Enhancing Wheat Productivity with Nitrogen and Bio-Fertilizers in the North Nile Delta

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Abstract: This investigation was conducted in the experimental farm of the Faculty of Agriculture, Kafr El-Sheikh University, Egypt, during the 2021/22 and 2022/23 growing seasons to explore the impact of mineral nitrogen fertilization and Bio-fertilizer inoculation on wheat (*Triticum aestivum* L.). The experiment utilized a randomized complete block design (RCBD) arranged in a split-split plot format with three replications. The study focused on two wheat cultivars: Sids 14 and Sakha 95 were placed in the main plots, four mineral nitrogen fertilizer rates (25, 50, 75 and 100 kg N fed.$^{-1}$) in the sub-plots, and Bio-fertilizer treatments with (*Azotobacter* sp., *Azospirillum* sp. and a control without inoculation) in the sub-sub plots. The results revealed a significant positive correlation between increasing nitrogen fertilization and Bio-fertilizers inoculation, leading to improvements in plant height (cm), fertile tillers, grains per spike, 1000-grain weight, grain yield (ton fed^{-1}), biological yield (ton fed^{-1}), straw yield (ton fed^{-1}), chlorophyll content and grain protein content (%). Sakha 95 consistently outperformed Sids 14 across all measured traits. The study concluded that applying 75 or 100 kg N along with inoculation yielded the highest grain output for Sakha 95, demonstrating that combining higher nitrogen levels with Bio-fertilizers inoculation substantially enhances wheat yield and quality in clay loam soils.

Keywords: wheat, nitrogen fertilizer, Bio-fertilizer, grain yield, yield components.

INTRODUCTION

Wheat is recognized globally as a crucial cereal crop and serves as Egypt's primary winter crop. It is the most crucial source of human food and provides straw for animal feeding (El-Sheref and El-Sherif, 2020). Wheat is a staple in the daily diet of most Egyptians, providing a crucial source of calories and proteins (El-Sorady *et al.,* 2022). In Egypt, approximately 5.8 million tons of wheat are imported (FAO 2021). This reliance on imports significantly strains the Egyptian national economy, as domestic production does not meet the country's needs. To address this, the Egyptian government is working to improve wheat production by sowing high-yielding cultivars and implementing best agricultural practices, such as the use of nitrogen fertilizers and efficient planting methods (El-Sheref and El-Sherif, 2020). Meeting the rising demand for wheat due to growing populations remains a significant challenge in many countries (Campuzano *et al.,* 2012). Any reduction in wheat yields due to biotic or abiotic factors can have a detrimental impact on global food security. Expanding wheat cultivation into newly reclaimed soils is essential, as the traditional farming areas in the Nile Valley face intense competition from other winter crops, particularly clover. Nitrogen is a key limiting factor in crop production and is essential for enhancing plant growth, biomass, yield, and protein content. The efficiency of nitrogen fertilizer is enhanced by using ammonium gas (Zaki *et al.,* 2016). Bio-fertilizers, also referred to as microbial inoculants, are artificially cultivated cultures of specific soil organisms that enhance soil fertility and boost crop productivity. They contribute nutrients through the natural processes of nitrogen fixation, potentially reducing the need for chemical fertilizers. Overuse of chemical fertilizers can result in low nitrogen use efficiency and increased environmental stress. Research by Zaki *et al.* (2016) and Hassanein *et al.* (2018) indicates that Bio-fertilizers can significantly enhance yield and yield-related traits. The objective of this research was to assess how nitrogen fertilizers and Bio-fertilizers affect yield and yield components of two wheat cultivars when cultivated in clay loam soil in the North Nile Delta.

MATERIALS AND METHODS

The experiments were conducted in 2021/2022 and 2022/2023 seasons in the experiment farm Faculty of Agriculture, Kafer El-sheikh University in the North Delta region of Egypt and employed a split-split plot design with three replicates. The design included: (i) Two wheat cultivars (Sids 14 and Sakha 95) placed in the main plots, (ii) Four nitrogen fertilizer levels (25, 50, 75 and 100 kg N fed.$^{-1}$) in the sub-plots, and (iii) Two Bio-fertilizer treatments (with and without inoculation) containing *Azotobacter* sp. and *Azospirillum* sp. in the sub-sub plots. Mineral nitrogen was applied as Urea (46.5% N) with a split dose: 20% during sowing, 40% 25 days after sowing, and 40% 25 days later. Superphosphate (15.5% P_2O_5) was applied before sowing at 100 kg fed^{-1}, and potassium fertilizer, in the form of potassium sulfate (48% K_2O), was applied before sowing at 50 kg fed.$^{-1}$ during seedbed preparation. A Bio-fertilizer mixture of *Azotobacter* sp. and *Azospirillum* sp., with a concentration of 10^8 cfu mL^{-1}, was applied at a rate of one liter per 30 kg of grains. This Bio-fertilizer was sourced from the Bio-fertilizers Unit, General Organization of Agriculture Equalization Fund, Agricultural Research Centre, Giza, Egypt. The wheat grains were mixed with the Bio-fertilizer 24 hours before sowing in both two seasons and the mixed grains were protected from sunlight exposure. Wheat was sown at a density of 350 grains

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per square meter in plots with six rows, each 3.5 meters in length and spaced 0.2 meter apart. Plots were separated by 1 meter, with a 2.5-meter gap between blocks. After sowing, the field was promptly irrigated. All other agronomic practices, excluding those being studied, were uniformly maintained across all treatments. The following traits were recorded from each plot: plant height (cm), number of spikes meter^{-2}, number of grains spike^{-1}, 1000-grain weight, biological yield, grain yield, straw yield, harvest index and protein percentage. grain protein content (%) was measured using a seed analyzer (Zeltex, ZX9500; Japan). To determine grain yield (ton fed.$^{-1}$), biological yield (ton fed.$^{-1}$), and straw yield (ton fed.$^{-1}$), an area of three-square meters was harvested from the center of each plot to minimize edge effects. The wheat cultivars used in the study included Sids 14 and Sakha 95. The name and pedigree of the cultivars are presented in Table (1). Soil samples were taken at random from the experimental site at a depth of 0 to 30 cm from the soil surface, some physical and chemical properties were illustrated in Table (2).

Chlorophyll pigments: Chlorophyll pigment concentrations (Chl. a, b and total Chl.; µg cm^{-2}) were assessed using fresh wheat flag leaves. After 65 days from sowing, two square centimeters of the flag leaf blade were collected. In the laboratory, pigments were extracted from the samples using 5 ml of N-N dimethyl formamide and stored overnight in the dark at 4°C. The absorbance of the extracts was measured with a spectrophotometer at wavelengths of 664 nm and 647 nm, according to the method was described by Moran (1982).

Statistical analysis: All data collected over the two seasons were analyzed using analysis of variance, with treatment means compared using the Duncan test (1955). Statistical analysis was conducted using the "MSTAT-C" software package (1990).

Table 1 : Pedigree and history of wheat cultivars

Cultivar	Pedigree and selection history
Sids 14	BOW "S" / VEE"S" // BOW"S" / TSI/3/ BANI SEWEF1 SD293 1SD-2SD-4SD-0SD
Sakha 95	PASTOR // SITE / MO /3/ CHEN / AEGILOPS SQUARROSA (TAUS) // BCN /4/ WBLL1. CMA01Y00158S-040POY-040M-030ZTM-040SY-26M-0Y-0SY-0S.

Table 2 : Some physical and chemical soil properties (0-30 cm)

Properties	2021/22	2022/23
Sand (%)	18.1	16.8
Silt (%)	42.1	42.6
Clay (%)	39.8	40.6
Texture	Clay loam	Clay loam
$CaCO_3$ (%)	2.17	1.48
pH (1:2.5 suspension)	8.2	8.5
Organic matter (g kg^{-1})	1.51	1.48
Available nitrogen (mg kg^{-1})	19.49	20.21
Available Olsen P (mg kg^{-1})	11.1	12
Available-K (mg kg^{-1})	498	466
Ec (dS/m)	3.5	4

RESULTS AND DISCUSSION

A-Varietal differences of wheat cultivars: Data from Tables 3, 4 and 5 revealed that between the wheat cultivars studied, Sakha 95 was the tallest and most productive. It reached heights of 110.2 cm and 102.8 cm in the two growing seasons, respectively. Sakha 95 also exhibited the highest number of fertile tillers meter^{-2}, 1000-grain weight and number of grains spike^{-1}, with values of 347.2 and 365.6 tillers meter^{-1}, 33.5 and 39.9 grams in the first and second seasons, respectively and 50.3 grains spike-1 in the first season (Table 3). Additionally, Sakha 95 revealed the highest values for biological yield, grain yield, straw yield with values of (13.730, 15.184, 3.177-, 3.324-, 10.554-, and 11.860-ton fed.$^{-1}$) in both two seasons, respectively. Although Sids 14 had a higher harvest index (24.88%) in the second season (Table 4). Sakha 95 also exhibited superior protein percentages in both seasons, with values of 12.9% and 13.2%. It recorded chlorophyll concentrations of 18.1 µg cm^{-2} for chlorophyll a, 7.2 µg cm^{-2} for chlorophyll b, and 24.7 µg cm^{-2} for total chlorophyll (a+b) in the first season and 26.1 µg cm^{-2} for total chlorophyll in the second season, as detailed in Table 5. These observations indicate that the variations among wheat genotypes are likely due to the genetic makeup of the cultivars. These results are consistent with earlier studies by El-Hag (2011), Omar *et al.,* (2014), Dalia and Shahein (2017), Rehman *et al.,* (2017), Gomaa *et al.,* (2018), Nehal (2018), Mahato and Kafle (2018), Abdel-Moneam *et al.,* (2021), Gawhara *et al.,* (2022), Alkasem *et al.,* (2023), Dalia (2023) and Dalia *et al.,* (2024).

B-Effect of nitrogen fertilizer: According to data in Table 3, increasing nitrogen fertilizer rates from 25 kg N fed.$^{-1}$ to 100 kg N fed.$^{-1}$ led to significant improvements in plant height, number of fertile tillers meter^{-2} and 1000-grain weight, with increases i.e. 8.7%, 14.5%, 33.0%, 26.6%, 26.1%, and 23.7% in both growing seasons compared to the lowest rate of 25 kg N fed.$^{-1}$. The application of 75 and 100 kg N fed.$^{-1}$ resulted in the highest number of grains spike^{-1} in the first season. Increasing nitrogen rate up to 100 kg N fed.$^{-1}$ enhanced the number of grains spike^{-1} by 15.5% and 29.1% to both seasons, respectively (Table 3). Additionally higher nitrogen levels significantly boosted biological yield, grain yield and straw yield, with recorded values of 13.922- and 14.691-tons fed.$^{-1}$, 3.180 and 3.233 tons fed.$^{-1}$, and 10.742 and 11.458 tons fed.$^{-1}$ in both seasons. The highest harvest index values were observed by 25 kg N fed.$^{-1}$ (24.23% and 25.23% in both seasons) and 75 kg N fed.$^{-1}$ (24.17%) in the first season (Table 4). Table 5 reveals notable differences in protein percentage, chlorophyll a, chlorophyll b and total chlorophyll a+b across various nitrogen fertilizer rates in both seasons. The highest protein percentages were achieved with appliying100 kg N fed.$^{-1}$, reaching 13.3% and 13.4% in the two seasons, respectively. Similarly, 100 kg N fed.$^{-1}$ resulted in the highest levels of chlorophyll a, chlorophyll b and total chlorophyll a+b, with values of 18.2 µg cm^{-2}, 18.9 µg cm^{-2}, 8.02 µg cm^{-2}, 8.8 µg cm^{-2}, 26.16 µg cm^{-2} and 27.6 µg cm^{-2} in both seasons. Conversely, while 75 kg N fed.$^{-1}$ also increased chlorophyll a, chlorophyll b and total chlorophyll a+b, the differences were not significant compared to 100 kg N fed.$^{-1}$, with recorded values of 17.7 µg cm^{-2}, 18.3 µg cm^{-2}, 7.69 µg cm^{-2}, 8.4 µg cm^{-2}, 25.3 µg cm^{-2} and 26.7 µg cm^{-2}.

Table 3: Means of plant height, number of fertile tillers m^{-2}, 1000 grain weight and number of grain spike^{-1} as affected by Wheat cultivars, Nitrogen fertilizer rates, Bio-fertilizer treatments and their interaction in 2021/22 and 2022/23 growing seasons.

Trait	Plant height (cm)		No fertile tillers m^{-2}		1000-grain weight		No. grain spike^{-1}	
Year	2021/22	2022/23	2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
				Cultivars (C)				
Sids 14	103.7	85.2	300.9	334.6	30.9	37.9	42.3	50.2
Sakha 95	110.2	102.8	347.2	365.6	33.5	39.9	50.3	53.5
F test	**	**	*	**	**	**	*	NS
				Nitrogen fertilizer rates kg N fed.$^{-1}$ (N)				
25 kg N fed.$^{-1}$	102.3d	87.8d	275.1c	292.8d	28.3d	33.7c	42.4c	44.6c
50 kg N fed.$^{-1}$	105.9c	91.3c	309.2b	337.9c	31.6c	39.8b	46.2b	52.3b
75 kg N fed.$^{-1}$	108.3b	96.4b	345.8a	371.1b	33.2b	40.6b	47.7ab	53.0b
100 kg N fed.$^{-1}$	111.3a	100.5a	366.1a	398.7a	35.7a	41.7a	49.0a	57.6a
F test	**	**	**	**	**	**	**	**
				Bio- fertilizer treatments (Bio.)				
Inoculation	109.5	95.7	337.8	366.7	32.9	42.6	48.6	56.0
Control	104.4	92.3	310.3	333.6	31.5	35.3	44.0	47.7
F test	**	**	**	**	**	**	**	**
				Interaction				
C x N	*	*	NS	NS	NS	NS	NS	NS
C x Bio.	**	*	*	**	**	**	**	NS
N x Bio.	NS	*	NS	**	NS	**	*	**
C x N x Bio.	NS	NS	NS	**	NS	**	NS	NS

*, **and NS indicated significant at P<0.05, P<0.01 and not significant, respectively.

The increase in growth and yield due to nitrogen fertilizer application can be attributed to nitrogen's crucial role as a constituent of nucleotides, proteins, chlorophyll and enzymes. These elements are integral to various metabolic processes that significantly influence both the vegetative and reproductive phases of plants. An optimal fertilizer dose i.e 125 kg N ha^{-1} was identified for wheat production, specifically for the 'Raj 3077' cultivar. Thus, effective nitrogen management is essential for optimizing wheat production and nitrogen nutrition should be integrated into a broader management approach that considers the significance of additional nutrients. These results are consistent with those reported by Namvar and Khandan (2013), Zaki *et al.* (2016), Hassanein *et al.* (2018), Gomaa *et al.* (2018), Nehal (2018), Hadwan *et al.* (2019), Nagwa *et al.* (2019), Gawhara *et al.* (2022) and Gajraj *et al.* (2023). These studies collectively emphasize the critical role of nitrogen in enhancing wheat yield and quality, supporting the need for precise nitrogen management in agricultural practices.

Thus, it could be concluded that managing nitrogen is crucial for enhancing wheat yields, and nitrogen nutrition should be integrated into a management plan that also emphasizes the value of other nutrients. These findings align with the studies conducted by Namvar and Khandan (2013), Zaki *et al.* (2016), Hassanein *et al.* (2018), Gomaa *et al.* (2018), Nehal (2018), Hadwan *et al.* (2019), Nagwa *et al.* (2019), Gawhara *et al.* (2022) and Gajraj *et al.* (2023).

C-Effect of bio fertilizer inoculation: Analysis of variance revealed that the application of Bio-fertilizer had a significant impact, leading to improvements all measured traits across both seasons. The Bio-fertilizer treatment enhanced plant height to 109.5 cm and 95.7 cm, showing a 4.3% increase and raised the number of fertile tillers meter^{-2} to 337.8 and 366.7, an increase of 9.4%. Additionally, it improved 1000-grain weight to be 32.9 g and 42.6 g, a 12.6% increase, and the number of grains spike^{-1} to be 48.6 and 56.0, marking a 16% rise. Biological yield reached 14.205 tons fed.$^{-1}$ and 14.809 tons fed.$^{-1}$, while grain yield was 3.234 tons fed.$^{-1}$ and 3.291 tons fed.$^{-1}$ and straw yield was 10.971 tons fed.$^{-1}$ and 11.518 tons fed.$^{-1}$. The harvest index for untreated plots was highest at 24.7% and 24.1% in the two seasons, respectively. The protein percentage increased to be 12.5% and 12.6%, chlorophyll a to 17.6 and 18.2, chlorophyll b to 7.1 and 7.9, and the combined chlorophyll (a+b) to 24.7 and 26.1 for two growing seasons, respectively. These results are consistent with findings of Namvar and Khandan (2013), Packialakshmi and Aliya (2014), Tamoor and Bano (2016), Zaki *et al.* (2016), Rehman *et al.* (2017), Hassanein *et al.* (2018), Mahato and Kafle (2018), Gawali *et al.* (2018), Nehal (2018), Deepa and Suruchi Tyagi (2019), Nagwa *et al.* (2019), Gawhara *et al.* (2022) and Gajraj *et al.* (2023).

Table 4: Means of biological yield, grain yield, straw yield and harvest index % as affected by Wheat cultivars, Nitrogen fertilizer rates, Bio-fertilizer treatments and their interaction in 2021/22 and 2022/23 growing seasons

Traits	Biological yield (ton fed.$^{-1}$)		Grain yield (ton fed.$^{-1}$)		Straw yield (ton fed.$^{-1}$)		Harvest index %	
year	2021/22	2022/23	2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
				Cultivars (C)				
Sids 14	12.123	11.601	2.94	2.856	9.183	8.745	24.34	24.88
Sakha 95	13.73	15.184	3.177	3.324	10.554	11.86	23.34	22.09
F test	*	**	**	**	*	**	NS	*
				Nitrogen fertilizer rates kg N fed.$^{-1}$(N)				
25 kg N fed.$^{-1}$	12.192bc	11.725c	2.934d	2.933bc	9.258bc	8.792c	24.23a	25.23a
50 kg N fed.$^{-1}$	12.757bc	13.006b	3.024c	3.031b	9.733bc	9.975b	23.92b	23.83b
75 kg N fed.$^{-1}$	12.836b	14.148ab	3.094b	3.165ab	9.742b	10.983ab	24.17a	22.58c
100 kg N fed.$^{-1}$	13.922a	14.691a	3.18a	3.233a	10.742a	11.458a	23.02c	22.3d
F test	**	**	**	**	**	**	*	* *
				Bio-fertilizer treatments (Bio.)				
inoculation	14.205	14.809	3.234	3.291	10.971	11.518	22.8	22.2
Control	11.649	11.976	2.882	2.891	8.767	9.086	24.7	24.1
F test	**	**	**	**	**	**	*	**
				Interaction				
C x N	NS	*	**	**	*	*	*	*
C x Bio	**	**	NS	*	**	*	*	NS
N x Bio	NS	NS	NS	NS	*	NS	*	NS
C x N x Bio.	**	NS	*	*	*	NS	*	NS

*, **and NS indicated significant at P<0.05, P<0.01 and not significant, respectively.

Interaction effects:

D-1- Interaction between wheat cultivars and nitrogen fertilizer rates: Data in Table 6 shows that interaction between wheat cultivars and nitrogen fertilizer significantly influenced all yield characteristics across both seasons, with grain yield being highly significant and biological yield significant only in the second season. According to the data presented in Table 6, optimal treatment for increasing plant height, biological yield, grain yield, straw yield, and chlorophyll a+b was Sakha 95 with 100 kg N fed.$^{-1}$. Conversely, most effective treatment for harvest index was Sids 14 with 25 kg N fed.$^{-1}$ These findings are consistent with the results reported by Zaki *et al.* (2016).

D-2- Interaction between wheat cultivars and Bio-fertilizer inculcation: Table 7 illustrates the impact of the interaction between wheat cultivars and Bio-fertilizer on various traits across both seasons. This includes plant height, number of fertile tillers meter^{-2}, 1000-grain weight, biological yield and straw yield. Additionally, the effect on the number of grains spike^{-1} and harvest index was observed in the first season, while grain yield was noted in the second season. Inoculation with Sakha 95 consistently resulted in the highest values for these characteristics. These findings suggest that Bio-fertilizer application significantly boosts growth and yield parameters in wheat cultivars, particularly Sakha 95. The interaction between cultivar and Bio-fertilizer enhances plant height, increases the number of fertile tillers, improves 1000-grain weight, raises the number of grains spike^{-1} and yields greater biological and straw outputs. The highest grain yield and harvest index observed in the first season underscore the beneficial effects of Bio-fertilizer on wheat production.

Table 5: Means of protein %, chlorophyll a, chlorophyll b and chlorophyll a+b as affected by Wheat cultivars, Nitrogen fertilizer rates, Bio-fertilizer treatments and their interaction in 2021/22 and 2022/23 growing seasons.

Trait	Protein%		chlorophyll a		Chlorophyll b		chlorophyll a+b	
Year	2021/22	2022/23	2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
				Cultivars (C)				
Sids 14	11.5	11.5	16.8	17.4	6.8	7.5	23.6	24.9
Sakha 95	12.9	13.2	17.5	18.1	7.2	8	24.7	26.1
F test	**	**	NS	*	*	*	*	*
				Nitrogen fertilizer rate kg N fed.$^{-1}$(N)				
25 kg N fed.$^{-1}$	11.3d	11.6c	15.9c	16.7b	5.81c	6.6b	21.72c	23.3b
50 kg N fed.$^{-1}$	11.7c	11.7c	16.8b	17.3b	6.56b	7.2b	23.30b	24.5b
75 kg N fed.$^{-1}$	12.4b	12.7b	17.7a	18.3a	7.69a	8.4a	25.33a	26.7a
100 kg N fed.$^{-1}$	13.3a	13.4a	18.2a	18.9a	8.02a	8.8a	26.16a	27.6a
F test	**	**	**	**	**	**	**	**
				Bio fertilizer treatments (Bio.)				
Inoculation	12.5	12.6	17.6	18.2	7.1	7.9	24.7	26.1
Control	11.9	12.1	16.7	17.4	6.8	7.6	23.6	24.9
F test	**	**	**	**	NS	NS	NS	*
				Interaction				
C x N	NS	NS	NS	NS	NS	NS	*	*
C x Bio.	NS	NS	NS	NS	NS	NS	NS	NS
N x Bio.	NS	NS	NS	NS	NS	NS	NS	NS
C x N x Bio.	**	NS	NS	NS	NS	NS	NS	NS

*, **and NS indicated significant at P<0.05, P<0.01 and not significant, respectively.

D-3- Interaction between nitrogen and Bio-fertilizer inculcation: The interaction between nitrogen fertilization and Bio-fertilizer inoculation significantly affected plant height and was highly significant for the number of tillers meter^{-1} and 1000-grain weight in the second season. It was also significant for straw yield and harvest index in the first season and for the number of grains spike^{-1} in both seasons. Applying 100 kg N fed.$^{-1}$ with inoculation produced the highest values for most traits, with the exception of the harvest index. The highest harvest index of 25.2% was observed with the application of 50 kg N fed.$^{-1}$ without inoculation, as shown in Table (8). Kandil *et al.* (2011) reported a notable increase in plant height, number of grains spike^{-1}, grain weight, grain yield and straw yield in wheat plants inoculated with *Azospirillum* sp. and *Azotobacter* sp. compared to non-inoculated controls. Similarly, Piccinin *et al.* (2013) found that combining chemical fertilizers with the microbial strains *Azotobacter* sp. and *Azospirillum* sp. improved plant growth parameters and yield components in wheat.

D-4- Interaction between wheat cultivars, nitrogen fertilizer and Bio-fertilizer inculcation: Table 9 presents the effects of the interaction between wheat cultivars, nitrogen fertilizer rates and Bio-fertilizer treatments on various traits. These traits include the number of tillers meter^{-2}, 1000-grain weight in the 2022/23 season, biological yield in the first season, grain yield in both seasons, straw yield, harvest index and protein percentage in the 2021/22 season. Sakha 95 treated with 100 kg N fed.$^{-1}$ and Bio-fertilizer achieved the highest values for most traits. However, the harvest index was highest with Sakha 95 at 25 kg N fed.$^{-1}$ without Bio-fertilizer. The combination of 100 kg N fed.$^{-1}$ or 75 kg N fed.$^{-1}$with Bio-fertilizer resulted in enhanced grain yield values. Hassanein *et al.,* (2019) found significant interactions between nitrogen rates, Bio-fertilizers and foliar treatments with urea for all attributes examined across two seasons.

Table 6: Mean of plant height, biological yield, gain yield, straw yield and chlorophyll a+b as affected by interaction between Wheat cultivars and Nitrogen fertilizer rates in 2021/22 and 2022/23 seasons

Characters		**Plant height (cm)**		**Biological yield (ton fed.$^{-1}$)**	**Grain yield (ton fed.$^{-1}$)**	
Season		2021/22	2022/23	2022/23	2021/22	2022/23
Sids 14	25 kg N fed.$^{-1}$	99.8g	77.7f	10.694g	2.843e	2.765ef
	50 kg N fed.$^{-1}$	102.4f	82.0e	10.829f	2.906d	2.795e
	75 kg N fed.$^{-1}$	105.2e	87.5d	12.116e	2.977d	2.883cd
	100 kg N fed.$^{-1}$	107.4d	93.5c	12.766d	3.033c	2.983c
Sakha95	25 kg N fed.$^{-1}$	104.7e	98.0b	12.755d	3.026c	3.100bc
	50 kg N fed.$^{-1}$	109.4c	100.5b	15.184c	3.142b	3.268b
	75 kg N fed.$^{-1}$	111.4b	105.3a	16.181b	3.210b	3.448ab
	100 kg N fed.$^{-1}$	115.2a	107.5a	16.616a	3.327a	3.483a
F test		*	*	*	**	**

Characters		Straw yield (ton fed.$^{-1}$)		Harvest index%		chlorophyll a+b	
Season		2021/22	2022/23	2021/22	2022/23	2021/22	2022/23
Sids 14	25 kg N fed.$^{-1}$	8.384e	7.929d	25.3a	26.0a	21.1d	22.5e
	50 kg N fed.$^{-1}$	9.167f	8.034g	24.1b	26.0a	22.6c	23.7de
	75 kg N fed.$^{-1}$	9.484e	9.234f	24.0b	23.9bc	24.7b	26.1abc
	100 kg N fed.$^{-1}$	9.700d	9.784de	24.0b	23.7c	26.0a	27.5ab
Sakha95	25 kg N fed.$^{-1}$	10.134c	9.655e	23.2cd	24.5b	22.4c	24.0cde
	50 kg N fed.$^{-1}$	10.300b	11.917c	23.8c	21.7d	24.1b	25.3b-d
	75 kg N fed.$^{-1}$	10.000cd	12.734b	24.4b	21.3d	26.0a	27.3ab
	100 kg N fed.$^{-1}$	11.784a	13.134a	22.1d	21.0e	26.3a	27.8a
F test		*	*	*	*	*	*

*, ** indicated significant at $P<0.05$, $P<0.01$, respectively.

Table 7: Mean of plant height, number of fertile tillers, 1000 grain weight in the first and second season, number of grain spike^{-1} in the first season, biological yield in both seasons, grain yield in the second season, straw yield in both seasons and harvest index in the first season, as affected by interaction between Wheat cultivars and Bio-fertilizer

cultivars	**treatment**	**plant height**		**Number of tillers m^{-2}**		**1000- grain weight**		**Number of grain spike^{-1}**
Season		2021/22	2022/23	2021/22	2022/23	2021/22	2022/23	2021/22
Sids 14	inoculation	105.1c	105.1c	345.3b	365.9b	42.5b	38.58c	38.58c
	control	102.3d	100.8d	336.8b	343.4c	35.9d	37.2d	37.2d
Sakha 95	inoculation	113.9a	113.7a	371.7a	397.5a	46.3a	43.42a	43.42a
	control	106.5b	106.6b	349.3b	365.3b	36.8c	40.92b	40.92b
F test		**	*	*	**	**	**	**

		Biological Yield ton fed.$^{-1}$		Grain yield ton fed.$^{-1}$	Straw yield ton fed.$^{-1}$		HI %
Season		2021/22	2022/23	2022/23	2021/22	2022/23	2021/22
Sids 14	inoculation	12.992b	13.045c	3.045b	9.942b	10.000c	24.0a
	control	11.255d	10.157d	2.667c	8.425d	7.489d	24.0a
Sakha95	inoculation	15.418a	16.572a	3.536a	12.000a	13.036a	23.2c
	control	12.043c	13.796b	3.113b	9.108c	10.684b	23.8b
F test		**	**	*	**	*	*

*, ** indicated significant at $P<0.05$, $P<0.01$, respectively.

Table 8: Mean of plant height, number of tillers m^{-2}, 1000 grain weight, number of grain spike^{-1}, straw yield and harvest index as affected by interaction between Nitrogen fertilizer rates and Bio-fertilizer treatments in 2021/22 and 2022/23 seasons

Treatment		Plant height	No. tillers m^{-2}	1000grain weight	No. grain spike^{-1}		Straw yield ton fed.$^{-1}$	Harvest index
Season		2022/23	2022/23	2022/23	2021/22	2022/23	2021/22	2021/22
25kg N fed^{-1}	Inoculation	89.0e	300.2f	35.8d	44.9d	47.0d	10.084d	23.75d
	Control	86.7f	285.5g	31.6e	39.8e	42.2e	8.4335f	24.70b
50kg N fed^{-1}	Inoculation	93.5d	343.7de	43.5c	47.5c	56.2b	11.000b	22.65f
	Control	89.0e	332.2e	36.0d	44.8d	48.3d	8.466f	25.20a
75kg N fed^{-1}	Inoculation	97.5b	392.0b	44.5b	49.8b	57.2b	10.700c	23.35e
	Control	95.3c	350.2d	36.7d	45.6cd	48.8d	8.783ef	25.00ab
100kg N fed^{-1}	Inoculation	102.7a	430.8a	46.5a	52.3a	63.8a	12.100a	21.80g
	Control	98.3b	366.5c	36.8d	45.6cd	51.3c	9.383e	24.25c
F test		*	**	**	*	**	*	*

*, **and indicated significant at P<0.05, P<0.01, respectively.

Table 9: Mean of number of tillers m^{-2}, 1000 grain weight, biological yield, straw yield, harvest index and protein% as affected by interaction between Wheat cultivars, Nitrogen fertilizer rates and Bio-fertilizer treatments in 2021/22 and 2022/23 seasons.

Treatments			No tillers m^{-2}	1000 grain weight	Biological yield ton fed.$^{-1}$	Grain yield ton fed.$^{-1}$		Straw yield ton fed.$^{-1}$	Harvest index	Protein %
			2022/23	2022/23	2021/22	2021/22	2022/23	2021/22	2021/22	2021/22
Sids 14	25 Kg N fed.$^{-1}$	Inoculation	288.7j	35.3g	11.523h	2.956j	2.940i	8.567h	31.0g	10.9i
		Control	269.7k	30.8i	10.930k	2.730o	2.590n	8.200i	36.0b	10.3j
	50 kg N fed.$^{-1}$	Inoculation	330.0gh	41.7d	12.753g	3.020h	2.980h	9.733e	33.0e	11.3h
		Control	318.3hi	35.0g	11.392j	2.792n	2.610m	8.600h	34.0d	10.2j
	75 kg N fed.$^{-1}$	Inoculation	367.7b	42.3d	13.657e	3.090f	3.040g	10.567e	35.0c	12.1f
		Control	343.0fg	37.3ef	11.264	2.864m	2.725l	8.400g	36.0b	11.5gh
	100 kg N fed.$^{-1}$	Inoculation	395.0c	45.0c	14.035d	3.135e	3.220f	10.900d	33.0e	12.8d
		Control	364.7de	36.0fg	11.432i	2.932k	2.745k	8.500g	32.0f	12.5e
Sakha 95	25Kg N fed.$^{-1}$	Inoculation	311.7hi	36.3efg	14.852c	3.252d	3.355c	11.600c	30.0h	12.4e
		Control	301.3ij	32.3h	11.467i	2.800n	2.845j	8.667g	37.0a	11.6g
	50 kg N fed.$^{-1}$	Inoculation	357.3def	45.3bc	15.645b	3.378c	3.495b	12.267b	34.0d	12.8d
		Control	346.0efg	37.0ef	11.239j	2.906l	3.040g	8.333i	36.0b	12.4e
	75 kg N fed.$^{-1}$	Inoculation	416.3b	46.7ab	14.269d	3.536ab	3.645a	10.833d	34.0d	13.3c
		Control	357.3def	36.0fg	12.152h	2.985i	3.250e	9.167f	35.0c	12.8d
	100 kg N fed.$^{-1}$	inoculation	466.7a	48.0a	16.907a	3.607a	3.650a	13.300a	31.0g	14.3a
		control	368.3d	37.7e	13.313f	3.046g	3.315d	10.267e	31.0g	13.6b
	F test		**	**	**	*	*	*	*	**

*, ** and; significant, highly significant.

CONCLUSION

It is notable that increasing nitrogen fertilization and using Bio-fertilizers enhance yield components and overall yield. Uses 75 or 100 kg N with inoculation achieved the greatest grain yield with Sakha 95 Therefore, it is advisable to use both organic and inorganic fertilizers to maximize yield while maintaining grain quality and safeguarding the environment. This integrated approach ensures optimal nutrient availability, promotes sustainable agricultural practices and supports environmental health.

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تعظيم انتاجية القمح باستخدام الاسمدة النيتروجينية والحيوية في شمال دلتا النيل

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المستخلص : أجريت تجربة حقلية خلال عامي 2021/ 2022 و 2022/ 23 في تربة طينية في مزرعة قسم المحاصيل بكلية الزراعة جامعة كفر الشيخ – مصر لبحث تأثير معدل السماد النيتروجين والسماد الحيوي على صفات المحصول ومكوناته ومحتوى البروتين في صنفين من القمح . (*Triticum aestivum* L.) استخدم تصميم القطع المنشقة مرتين في قطاعات كاملة العشوائية في ثلاث مكررات. كانت العوامل التجريبية: صنفان (سدس 14 وسخا 95) و أربعة مستويات من سماد النيتروجين المعدني (25 ، 50 ، 75 ، 100 كجم نتروجين للفدان) و مستويين من السماد الحيوي (التلقيح بـ *Azospirillum sp*. *Azotobacter sp* وبدون تلقيح = كنترول) وزعت الاصناف توزيع عشوائي في القطع الرئيسية ووزعت مستويات التسميد المعدني في القطع المنشقة الاولى والتسميد الحيوي في القطع المنشقة الثانية وأوضحت النتائج أن أعلى محصول من القمح ومكوناته ومحتوى البروتين في الحبوب سجل بواسطة الصنف سخا 95 مقارنة بالصنف سدس14 و ارتبط المحصول ومكوناته ارتباطًا وثيقًا بالتسميد بالنيتروجين والتلقيح الحيوي. استخدام معدل التسميد بالنيتروجين المرتفع والسماد الحيوي *Azotobacter sp*. و *Azospirillum sp*. زاد معنويا كلا من متوسط ارتفاع النبات (105.9 ، 102.6سم) ، عدد السنابل / متر المربع (382.4 و 358.3) ، عدد الحبوب / السنبلة (4638 و52.3) ، وزن 1000 حبة (38.7 و 37.8) ، محصول الحبوب (3.18 و 3.233 طن / فدان) ، المحصول البيولوجي (13.922 و 14.691 طن / فدان) ، الكلوروفيل أ + ب (26.88 و 25.4) ومحتوى بروتين الحبوب (13.35٪ و 12.55٪). ومن النتائج السابقة يتبين أن زيادة التسميد النيتروجيني مع استخدام الأسمدة الحيوية يؤدى الى زيادة المحصول ومكوناته. توصى الدراسة بتسميد القمح (صنف سخا 95) بالسماد النيتروجيني بمعدل 75–100 كجم نيتروجين / فدان مع المعاملة بالتسميد الحيوي وذلك تحت ظروف محافظة كفرالشيخ منطقة شمال الدلتا، مصر .