EFFECT OF FOLIAR NOURISHMENT WITH GREEN ALGA (*SPIRULINA PLATENSIS*), SILICON AND BORON NANOPARTICLES ON YIELD AND ITS ATTRIBUTES OF FABA BEAN

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Abstract. Nanotechnology offers great opportunities for sustainable management of several crops production. The use of nanofertilizers derived from nutrients is highly concerning from an agro-environmental point of view. The impacts of nanoagrochemicals on faba bean plants under field conditions have not yet been verified. This experiment was conducted in 2021/2022 and 2022/2023, seasons at the experimental farm, Faculty of Agriculture, Assiut University, Egypt. The objective of the current study was to evaluate the foliar application of *Spirulina* at 2.0 gL^{-1}, silicon nanoparticles (SNPs), Boron nanoparticles (BNPs) each at 100 ppm L^{-1} individually or in combination with using two cultivars (Nubaria 1 and Sakha 3). Strips-Block design was conducted using three replications. Results revealed that the separate or combined treatments exceeded significantly seed yield realative to control with insignificant differences between = cultivars. Moreover, the shedded flowers decreased significantly, consequently the setted pods and seed yield were increased significantly. The shedding (%) was negatively correlated with all studied traits under all treatment combinations in particular *Sp* + SNPs + BNPs. The nine principal components with eigen values greater than one contributed 92.20 and 86.8% of the total variability traits amongst faba evaluated in the first and second seasons, respectively.
Keywords: *cultivars, correlation, nutrients, nanoagrochemicals, Principal Component Analysis, shedded flowers, silicon and boron, Spirulina*

Introduction

Faba bean (*Vicia faba* L.) is one of the most important winter pulse crops. It is high in protein, which makes it important for both human and animal nutrition (Crepon et al., 2010). It is a great crop to fix atmospheric nitrogen, and supply nitrogen input into the temperate agricultural systems. In addition, it significantly contributes to the increase of soil fertility (Samuel et al., 2008; Boubekeur et al., 2012). The world's farmed faba bean area was approximately 2684296 ha^{-1} (FAO, 2022) which yielded approximately 6144394.66 tons of dry seeds. The area cultivation of faba beans in Egypt reached approximately 25,105 ha^{-1} in 2022, producing approximately 103,129.31 tons of dry seeds. To reduce the high percentage of buds, flowering, and immature pods abscission to grow into fully mature pods in this plant, plant physiologists and breeders are studying

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the problem of shedding intensity. Several studies have been conducted to maximize flower set and diminish pre-harvest abscission of immature faba beans or other crops through the application of various nutrients, such as mineral fertilizers and plant growth regulators (Bastawisy and Sorial, 1998).

For many crops, foliar administration of micronutrients (MINs) is a more widely recognized, cost-effective, and efficient method. Accordingly, spraying the micronutrient to cultivated plants on specific soil types in Egypt resulted in improving the growth and increasing the yield (Abd El Hamid and Sarhan, 2008; El-Desuki et al., 2010). Plants rely on MINs for a variety of vital functions, including photosynthesis, carbohydrate metabolism, respiration, photolysis, protein synthesis, and the phenyl-propanoid pathway. Plant metabolism is also impacted by MINs, as they can change the phenolic contents and lignin in the cell and the stability of the membrane (Dutta et al., 2017). Foliar application would be a crucial component of soil fertility sustainability and might counteract the detrimental impacts of nutrients removed from the soil (El-Fouly et al., 2010). Nutrients are a very practical and effective way to keep agriculture sustainable (Dewal and Pareek, 2004). The two most significant physiological activities that MINs are involved in the photosynthesis and respiration (Mengel et al., 2001).

A lack of these nutrients might hinder these processes, which limits yield growth. For instance, boron (B) is a crucial nutrient for plant development and growth (Marschner, 1995) yield formation (Khayyat et al., 2007;) and fruit quality (Dordas, 2006; Dordas et al., 2007) in commercial plant production.

Boron deficiency in crops is more common (Gupta, 1993). MINs spraing i.e. B, on leaves have a significant impact on sink limitations, chloroplast formation, flower formation, protein and carbohydrate metabolism, pollen germination, pollen tube growth, and yield (Tersahima and Evans, 1988). Additionally, enhanced reproduction and the transfer of sugars depend on B. It also regulates the potassium and calcium in the plant. The construction of cell walls (O'Neill et al., 2004), the activities of cellular membranes (Goldbach et al., 2001), and anti-oxidative defense mechanisms (Cakmak and Romheld, 1997) are all significantly impacted by B. A global issue for field crop productivity is B deficiency (Wei et al., 1998), and a range of soil variables influence B availability to plants (Goldberg et al., 2000).

Supplemental silicon (Si) has been shown to increase production and lessen biotic and abiotic stressors on plants (Epstein, 1999). Furthermore, several studies have demonstrated that Si is useful in reducing salinity in a variety of plant species, including tomato (Liang et al., 1996, 2003; Romero-Aranda et al., 2006), wheat (Ahmad et al, 1992; Tuna et al., 2008), cucumber (Adatia and Besford, 1986; Zhu et al., 2004) and maize (Moussa, 2006).

Green-blue microalgae known as cyanobacteria, or Spirulina platensis, have the potential to improve soil fertility, crop growth and yield, and environmental quality in sustainable agriculture. Beyond such applications, its use in agriculture as biostimulants and fertilizers for plant growth has garnered more attention in recent years (Anitha et al., 2016; Godlewska et al., 2019; El Sherif, 2020; Yanni, 2020).

The current study aims to reduce the percentage of flowers and immature pods that shed from broad bean plants while increasing the final yields of green pods and seeds by using foliar spray containing algae extract Spirulina platensis, B, and Si.

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Materials and methods

Experimental site and design

The current study was conducted during two consecutive seasons of 2021–2022 and 2022–2023, at the experimental farm of the Agronomy Department, Faculty of Agricultural, Assiut University, Egypt (27° 18' N, 31° 16' and 53 m a.s.l.). The experiment was carried out using randomized complete block design (RCBD) in a strip block arrangement with three replicates. The physical and chemical properties of the experimental site are shown in *Table 1*.

Table 1. *Some physical and chemical properties of the experimental Soil*

Season	2021-2022	2022-2023
Mechanical analysis		
Sand	26.4	26.8
Silt	24.9	24.5
Clay	49.7	49.5
Soil type	Clay	Clay
Chemical analysis		
PH	7.78	7.76
Organic matter %	1.73	1.71
Total N%	0.09	0.08
Total $CaCO_3$%	1.18	1.23

Treatment combinations

A. ***Synthesis of Bio-Silica Nanoparticles (BSNPs)*:** Nanotech Egypt Co. (Dreamland, Egypt) supplied silicon dioxide (SiO_2) nanoparticles (NPs) with a 29-nm diameter and in a spherical shape (hydrophilic, 99.99% purity).

B. ***Nano Chelated Boron Fertilizer***: produced with "advanced chelate technology," the fertilizer has 9% chelated B, is absorbed at pH 3–11, and is completely soluble in water. Speeding the transport of chemicals generated during photosynthesis to the site of consumption. It boosts pod production and keeps them from dropping. Nanoparticles (NPs) was supplied from Nano Gate Creating New Scientific Horizons Company, Nasr City, Ciro, Egypt.

C. ***The strain MIYE 101 of Spirulina platensis*** (Gomont) Gentler was obtained from the Phycology Lab of the Faculty of Science at Assiut University in Egypt. Using the keys of (Vymazal, 1995), an inverted divert light microscope was utilized to identify the microalga up to species. The trachoma width is comprised of cylindrical cells, which are smaller than wide cells and have a diameter ranging from 8 to 10 µm.

During the two growing seasons, the plants were treated (sprayed) three times by the experimental treatments; 35, 50, and 65 days from sowing date (*Table 2*).

Furthermore, two cultivars i.e. **Nubaria-1** and **Sakha-3** were randomly distributed horizontally plot. Five ridges, each three meters long and sixty centimeters apart, made up the plot. One plant per hill, spaced 15 cm apart, was the seed spacing used for both sides of the ridge.

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Table 2. *The experimental treatments*

No.	Treatments	Concentration
1.	Control (C)	Tap water
2.	*Spirulina* (Sp)	2.0 g L^{-1}
3.	Silicon nanoparticles (SNPs)	100 ppm L^{-1}
4.	Boron nanoparticles (BNPs)	100 ppm L^{-1}
5.	SNPs and BNPs	Each at 100 ppm L^{-1}
6	Spirulina + SNPs	Spirulina at 2.0 g L^{-1} while SNPs at 100 ppm L^{-1}
7	Spirulina + BNPs	Spirulina at 2.0 g L^{-1} while BNPs at 100 ppm L^{-1}
8	Spirulina (2.0 g L^{-1}) + SNPs + BNPs	Spirulina at 2.0 g L^{-1} while each of SNPs and BNPs at 100 ppm L^{-1}

The sowing dates: the seeds were 20 and 19 October of 2021/2022 and 2022/2023, respectively. The recommended agricultural practices for faba bean plants, including tillage, irrigation, weed and disease control, harvesting, etc., were carried out as usual.

Examined characteristics

To estimate the following parameters, five plants were randomly selected from the center row of each plot and marked in the field from the beginning of flowering to harvest time to account the number of flowers, in both seasons:

1. Plant height (PH)
2. Number of branches/plant (NBP).
3. Height of the first pod cm (HFP).
4. Number of pods/plant (NPP).
5. Pods weight/plant (PWP), g
6. Weight of 100 seeds, g (SI)
7. Sees yield/ha, ard (SYH).
8. Shedding percentage

$$\text{Shp} = \left(\frac{Total\ No.\ of\ flowers/plant - No.of\ setted\ pod/plant}{Total\ No.of\ flowers/plant}\right)*100 \qquad \text{(Eq.1)}$$

9. Seed Setting

$$\text{SS} = \left(\frac{Number\ of\ pods/plant}{Total\ No.of\ flowers/plant}\right)*100 \qquad \text{(Eq.2)}$$

Statistical analysis

All data were subjected to the analysis of variance according to Gomez and Gomez (1984). The correlation coefficients among studied traits for both growing seasons were computed using R Studio (RStudio, 2020). In addition, principal component analysis (PCA) is a widely used statistical tool to analyze genetic variation among plant genotypes and determine the most important variables contributing to variation (Price et al., 2006). In the present study with correlation matrix method was performed using R studio and the PC1 and PC2 with highest eigenvalues were selected, as proposed by Jeffers (1967). A biplot of the first two components were used for grouping treatment combinations and illustrating the relationship between the studied traits and treatment combinations.

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Results and Discussions

Analysis of variance

The analysis of variance of all studied traits is shown in *Table 3*. The mean squares of the spraying foliar application with green alga of *Spirulina platensis*, SNPs and BNPs treatments were highly significant in both growing seasons for all studied traits, except shedding percentage in second season. Moreover, the difference between cultivars was significant for plant height in both seasons, number of pods/plant and pods weight/plant in first season. Also, the differences were significant and highly significant for branch number /plants, and seed setting in second season, respectively (*Figures 1-5*). In addition, the interaction between foliar application with cultivars was revealed to be not significant in most studied traits, except pods weight/plant in first season, number of branches/plant and seed yield (ard./ha.) monitored significant difference in second season. All foliar sprayings which included *Spirulina* (Sp), SNPs and BNPs separately or combined were exceeded significantly the seed yield compared to the control treatment (water) with no significant differences between the two cultivars.

Means of studied traits

The highest values of seed yield were 26.10 and 24.1 ard./ha. which recorded when used Sp, SNPs and BNPs at the same time in the first and second seasons, respectively (*Figure 6*). These results reflected the increasing percentage of seed yield by 20.28 and 15.31% compared to the general mean of all foliar application. In the same minatory the Nubaria 1 yielded 26.5 ard./ha in the first season whereas Sakha 3 produced 24.6 ard./ha in the second season which possessed 21.56 and 16.92% comparing increasing over the general mean of the cultivar upon all foliar application as highest yield when sprayed with all Sp, SNPs and BNPs as a combined treatment. These remarkable results revealed the main role of these microelements and *Spirulina* in nanoparticles to increase the yield. The previous result could be touch many of studied traits as a yield component such as plant height, number of branches and pod/plant, pods weight/plant, seed setting and 100-seed weight (*Figures 7 and 8*) Concerning to the shedding percentage as an important trait to express the setted pods of plant, all foliar sprayings decreased significantly the shedded flowers specially in first season, consequently increase significantly the setted pods and seed yield. To minatory the data in *Figure 9*, the shedding percentages were less values of 88.1 and 91.3% as average in first and second seasons, respectively, when both cultivars received the combined treatment of Sp, SNPs and BNPs with no significant difference between both cultivars. The results are in a good agreement with the previous studies which reported that the foliar application of Sp, SNPs and BNPs enhanced the yield parameters of various plants including common bean (Corbo et al., 2018; Moussa and Hassen, 2018; Wathiq et al., 2022), bean (Boghdady et al., 2017) and peas (Zitna et al., 2018). Such enhancement effect of Spirulina, Si and B might be attributed to their favorable effects on the metabolism and biological activities and their stimulating role on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth of faba bean as mention by Wanas (2002) and El-Sherbeny et al. (2007). Moreover, the current results are in line with those obtained by EL-Yazied and Mady (2012). The makers and experts advised using this nano-fertilizer when a plant shows signs of B insufficiency.

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Table 3. *Mean squares of the studied traits for spray nanoparticles and cultivars in the two sowing seasons*

Traits	Source of variations											
	Sprayings (S)		**Error (a)**		**Cultivars (C)**		**Error (b)**		**S*C**		**Error (C)**	
	2021-2022	**2022-2023**	**2021-2022**	**2022-2023**	**2021-2022**	**2022-2023**	**2021-2022**	**2022-2023**	**2021-2022**	**2022-2023**	**2021-2022**	**2022-2023**
D.F	7		14		1		2		**7**		14	
Plant height (cm)	152.25**	470.68**	30.92	19.85	145.95**	4.69*	0.92	0.23	4.66	22.83	22.65	17.24
Number of branches/plants	0.92**	4.67**	0.03	0.17	0.49	4.32*	0.04	0.07	0.04	0.61*	0.08	0.23
Height to first pod (cm)	12.07**	44.83**	4.67	3.37	0.54	0.85	0.79	2.04	1.29	1.13	2.81	2.19
Number of pod/plants	74.82**	29.18**	0.71	0.51	7.02*	1.61	0.34	0.68	1.09	0.39	0.89	0.16
Pods Weight/plant	711.64**	634.76**	3.98	4.78	109.89*	341.60	5.91	28.69	28.03**	13.05	3.31	5.15
Seed yield (Ard./ha.)	47.54**	21.11**	0.87	1.70	0.30	1.13	0.68	1.69	1.80	7.37**	1.35	0.98
100-seed weight (g)	110.48**	109.29**	1.93	7.56	7.74	1.82	1.78	6.12	2.19	3.14	3.73	1.37
Seed setting	9.71**	4.87**	0.70	0.22	0.22	1.52**	0.29	0.01	0.26	0.01	0.21	0.14
shedding percentage	9.83**	5.98	0.66	7.91	0.29	1.31	0.37	1.46	0.28	0.10	0.53	7.17

*and **significant at the 5% and 1% levels of probability respectively

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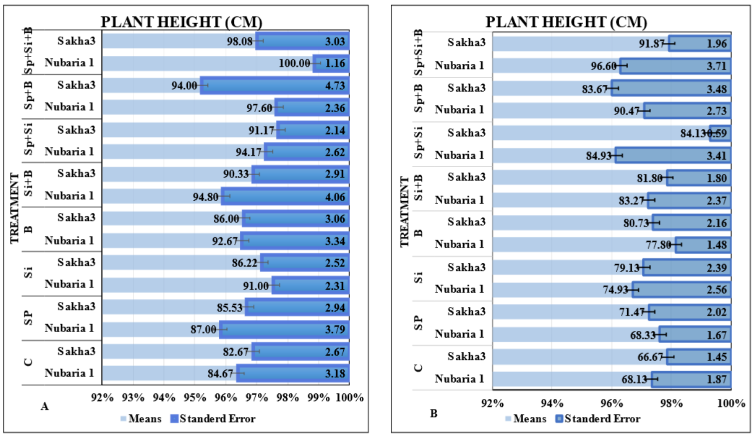

Figure 1. *Plant height (cm) as influenced by the interaction among effect of spray nanoparticles and cultivars treatments on faba bean 2021/2022 (A) and 2022/2023 season (B). Control (C), Spirulina (Sp), silicon nanoparticles (SNPs), boron nanoparticles (BNPs)*

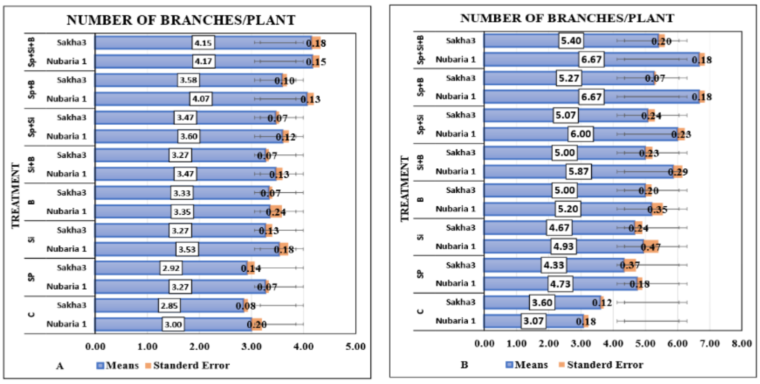

Figure 2. *Number of branches/plants as influenced by the interaction among effect of spray nanoparticles and cultivars treatments on faba bean 2021/2022 (A) and 2022/2023 season (B). Control (C), Spirulina (Sp), silicon nanoparticles (SNPs), boron nanoparticles (BNPs)*

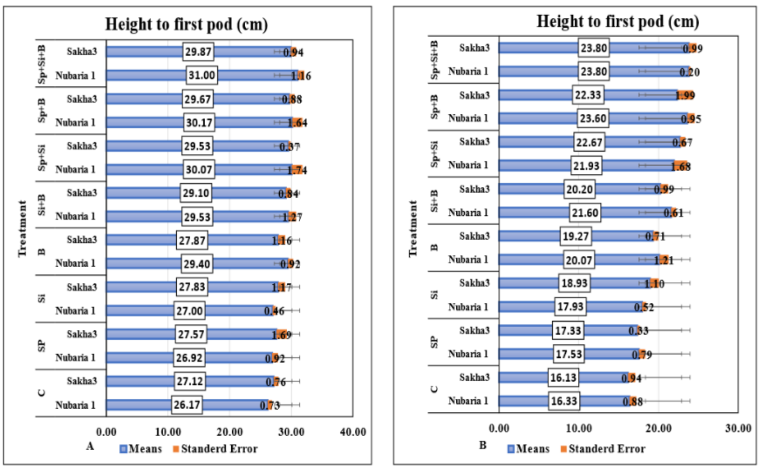

Figure 3. *Height to first pod (cm) as influenced by the interaction among effect of spray nanoparticles and cultivars treatments on faba bean 2021/2022 (A) and 2022/2023 season (B). Control (C), Spirulina (Sp), silicon nanoparticles (SNPs), boron nanoparticles (BNPs)*

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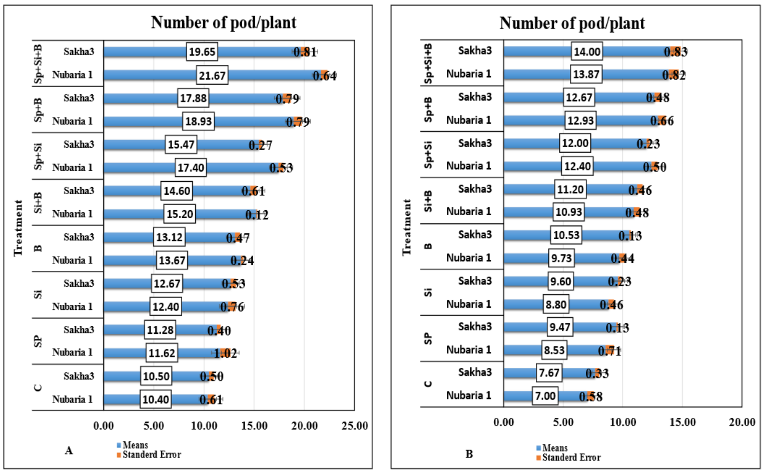

Figure 4. *Number of pod/plants as influenced by the interaction among effect of spray nanoparticles and cultivars treatments on faba bean 2021/2022 (A) and 2022/2023 season (B). Control (C), Spirulina (Sp), silicon nanoparticles (SNPs), boron nanoparticles (BNPs)*

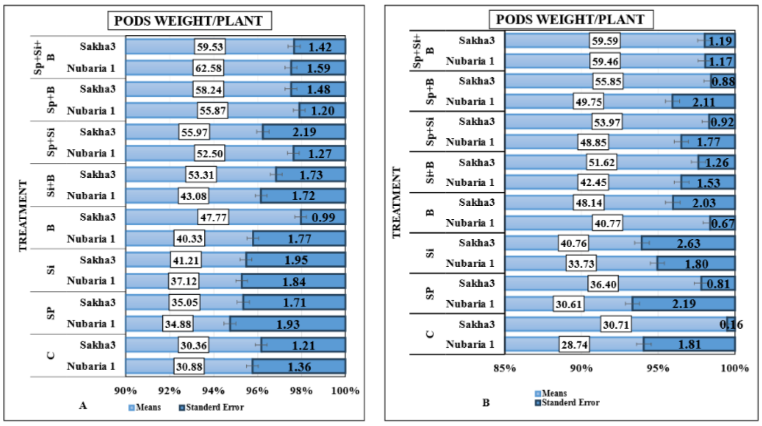

Figure 5. *Pods weight/plant influenced by the interaction among effect of spray nanoparticles and cultivars treatments on faba bean 2021/2022 (A) and 2022/2023*

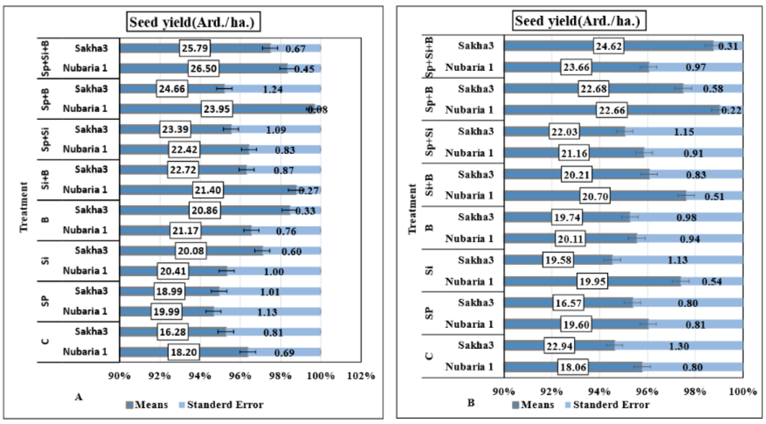

Figure 6. *Seed yield (ard/ha.) influenced by the interaction among effect of spray nanoparticles and cultivars treatments on faba bean 2021/2022 (A) and 2022/2023 season (B). Control (C), Spirulina (Sp), silicon nanoparticles (SNPs), boron nanoparticles (BNPs)*

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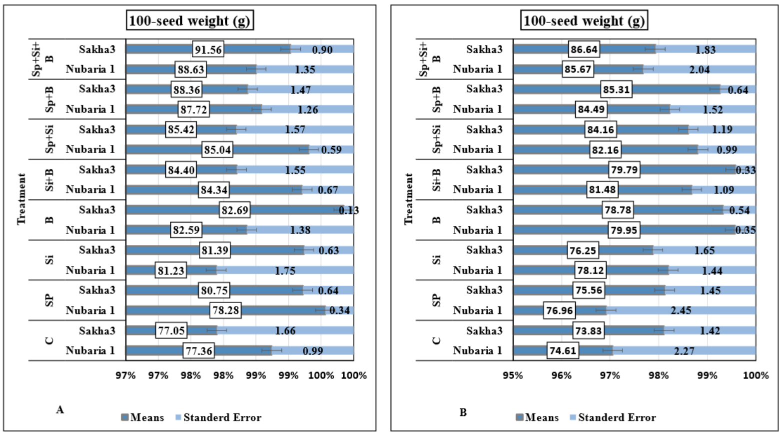

Figure 7. *100-seed weight influenced by the interaction among effect of spray nanoparticles and cultivars treatments on faba bean 2021/2022 (A) and 2022/2023 season (B). Control (C), Spirulina (Sp), silicon nanoparticles (SNPs), boron nanoparticles (BNPs)*

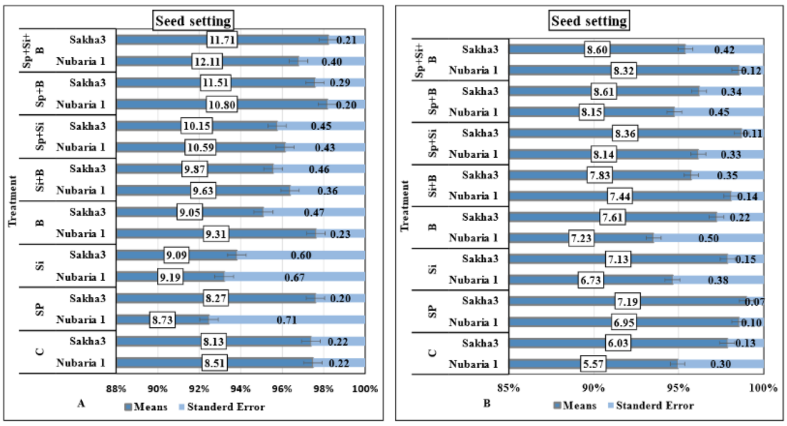

Figure 8. *Seed setting influenced by the interaction among effect of spray nanoparticles and cultivars treatments on faba bean 2021/2022 (A) and 2022/2023 season (B). Control (C), Spirulina (Sp), silicon nanoparticles (SNPs), boron nanoparticles (BNPs)*

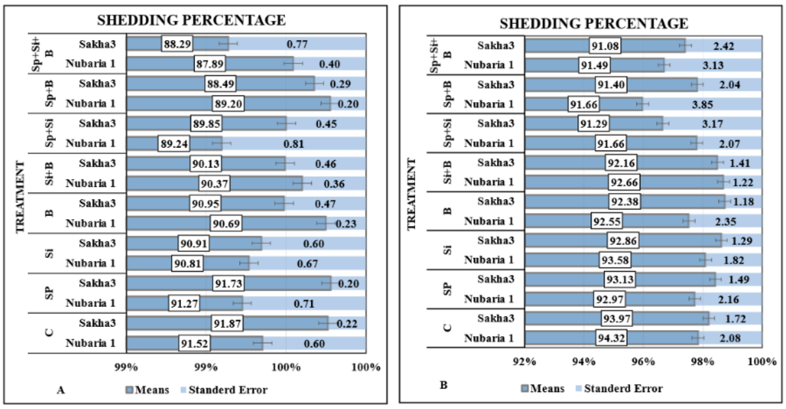

Figure 9. *shedding percentage influenced by the interaction among effect of spray nanoparticles and cultivars treatments on faba bean 2021/2022 (A) and 2022/2023 season (B). Control (C), Spirulina (Sp), silicon nanoparticles (SNPs), boron nanoparticles (BNPs)*

All foliar applications of *Spirulina platensis*, Si and B increased the seed yield and its components and decreased the shedding percentage may be due to different reasons i.e a- *S. platensis* has important role for plant as source of nutrients, proteins, vitamins, essential amino acids, fatty acids, phytohormones and antioxidant compounds; b- B plays a basic role for cell wall formation, stability, biological function, movement of sugar/energy into growing parts of plants, pollination as well as seed set; and c- Si helps plants to increase its defense to both biotic and abiotic stress and promotes thicker and stronger stalks, leaves and roots.

Estimation of correlation coefficients analysis

Correlation coefficients were estimated among nine traits (*Figure 10*) in the first and second seasons respectively. It had significant positive correlation with plant height (cm), number of branches/plants, height to first pod (cm), number of pod/plants, pods weight/plant, 100-seed weight (g), seed yield (Ard./ha.) and seed *setting* but a significant negative correlation with shedding percentage in first and second seasons respectively. Seed yield (ard./ha.) had a significant positive correlation with number of pod/plant and pods weight/plan. Seed setting was significantly associated with number of pod/plant and seed yield (ard./ha.) Similarly, 100-seed weight(g) had significant correlation with number of pod/plant and pods weight/plant. The shedding percentage had a significant negative correlation with all traits especially number of pod/plant and seed setting in the first season. But in the second seasons plant height (cm) had a significant positive correlation with height to first pod (cm) and number of pod/plant. Height to first pod (cm) was significantly associated with a number of pod/plant and 00-seed weight (g) Similarly, a number of pod/plants had a significant correlation with pods weight/plant,100-seed weight (g) and seed setting. shedding percentage had a significant negative correlation with all traits special seed setting. Similar results have been also reported by Chaubey et al. (2012), Mulualem et al. (2013), Sharifi and Aminpana (2014), Kumar et al. (2017) and Tiwari et al. (2019). The present study suggested that plant height, number of pod/plants, pods weight/plan, and 100-seed weight(g) had strong positive correlations with all the traits so simultaneous improvement of both the associated characteristics will be achieved if used in the selection criterion.

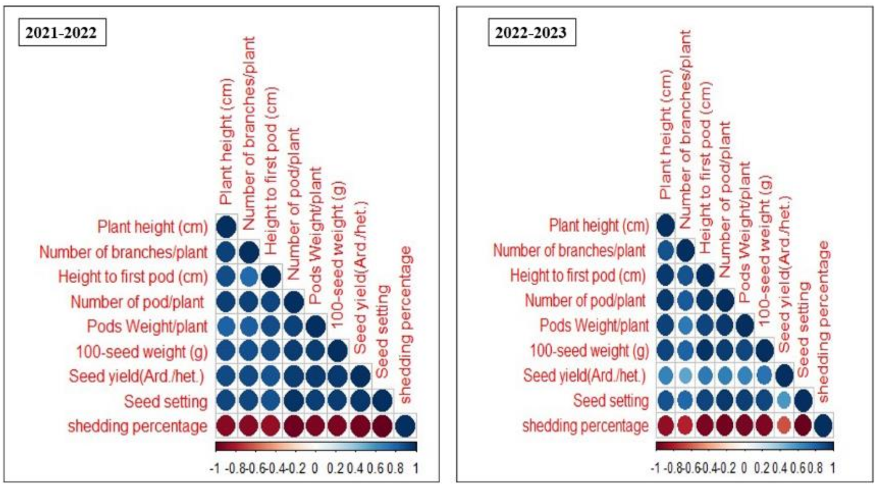

Figure 10. *Putative correlation coefficients between yield and its components of faba bean under spray SNPs and BNPs and cultivars treatments in 2021/2022 and 2022/2023 season. The darker color is more correlated, and the lighter color is less correlated*

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Principal Component Analysis

Nine studied trait combinations were involved in the principal component analysis in a correlation matrix approach (*Figures 11-12*). The analysis extracted two components (PC1 and PC2), they recorded high Eigenvalues (8.301 and 0,278) and (7.816 and 0.549) in both seasons, respectively (*Tables 4 and 5*). The PC1 and PC2 explained (92.23 and 3.08%) and (86.83 and 6.09%) of the total variation in both seasons, respectively (*Table 4; Figures 11 and 12*). Low positive correlation values were observed about PC1 and PC2 except Ship had a negative correlation (*Table 5*), indicating the existence of sufficient association with the direction of the variability in the data set.

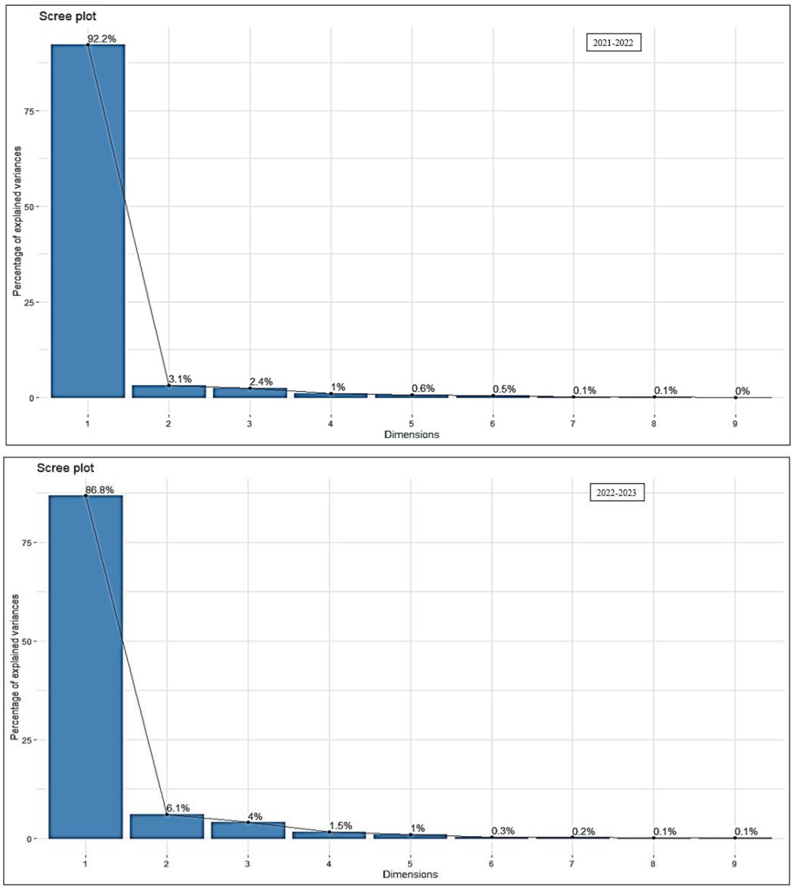

Figure 11. *Scree plot for nine principal components in 16 treatments*

In the first season (2021-2022), Parameters such as NBP, PH, NPP and SS were positively loaded with PC1. In the second season, the parameters SYH, SI, PH, NPP and HFP were positively loaded with PC2. Results revealed that the spray nanoparticles and cultivars treatments are more diverse from each other. Environmental fluctuations represent a major threat to yield production worldwide, and genotypes may have the option to tolerate unfavorable conditions caused by environmental change and, therefore, be valuable as potential guardians in plant breeding to improve defoliation tolerance in faba bean. In PC analysis, plant height, branch number/plant were strongly correlated and positively with PC2 while pods weight/plant was strong correlation negative in PC2 in the first season. But height to first pod and number of pod/plant same correlated positively

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in PC1while seed yield (ard./ha.) strong correlated positively in PC2 in the second season. There is a similarity in both seasons in the characteristics associated with number of pod/plant correlated positive in PC2 in the first season and correlated in PC1 in the second season. Similar results have been also reported by Mahmoud et al. (2022).

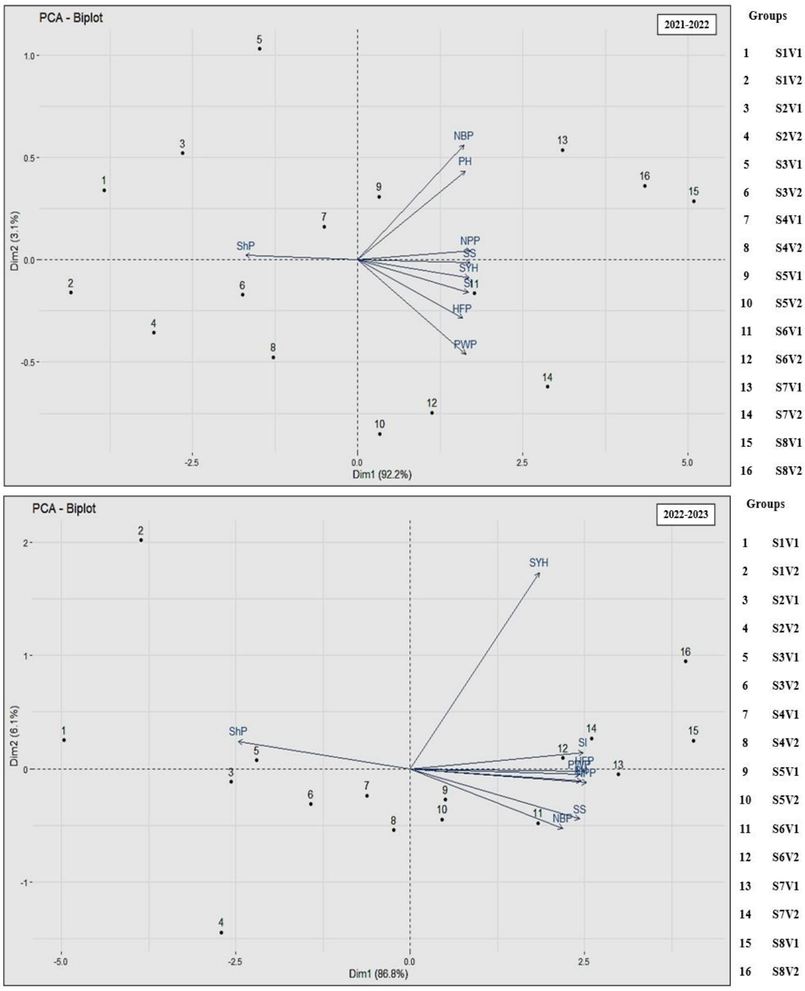

***Figure 12.** Plots from the PCA demonstrating the contribution of the 16 interactions between SNPs and BNPs (8) and cultivars (2) treatments to the variation to different axis and the grouping of faba bean according to PC1 and PC2*

***Table 4.** Eigenvalues and variance percentage of the nine major factors obtained from the PCA of nine traits performed on faba bean cultivars and spray of SNPs and BNPs*

PC	2021-2022		2022-2023	
	Eigenvalue	**% Variance**	**Eigenvalue**	**% Variance**
1	8.301	92.238	7.816	86.839
2	0.278	3.088	0.549	6.095
3	0.214	2.379	0.356	3.959
4	0.090	1.003	0.138	1.534
5	0.057	0.635	0.089	0.987
6	0.045	0.497	0.024	0.266
7	0.009	0.095	0.018	0.198
8	0.006	0.062	0.006	0.067
9	0.000	0.004	0.005	0.056

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Table 5. *Estimates of correlation coefficients among nine traits in faba bean cultivars and spray of SNPs and BNPs*

					2021-2022				
	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**	**PC 8**	**PC 9**
PH	0.327	0.482	0.391	0.057	-0.369	0.268	-0.466	0.281	0.016
NBP	0.323	0.612	-0.201	0.284	0.513	-0.129	0.036	-0.345	0.008
HFP	0.319	-0.301	0.767	-0.021	0.205	0.017	0.172	-0.382	0.018
NPP	0.344	0.050	0.070	-0.270	0.293	-0.256	0.371	0.715	-0.033
PWP	0.329	-0.509	-0.226	0.203	0.392	0.153	-0.577	0.171	0.037
SI	0.336	-0.177	-0.077	0.504	-0.473	-0.606	0.069	-0.011	-0.018
SYH	0.339	-0.096	-0.241	0.258	-0.191	0.670	0.511	0.015	-0.060
SS	0.341	-0.020	-0.232	-0.475	-0.185	-0.045	-0.019	-0.216	0.722
ShP	-0.341	0.027	0.209	0.506	0.156	0.064	0.122	0.260	0.687
					2022-2023				
	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**	**PC 8**	**PC 9**
PH	0.343	-0.056	0.215	0.649	-0.077	-0.141	0.039	-0.334	0.523
NBP	0.307	-0.277	0.759	-0.263	-0.277	0.096	-0.240	0.017	-0.201
HFP	0.352	-0.011	0.114	0.074	0.445	-0.526	0.121	0.603	-0.071
NPP	0.354	-0.065	-0.068	0.097	-0.133	0.280	0.783	-0.066	-0.378
PWP	0.341	-0.027	-0.393	0.409	-0.268	0.173	-0.512	0.231	-0.379
SI	0.347	0.076	-0.006	-0.115	0.724	0.476	-0.203	-0.263	0.007
SYH	0.260	0.915	0.106	-0.163	-0.227	-0.019	-0.010	0.025	0.065
SS	0.341	-0.236	-0.304	-0.399	-0.226	0.226	0.049	0.328	0.604
ShP	-0.344	0.127	0.320	0.359	0.064	0.555	0.083	0.538	0.159

Conclusions

It is advised that all foliar sprayings that contain Spirulina (Sp), SNPs and BNPs either separately or in combination with one another significantly outperform the seed yield when compared to the water control treatment, with no discernible differences between the two cultivars. Furthermore, the highest recorded seed yield when Sp, SNPs and BNPs were applied simultaneously in the first and second seasons. These astounding findings demonstrated how these microelements nanoparticles and spirulina have a major impact in raising the production of faba beans. It is clear that the shedding percentage was negatively correlated with all studied traits under all treatment combinations in particular SNPs + BNPs + *spirulina*. The PCA revealed high contribution of PC1 by 92.20% and 86.8% of the total variability traits amongst faba evaluated in the first and second seasons, respectively.

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