grain spike, TWK: Thousand Karnal weight, GY: grain yield, N,P,K , Na , Se : selenium concentrate and Si :silica concentrate

3.3 Relationships among all studied traits under different treatments

3.3.1 Pearson correlation coefficients

Pearson correlation coefficient among all studied characters over the four saline water irrigation treatments, SiO2 NPs and Se NPs were done to comprehend the associations among all studied characters as shown in Fig. 4. The results clearly indicated that the grain yield GY had significantly positive correlated with LT, PH, HD, TKW, SiO2 NPs and Se NPs, while had significantly negative correlated with *Fv/Fm*, and NGS. (Fig. 4). Similar both of SPAD and HD traits had highly significantly negative correlated with Fv/Fm, NGS, LT, TKW, SiO2 NPs and Se NPs characters as shown in (Fig. 4). These results were in agreement with (Mariey et al 2022 a, b & 2023; Falouti et al., 2024; Abdelrady et al., 2024) they reported that the correlation analysis was necessary for the plant breeders to know the information about the relationship between different traits to get high yield in through their positive or negative correlated in breeding programs selection for salinity stress.

3.3.2 Principal component analysis (PCA) analysis

The loading of PCA plots graphs accessible in the horizontal axis showed the direction of connotation among the all studied characters. The first and two principal components described for 100 % (PCA1= 80.7% + PCA2 =19.3%) of the total changeability (Fig. 5). The PCA loadings divided the studied characters into parallel classes. Therefore, the characters with the nearest vector length that located in the one quarter of the graph are more correlated, The results showed that SPAD and HD were located in the left side (negative) of the horizontal axis according to their negative correlations with most other characters (Fig. 4), while the other 11 characters were located in the right side (positive) of the horizontal axis according to their positive correlations with most other characters. Our results in a good harmony with (Mohamed et al 2021; Mariey et al., 2021; Mariey et al., 2023; Ahmed et al., 2024) they using the principal components model in barley, and they reported that these methods give a set of useful graphs that help plant breeders to discover the interrelationships among environments, genotypes, and relations between genotypes and environment.

4. CONCLUSIONS

Application of using NPs-Si and NPs-Se could be the good defend for barley plants against the risky effect of salinity stress, also there were no expressive differences between the NPs-Si and NPs-Se applications; both were active compared to the control in most measured characteristics but results showed that using NPs-Si gave the maximum values for all studied traits .So, we could conclude that the application of SiO2 NPs was more efficient more the application of Se NPs in improving barely photosynthetic parameters and grain yield Productivity under saline irrigation water.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Abdelrady, W.A., Ma, Z., Elshawy, E.E., Wang, L., Askri, S.M., Ibrahim, Z., Dennis, E., Kanwal, F., Zeng, F., & Shamsi, I.H. (2024). Physiological and biochemical mechanisms of salt tolerance in barley under salinity stress. *Plant Stress, 11*.

Aboelsoud, H.M., AbdelRahman, M.A.E., Kheir, A.M.S., Eid, M.S.M., Ammar, K.A., Khalifa, T.H., & Scopa, A. (2022). Quantitative estimation of saline-soil amelioration using remote sensing indices in arid land for better management. *Land, 11*(7), 1041. https://doi.org/10.3390/land11071041

Ahmed, K.R., Hussein, N.M., & Mariey, S.A. (2024). Study on applications of hot pepper and quinoa's saponin extract in control of barley crop cultivars aphid insects. *Journal of Biochemistry International, 11*(1), 57–71. https://doi.org/10.56557/jobi/2024/v11i19038

Akhter, M.S., Noreen, S., Mahmood, S., Athar, H., Ashraf, M., Alsahli, A.A., & Ahmad, P. (2021). Influence of salinity stress on PSII in barley (*Hordeum vulgare* L.) genotypes, probe chlorophyll-a fluorescence. *Journal of King Saud University Science, 33*, 101239.

Alharbi, K., Osman, H.S., Rashwan, E., Hafez, E.M., & Omara, A.E. (2022). Stimulating the growth, anabolism, antioxidants, and yield of rice plants grown under salt stress by combined application of bacterial inoculants and nano-silicon. *Plants, 11*, 3431

Amer, K.A.; Abou El Enein, R.A.; El-Sayed, A.A.; Noaman, M.M.; Ahmed, I.A.; El-Moselhy, M.A.; Moustafa, K.A.; Abd El-Hamid, M.; Megahed, M.A.; El-Bawab, A.M.O.; et al. (**2017).** Giza 137 and Giza 138, *.* , new Egyptian six-rowed Barley cultivars for new land. *Egypt. J. Plant Breed21*, 380–395..

Amer, M.M., & El-Emary, F.A. (2018). Impact of foliar with nano-silica in mitigation of salt stress on some soil properties, crop-water productivity, and anatomical structure of maize and faba bean. *Environmental Biodiversity and Soil Security, 2*, 25–38.

Amer, M.M., Aboelsoud, H.M., Sakher, E.M., & Hashem, A.A. (2023). Effect of gypsum, compost, and foliar application of some nanoparticles in improving some chemical and physical properties of soil and the yield and water productivity of faba beans in salt-affected soils. *Agronomy, 13*(4), 1052. https://doi.org/10.3390/agronomy13041052

Badawy, S.A., Zayed, B.A., Bassiouni, S.M.A., Mahdi, A.H.A., Majrashi, A., Ali, E.F., & Seleiman, M.F. (2021). Influence of nano-silicon and nano-selenium on root characters, growth, ion selectivity, yield, and yield components of rice (*Oryza sativa* L.) under salinity conditions. *Plants, 10*, 1657. https://doi.org/10.3390/plants10081657

Bartlett, M.S. (1937). Properties of sufficiency and statistical tests. *Proceedings of the Royal Statistical Society Series A, 160*, 268.

El-Ramady, H., Alshaal, T., Elhawat, N., El-Nahrawy, E., Omara, A., El-Nahrawy, S., Elsakhawy, T., Ghazi, A., Abdalla, N., & Fári, M. (2018). Biological aspects of selenium and silicon nanoparticles in the terrestrial environments. In *Phytoremediation* (pp. 235–264). Springer. Switzerland.

Falouti, M., Ellouzi, H., Amraoui, S., Hemissi, I., Bounaouara, F., Rabhi, M., Abdelly, C., Zorrig, W., & Slama, I. (2024). Silicon (Si) seed priming improves growth and photosynthetic efficiency of barley plants under salt stress in agricultural field conditions. *Journal of Plant Growth Regulation*.

Finocchiaro, F., Terzi, V., & Delbono, S. (2023). Barley: From molecular basis of quality to advanced genomics-based breeding. In *Compendium of Crop Genome Designing for Nutraceuticals* (pp. 1-38). Springer Nature Singapore.

Ghazi, A.A., El-Nahrawy, S., El-Ramady, H., & Ling, W. (2022). Biosynthesis of nano-selenium and its impact on germination of wheat under salt stress for sustainable production. *Sustainability, 14*, 1784.

Hussein, H.A.A., Darwesh, O.M., & Mekki, B.B. (2019). Environmentally friendly nano-selenium to improve antioxidant system and growth of groundnut cultivars under sandy soil conditions. *Biocatalysis and Agricultural Biotechnology, 18*, 101080.

Ismail, L.M., Soliman, M.I., Abd, E.M., & Abdel-Aziz, H. (2022). Impact of silica ions and nano-silica on growth and productivity of pea plants under salinity stress. *Plants, 11*, 494.

Mahlooji, M., Seyed Sharifi, R., Razmjoo, J., Sabzalian, M.R., & Sedghi, M. (2018). Effect of salt stress on photosynthesis and physiological parameters of three contrasting barley genotypes. *Photosynthetica, 56*(2), 549–556.

Mansour, E., Moustafa, S., Mohamed, I.E., Abdel-Hamid, S.M.A.I., Abdel-Rahman, M.A., & Hany, M.A.W. (2021). Field responses of barley genotypes across a salinity gradient in an arid Mediterranean environment. *Agricultural Water Management, 258*, 107206.

Mariey, A. Samah Farid M. A. and Khatab I. A., (2016). Physiological and Molecular characterization of some Egyptian barley (hordeum vulgare l.) cultivars for salt tolerance. Egypt. J. Genet. Cytol., 45:367-382

Mariey, S.A., Ahmed, K.R., Agwa, A.M.E., Farid, M.A., & Serag, A.M. (2019). Biochemical and molecular genetic markers associated with salt stress tolerance in Egyptian barley cultivars. Egyptian Journal of Plant Breeding, 23, 183–197.

Mariey, S.A., El-Bialy, M.A., Khder, R.A., Mohamed, E.N., Meleah, A.M., & Khatab, I.A. (2023). Comprehensive evaluation and economic analysis in some barley genotypes under soil salinity. Asian Journal of Agriculture, 7(1).

Mariey, S.A., Ghareeb, Z.E., Shahein, A.M.E.A., Meleha, A.M.I., Gomaa, H.A., Rady, A.M.S., & Khatab, I.A. (2022c). Genetic diversity analysis among some barley genotypes using multivariable and molecular markers under different levels of soil salinity stress. Asian Journal of Plant and Soil Sciences, 7(1), 219–236.

Mariey, S.A., Khatab, I.A., Mousa, E.H., Alyamani, A., & Farid, M.A. (2022a). The influence of the salinity and weed control treatments on some barley cultivars and its associated weeds. Journal of Global Agriculture and Ecology, 13(2), 26–50.

Mariey, S.A., Khatab, I.A., Mousa, E.H., Alyamani, A., & Farid, M.A. (2022b). Identification of distinctive agro-physiological and molecular responses to seawater stress among tolerant and sensitive genotypes of barley. Fresenius Environmental Bulletin, 31, 9988–10006.

Mariey, S.A., Samah, M., Ghareeb, Z.E., & Abo Zaher, S.E. (2021). Genetic diversity of Egyptian barley using agro-physiological traits, grain quality, and molecular markers. Current Science International, 10, 58–71.

Mohamed, A.H., Omar, A.A., Attya, A.M., Elashtokhy, M.M.A., Zayed, E.M., & Rizk, R.M. (2021). Morphological and molecular characterization of some Egyptian six-rowed barley (Hordeum vulgare L.). Plants, 10, 2527.

Noaman, M.M.; El-Sayed, A.A.; Abo El-Enein, R.A.; Ahmed, I.A.; El-Gamal, A.S.; El Sherbiny, A.M.; Abd El-Hameed, M.m.; Megahed, M.A.; Moselhy, M.A.; El-Bawab, A.M.; et al (2006). Giza 132, a new drought tolerant six-rowed barley cultivar. Egypt. J. Appl. Sci., 21, 46–58

Piper, C.S. (1950). Soil and plant analysis. Interscience Publication.

Seleiman, M.F., Almutairi, K.F., Alotaibi, M., Shami, A., Alhammad, B.A., & Battaglia, M.L. (2021). Nano-fertilization as an emerging fertilization technique: Why can modern agriculture benefit from its use? Plants, 10, 2.

Shah, S.H., Houborg, R., & McCabe, M.F. (2020). Response of chlorophyll, carotenoid, and SPAD 502 measurement to salinity and nutrient stress in wheat (Triticum aestivum L.). Agronomy, 7, 61.

Szarka, V., Jokai, Z., El-Ramady, H., Abdalla, N., Kaszás, L., & Domokos-Szabolcsy, E. (2020). Biofortification of *Stevia* *rebaudiana* (Bert.) plant with selenium. *Environmental Biodiversity and Soil Security, 4*, 19–31.

Taha, R.S., Seleiman, M.F., Shami, A., Alhammad, B.A., & Mahdi, A.H.A. (2021). Integrated application of selenium and silicon enhances growth and anatomical structure, antioxidant defense system, and yield of wheat grown in salt-stressed soil. *Plants, 10*, 1040.

Zeeshan, M., Lu, M., Sehar, S., Holford, P., & Wu, F. (2020). Comparison of biochemical, anatomical, morphological, and physiological responses to salinity stress in wheat and barley genotypes differing in salinity tolerance. *Agronomy, 10*, 127.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). This publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

© Copyright (2025): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.ikprress.org/review-history/12738