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Effect of Bio and Mineral Nitrogen Fertilization on the Quality and Storability of Three Onion Cultivars Under Arid Region Conditions

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Abstract

This study was conducted at the Research Experimental Farm of the Faculty of Agriculture and Natural Resources, Aswan University, Aswan**,** Egypt, during two successive seasons 2022–2023 and 2023–2024. It assessed the combined effects of nitrogen fertilization and biofertilizer inoculation on quality, and storability performance of three Egyptian onions (*Allium cepa* L.) cultivars:-(Giza 6 Mohassan, Giza Red, and Giza White), grown under sandy soil conditions. Five diazotrophic bacterial strains (*Enterobacter cloacae, Sphingomonas paucimobilis, Bacillus licheniformis* (k.95), *Bacillus licheniformis*(ECto3), Mixture of bacterial strains) and three nitrogen levels (50%, 75%, and 100% % dose of N) were evaluated. The integration of strain (*Bacillus licheniformis* (ECto3)) with 100 % dose of N resulted in the highest accumulation of NPK elements in onion bulbs. Giza White recorded the highest dry weight, total soluble solids, total sugars. Additionally, strain (Mixture of bacterial strains) combined with 50 % dose of N led to enhanced sugar accumulation and improved storage stability. Giza 6 Mohassan exhibited superior long-term storage performance, especially when combined with biofertilizer strains (*Bacillus licheniformis* (k.95)) or (Mixture of bacterial strains) and moderate nitrogen levels (50% or 75% dose of N). The results also revealed the superiority of the Giza 6 Mohassan cultivar in terms of vitamin C content. These findings highlight the potential of integrated fertilization strategies to improve onion quality, storability, nutrient uptake, bulb quality, and postharvest performance while reducing dependence on chemical nitrogen inputs.

Keywords: *Allium cepa* L.; Biofertilizers; Nitrogen levels; Bulb quality; Storage stability.

1. Introduction

Onions (*Allium cepa* L.) constitute a significant category of vegetable crops globally and are cultivated throughout the year due to their nutritional significance and diverse culinary applications **[1]**. Their origins can be traced back to Central Asia, with additional centers of domestication located in the Near East and the Mediterranean Basin **[2].** This species is classified within the genus Allium, which encompasses over 500 species, the majority of which are bulbous perennials. Egypt holds the position of the fourth largest exporter of onions worldwide, with an average annual output of 357.64 thousand tons, accounting for 8% of the total global area dedicated to onion cultivation **[3-4].** Onions serve as a vital source of economic revenue and employment, thereby contributing significantly to economic development **[5].** Onions are regarded as a nutritional asset due to the presence of phytochemical constituents such as polyphenols, flavonoids, and organic acids, which confer substantial health benefits **[6-7]**.

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In recent times, there has been a growing necessity to develop alternative approaches for the collection, processing, composting, and utilization of organic manures and biofertilizers such as Azotobacter, Azospirillum, Acetobacter, Rhizobium, Azolla, blue-green algae, and phosphate-solubilizing bacteria, all of which contribute significantly to enhancing soil fertility, During the early 1970s, chemical fertilizers particularly nitrogen (N), phosphorus (P), and potassium (K) played a crucial role in improving both the yield and quality of crops **[8].** However, in recent years, the excessive and unbalanced use of these chemical fertilizers has led to a range of adverse consequences, including the deterioration of soil fertility and health, the emergence of multiple nutrient deficiencies, and a decline in microbial activity. Collectively, these factors have resulted in reduced crop productivity and quality **[9].**

Biofertilizers are carrier-based inoculants containing cells of efficient strains of specific microorganisms, used by farmers to enhance soil fertility through N fixation, phosphate solubilization, or the stimulation of plant growth by synthesizing growth-promoting substances. They play a crucial role in the selective absorption of essential elements by plants. The use of biofertilizers is encouraged to reduce the reliance on chemical fertilizers and protect the environment **[10].** The utilization of PSB bio-fertilizers has been shown to elevate crop yields by an estimated range of 10 to 30%. Inoculation with Azospirillum facilitates enhanced vegetative development in plants while concurrently diminishing the dependence on N-based fertilizers by approximately 20-30%. The application of Azospirillum has a profound impact on nutrient uptake, thereby augmenting crop productivity through the enhancement of soil fertility. Bio-fertilizers not only furnish additional nutrients but also optimize the effectiveness of nutrients that have already been administered **[11].** Generally, biofertilizers can be adeptly employed on onion cultivars when environmental conditions are conducive to the specific type of fertilizer in use, yet the anticipated outcomes should remain pragmatic **[12].**

Nitrogen constitutes the predominant element in plant tissues in comparison to other mineral nutrients. It assumes a pivotal role in the synthesis of chlorophyll, proteins, amino acids, and various compounds that are indispensable for growth, photosynthesis, and metabolic processes. An adequate supply of N fosters root development and enhances the absorption of other nutrients **[13-14-15].** Elucidated that onion, being a plant with a shallow root system, possesses elevated N demands. Nonetheless, an overabundance of N results in accelerated growth, postponed maturation, heightened vulnerability to pest infestations, diminished dry matter content, truncated storage durations, and ultimately, a reduction in yield and quality. Conversely, in soils deficient in N, onions may display stunted growth and inferior bulb quality, culminating in a decline in yield and shelf life **[16].** The quantity of N administered to onion crops is contingent upon both the geographic region and the specific variety, with high-yielding cultivars generally necessitating greater N input than their low-yielding counterparts. Additionally, disparate climatic zones exhibit varied responses of onion crops to applied N **[17-18].** In certain locales, elevated N applications are requisite for enhancing yield and quality; however, substantial quantities of N remain in the soil post-harvest. According to **[19],** nearly 50% of the 120 kg ha^{-1} of N typically applied to onion fields is subject to leaching from the soil. Nitrogen is required in markedly greater amounts than most other nutrients. It is an essential constituent of proteins, enzymes, and vitamins in plants and acts as a fundamental element of chlorophyll, the critical molecule involved in photosynthesis **[20].**

2. Material and Methods

This investigation was conducted at the experimental farm of Faculty of Agriculture and Natural Resources, Aswan University, Aswan, Egypt, during the two winter seasons of 2022/2023 and 2023/2024 to study the effect of biofertilizers in reducing the requisite amounts of mineral fertilizers, while simultaneously analyzing their influence on the growth performance and qualitative attributes of three distinct onion cultivars (*Allium cepa L.;* cv. Giza 6 Mohassan (yellow), Giza Red, and Giza White). In advance of transplanting, random surface soil samples were systematically collected from diverse locations within the soil profile to a depth of 30 cm, with the objective of determining the physical and chemical characteristics of the soil, as delineated by **[21-22].** These attributes are presented in Table (1). The average maximum and minimum temperatures for Aswan governorate during agricultural months are presented in Table (2).

Table (1). Physical and chemical properties of the experimental site during both seasons of the experiment (2022/2023 and 2023/2024).

Soil propertyies *	Seasons	
	2022/2023	2023/2024
Physical properties		
Clay (%)	3.32	3.43
Silt (%)	0.00	0.00
Sandy (%)	96.44	95.49
Textural class	Sandy	Sandy
Chemical properties		
Soluble cations in (1:1) soil to water extract mmol/L)		
Ca^{++}	3.04	3.10
Mg^{++}	1.11	1.09
K^{+}	0.87	0.89
Na^{+}	0.79	0.82
Soluble anions in (1:1) soil to water extract(mmol/L)		
CO_3^{--}	0.00	0.00
HCO_3^{-}	7.13	7.17
Cl^{-}	3.60	3.66
SO_4^{--}	0.45	0.46
pH (1:1 soil suspension)	7.61	7.70
EC (ds/cm) at 25°C	0.30	0.35
Available N (mg/kg soil)	128.11	131.10
Available P (mg/kg soil)	9.41	10.01
Available K (mg/kg soil)	177.00	181.01

*The analyses were carried out at Soil Fertility Department, Faculty of Agriculture Aswan, University.

Table (2). The average maximum and minimum temperatures during agricultural months.

Month	Air temperature [°C]			Air temperature [°C]		
	Max.	Min.	x^{-}	Max.	Min.	x^{-}
	2022/2023			2023/2024		
1-15 Dec.	28.49	11.259	19.87	29.77	14.13	21.95
16-31 Dec.	26.33	10.713	18.52	27.47	12.28	19.88
1-15 Jan.	23.70	7.783	15.74	26.26	10.80	18.53
16-31 Jan.	28.15	10.391	19.27	24.49	8.63	16.56
1-15 Feb.	23.57	8.351	15.96	25.46	8.55	17.01
16-28 Feb.	26.79	9.743	18.27	27.55	11.88	19.72
1-5 Mar.	34.20	13.680	23.94	33.15	15.56	24.36
15-31 Mar.	31.50	16.398	23.95	32.56	14.17	23.36
1-15 Apr.	35.14	19.815	27.48	35.93	18.41	27.17
15-30 Apr.	38.76	19.690	29.23	40.33	20.53	30.43
1–15 May	38.84	11.259	19.87	29.77	14.13	21.95

2.1 Agricultural practices

The seeds were sown in the nursery on the 1st of October (cultivars Giza 6 Mohassan, Giza Red, and Giza White), during which time the experimental field underwent plowing and pulverization. Subsequently, the seedlings were transplanted from the nursery after a period of 45 days, specifically on November 15th, into the open field utilizing a drip irrigation system.

2.2 The experimental treatments

Onion Cultivars

Three colored genotypes of onion cv. namely " Giza 6 Mohassan (yellow) ", “Giza Red” and “Giza White " were used in this study. These cultivars were obtained from the Agricultural Research Center (ARC).

Chemical N-Fertilizers

Three levels of nitrogen fertilization (50%, 75%, and 100% N of the recommended dose) were applied in the experiment, in the form of ammonium nitrate.

*Onion plants require 90 to 120 units of nitrogen per feddan, according to the recommendations of the Agricultural Research Center.

Bacterial strains

One strain (*Enterobacter coleace*) isolated from Fac. of Energy Engenering, Aswan university and other Three strains (*Sphinogomonas paucimobilis*, *Bacillus licheniformis* (k.95), *Bacillus licheniformis* (ECto3) obtained via the Environmental Studies and Research Unit (ESRU), Fac. of Agri., Cairo Univ. These strains were assessed for plant growth-promoting substances (PGPR) characteristics, including acetylene-reducing activity (83.77-497.8 nmoles/hr./culture), IAA (2.81 – 9.91), and solubilization of phosphate (1.6-2.37 PSI) and potassium (3.36 KSI).

Bio fertilizers Inocula

A variety of diazotrophs was used for inoculating onion plants grown at experimental farm of Faculty of Agriculture and Natural Resources, Aswan University. Four associative N_2-fixing candidates; *Bacillus licheniformis*, *Sphinogomonas paucimobilis, Bacillus licheniformis 2 and Enterobacter coleace.* Liquid cultures of associative diazotrophs were separately grown in nutrient both with continuous shaking and/or aeration to obtain a population density of ca. 10^6 cell ml^{-1}. Each strain was 5 L diluted with 5 L well water as 1:1 ratio, to soak transplants roots for a 30 min. prior to seedlings.

0. *Control (Without bacterial inoculation 50 kg N only, 75 kg N only, 100 kg N only)*
1. *Enterobacter cloacae*
2. *Sphingomonas paucimobilis*
3. *Bacillus licheniformis* (k.95)
4. *Bacillus licheniformis* (ECto3)
5. Mixture of bacterial strains (1+2+3+4)

2.3 Experimental Layout

The experimental design was structured as a factorial arrangement within a Randomized Complete Block Design (RCBD) featuring three replications. The experiment included 54 treatments, consisting of three onion cultivars (Giza 6 Mohassan, Giza Red, and Giza White), three nitrogen fertilization levels (50%, 75%, and 100% of the recommended N dose), and five bacterial strains (control + strains1, strains2, strains3, strains4, and strains5), a total of 162 interaction combinations between cultivars, nitrogen fertilization levels, and bacterial strains were evaluated, in addition to a control. Each experimental unit comprised six rows, each measuring 8 meters in length and 0.80 meters in width, with onion plants spaced 10 cm apart within each row. In total 450 plants on average per unit experimental plot, 54 plots were established across the experiment. Irrigation and fertilization practices were applied in accordance with the recommendations of the Ministry of Agriculture.

2.4 Harvesting

Whole onion plants were harvested at 14th of May 2023 and 12th of May 2024, in the first and second seasons, respectively. Harvested onion bulbs were weighed immediately, and then were cured, for 30 days, in a clean, shaded, well-ventilated and dry room, at a temperature (25ºc ±2). After finishing the curing process, onion bulbs of each experimental unit were weighed.

2.5 Chemical analysis

1. Nitrogen analysis: total nitrogen was determined according to the khjeldahl method **[26].**
2. Phosphor analysis: phosphor measured using spectrophotometers by **[26].**
3. Potassium and calcium analysis: Potassium and calcium were determined by flame photometer **[26].**

2.6 Chemical bulb characteristics

Total soluble solid (T.S.S Brix)

The total soluble solids content (Brix) in onion bulbs was measured using a digital refractometer at harvest and after the curing period, according to the method of **[23]** Juice was extracted from three randomly selected bulbs per plot, and the T.S.S. percentage was determined by taking the average of the three readings.

Total and Reducing Sugars (%)

The total and reducing sugars were estimated using the volumetric method described by **[24]** The percentage of non-reducing sugars was calculated by subtracting reducing sugars from total sugars.

- Total sugars (%)
- Reducing sugars (%)

Non-reducing sugars (%) = Total sugars − Reducing sugars

Vitamin C (mg/100g FW)

Vitamin C content was determined by titrimetric estimation using 2,6 dichlorophenolindophenol, following the method described by **[25].**

2.7 Dry Weight Determination *(%)*

Three plants were randomly selected from each experimental unit. The onion bulbs were sliced and oven-dried at 70 °C until a constant weight was achieved. The dry weight (g) per plant was then recorded. For subsequent chemical analyses, accurately weighed portions of the dried tissue were used.

2.8 Weight loss (%)

After the completion of the curing process, onion bulbs from each experimental unit were weighed, packed in small nylon mesh bags, and stored under ambient room conditions. The weight of bulbs was recorded at the beginning and at the end of each storage interval (i.e., 30 days, and after 6, 7, 8, 9, and 10 months of storage). Weight loss (%) at each storage interval was calculated by subtracting the final bulb weight from the initial bulb weight, and the result was expressed as a percentage using the following formula:

$$Total\ weight\ loss\ \% = \frac{Original\ bulb\ weight - Remained\ bulb\ weight}{Original\ bulb\ weight} \times 100$$

2.9 Statistical Analysis

All collected data were statistically analyzed according to the Randomized Complete Block Design (RCBD) using the MSTAT-C software package **[27].** The treatment means were compared using Duncan's multiple range test at probability of 5% level according to **[28].**

3. Results and Discussion

Nitrogen

Based on cultivar type and integrated fertilization strategies that combine mineral nitrogen and biofertilizers, data in Tables (3) show notable differences in the nitrogen content of onion bulbs over the winter seasons of 2022–2023 and 2023–2024. Nitrogen buildup was significantly influenced by cultivar selection. In the first season, the Giza 6 Mohassan had the lowest nitrogen concentration (1.96%), while the Giza Red had the highest (2.40%), followed by the white (2.21%). The second season, however, saw a change in this pattern, with the Giza 6 Mohassan performing better than the others (3.27%), followed by the red (2.88%), and the Giza White exhibiting the lowest concentration (2.42%). These variations highlight how nitrogen absorption efficiency is impacted by genotype × environment interactions. Nitrogen levels were strongly impacted by fertilization treatments. The combined application of strain *B. licheniformis* (ECto3+ 100 % dose of N resulted in the greatest bulb nitrogen concentrations in both seasons, reaching up to 3.87%. Conversely, strain *Enterobacter cloacae* + 50 % dose of N in 2022/2023 and the control (0 + 50 % dose of N) in 2023/2024 showed the lowest values under limited input treatments. Given that bio-inoculants increase rhizosphere activity and root surface area, which facilitates better nitrogen uptake and assimilation, this trend highlights the synergistic advantages of combining biofertilizers with sufficient mineral nitrogen **[13].**

Data in Table (4) show that cultivar, nitrogen level, and biofertilizer strain all had statistically significant interaction effects. The Giza Red treated with strain *B. licheniformis*(ECto3) + 100 % does of N, which averaged between 3.41% and 4.55% in both seasons, notably had the highest nitrogen

content. The Giza 6 Mohassan under control conditions in 2022/2023 and the Giza White treated with strain *Enterobacter cloacae* + 50 % dose of N in 2023/2024, on the other hand, had the lowest nitrogen values (1.31%). These results demonstrate the higher nitrogen-use efficiency of specific cultivar-treatment combinations, the Giza Red in particular when combined with strain *B. licheniformis*(ECto3) and the entire nitrogen dose. The findings show how biofertilizers can improve nitrogen uptake, particularly in systems with fewer chemical inputs, and they also highlight the significance of cultivar specific fertilization techniques. these results are consistent with those obtained by **[29-30].**

Phosphorus estimation

According to the findings in Tables (3), during the winter seasons of 2022–2023 and 2023–2024, cultivar type, mineral nitrogen levels, and biofertilizer treatments all had a substantial impact on the amount of phosphorus in onion bulbs. The Giza Red had the highest phosphorus level (0.0023%) in the first season, while the Giza White and Giza 6 Mohassan cultivars had comparable but lower values (0.0018%). The Giza White, however, outperformed the others in 2023–2024, peaking at 0.0078%, followed by the Giza Red (0.0075%) and Giza 6 Mohassan (0.0071%) cultivars. The significance of choosing cultivars with higher phosphorus uptake efficiency under varied field conditions is highlighted by this seasonal shift, which highlights a potential genotype × environment interaction. Phosphorus levels in relation to fertilization responded significantly to comprehensive treatments. The maximum phosphorus content (0.0031%) was obtained in 2022/2023 when strain *S. paucimobilis* + 75 % dose of N was applied, while the most effective strain in 2023/2024 was strain *B. licheniformis*(ECto3**)** + 50 % dose of N (0.0015%). The lowest phosphorus concentrations, which ranged from 0.00048% to 0.0011%, were consistently obtained from the control treatment (0 + 50 % dose of N), underscoring the limited effectiveness of chemical nitrogen alone in the absence of microbial assistance. By solubilizing bound phosphorus in the rhizosphere through microbial mechanisms such phosphatase enzyme release and organic acid synthesis, biofertilizer strains especially strains *S. paucimobilis* and *B. licheniformis*(ECto3)**,** seem to increase phosphorus availability. Together with moderate nitrogen levels, these mechanisms promote root growth and raise the need for phosphorus, which leads to increased uptake and translocation into bulb tissues. However, too much nitrogen can inhibit microbial activity, while too little can increase the reliance of plants on microbes. These results are in agreement with the findings of **[11-31].**

Data in Table (4)illustrates the interaction among cultivars, mineral nitrogen fertilization, and biofertilization. Notably high phosphorus levels were recorded when these factors were combined. The Giza Red cultivar treated with strain *B. licheniformis*(ECto3) + 50 % dose of N obtained the greatest phosphorus content (0.00427%) in 2022/2023, while the Giza 6 Mohassan cultivar achieved a remarkable 0.0235% under the same treatment in 2023/2024. These interaction effects further elucidated cultivar specific responses. The Giza White cultivar, on the other hand, showed consistently low phosphorus levels in both seasons and treatments, particularly under the 0 + 50 % dose of N regime. This suggests that the cultivar is less susceptible to microbial inoculation and has a lower efficiency of nutrient absorption. As previously stressed by **[32-33],** these results highlight the significance of combining cultivar selection with suitable biofertilizer nitrogen strategies to

maximize phosphorus utilization, supporting the ideas of sustainable agriculture and improved nutrient use efficiency.

Potassium estimation

Data in Tables (3) shows that during the winter seasons of 2022–2023 and 2023–2024, the type of cultivar, the amount of nitrogen fertilization, and the use of biofertilizers all had a substantial impact on the potassium concentration in onion bulbs. The Giza 6 Mohassan cultivar had the greatest mean potassium concentration (2.59%) in the 2022–2023 season, closely followed by the Giza White cultivar (2.57%), while the Giza Red cultivar had the lowest amount (2.43%). It is noteworthy that this pattern changed during the 2023–2024 growing season, with the Giza Red cultivar exhibiting the greatest potassium content (3.21%), followed by the Giza 6 Mohassan (2.93%) and Giza White (2.86%) cultivars. These seasonal fluctuations highlight how important genotype by environment interactions are in influencing onion bulb nutrition accumulation. in terms of fertilization methods, the maximum potassium concentrations were consistently obtained in both seasons with the combined application of 50 % dose of N and biofertilizer strain *B. licheniformis* (k.95), with averages of 3.71% and 4.33% in 2022/2023 and 2023/2024, respectively. On the other hand, 2022/2023 0 + 50 % does of N treatment (1.47%) and 2023/2024 *S. paucimobilis* + 50 % dose of N treatment (2.11%) had the lowest results. These results demonstrate the vital role that microbial inoculants play in improving potassium uptake, especially when used in combination with modest doses of mineral nitrogen. Additionally, potassium content was greatly impacted by the interplay between cultivar, nitrogen level, and biofertilizer treatment.

Table (3). Averages values of N, P and K of onion plants as affected by cultivars, N mineral and N biofertilization during the winter seasons of 2022/2023 and 2023/2024.

Treatments	NPK estimation					
	Nitrogen.		Phosphorus		Potassium	
	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
cultivars						
Giza 6 Mohassan	1.96 b	3.27a	0.0018 b	0.0071a	2.59 a	2.93b
Giza Red	2.40 a	2.88b	0.0023 a	0.0075a	2.43 b	3.21a
Giza White	2.21 a	2.42c	0.0018 b	0.0078a	2.57 ab	2.86b
N biofertilization						
50%N+ without biofertilizers (0)	1.81 fg	2.27h	0.0011 g	4.87j	1.47 h	3.08def
75% N+ without biofertilizers (0)	2.34 b-e	2.84def	0.0023 bcd	0.0012j	2.46 def	3.23cde
100%N+ without biofertilizers (0)	2.14 c-f	2.95cde	0.0017 c-g	0.0017ij	2.27 fg	3.08def
50%N +*Enterobacter cloacae* (1)	1.56 g	2.71efg	0.0022 bcd	0.0071e-h	2.12 g	2.95fgh
75%N + *Enterobacter cloacae* (1)	2.38 bcd	2.84def	0.0015 d-g	0.0048ghi	2.98 c	3.26bcd
100%N + *Enterobacter cloacae* (1)	2.48 bc	3.23bcd	0.0021 b-f	0.0081def	3.71 b	3.47b
50%N + *Sphingomonas paucimobilis* (2)	2.01 ef	2.89def	0.0012 fg	0.0073d-h	1.38 h	2.11j
75%N + *Sphingomonas paucimobilis* (2)	1.89 fg	2.71efg	0.0031 a	0.012bc	2.29 efg	2.85ghi
100%N + *Sphingomonas paucimobilis* (2)	2.36b-e	3.41b	0.0025 ab	0.0080d-g	3.22 c	3.17de
50%N+ *Bacillus licheniformis* (K.95) (3)	1.85 fg	2.33gh	0.0026 ab	0.013ab	4.33 a	3.71a
75%N + *Bacillus licheniformis* (K.95) (3	2.09def	2.58e-h	0.0022 b-e	0.0089def	1.67 h	2.29j
100%N + *Bacillus licheniformis* (K.95) (3	2.10 def	2.51fgh	0.0019 b-g	0.0097cde	3.14 c	3.44bc
50%N+ *Bacillus licheniformis*(ECto3) (4)	2.14 c-f	2.76ef	0.0025 abc	0.015a	2.85 de	3.02efg
75%N + *Bacillus licheniformis* (ECto3) (4)	2.05def	2.58e-h	0.0014 efg	0.0044hi	2.65 d	3.17de
100%N + *Bacillus licheniformis*(ECto3) (4)	3.14 a	3.87a	0.0022 b-e	0.0086def	2.12 g	2.67i
50%N + Mixture of strains (1+2+3+4) (5)	2.34 b-e	2.82def	0.0019 b-g	0.0074d-h	2.57 de	2.85ghi
75%N + Mixture of strains (1+2+3+4) (5)	2.13 c-f	2.82def	0.0013 fg	0.011cd	2.33 efg	2.89fgh
100%N + Mixture of strains (1+2+3+4) (5)	2.63 b	3.36bc	0.0025 abc	0.0057fgh	2.35 d-g	2.77hi

- Values having the same alphabetical letter(s) did not show a significant difference at 0.05 level of significance according to Duncan's multiple range test..

Table (4). Averages values of N, P and K of onion plants as affected by the interaction among cultivars, N mineral and N biofertilization during the winter seasons of 2022/2023 and 2023/2024.

Treatments		NPK estimation					
		Nitrogen		Phosphorus		Potassium	
Cultivars	Fertilization	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Yellow	50%N+ without biofertilizers (0)	1.31 S	2.45m-s	5.07E-04 n-q	0.00066mn	1.32r-v	3.07i-p
	75% N+ without biofertilizers (0)	2.53 c-j	3.73b-f	0.0023733 b-j	0.00195k-n	2.08l-o	3j-p
	100%N+ without biofertilizers (0)	1.66 s-o	3.5c-h	0.00266 b-i	0.00226k-n	2.111mn	3.12h-o
	50%N +*Enterobacter cloacae* (1)	1.43 sub	3.33c-k	0.0016933 g-p	0.00632e-l	1.73n-u	3.02j-p
	75%N + *Enterobacter cloacae* (1)	1.49 s-d	2.63k-q	0.0018633 f-o	0.00524f-n	4.46a	3.69cde
	100%N+*Enterobacter cloacae* (1)	2.49 d-k	3.91a-e	0.001953 e-m	0.01105de	3.39e-h	3.1h-p
	50%N+*Sphingomonas paucimobilis* (2)	1.43 sub	3.09f-n	0.00151 i-p	0.00424i-n	1.54p-v	2.38t-w
	75%N+*Sphingomonas paucimobilis* (2)	2.01 i-q	3.38c-j	0.00297 a-h	0.0169bc	3.02hij	2.9k-q
	100%N+*Sphingomonas paucimobilis* (2)	2.07 h-p	3.33c-k	0.0024267 b-j	0.00783d-j	3.96a-d	3.24g-l
	50%N+ *Bacillus licheniformis* (K.95) (3)	1.83 m-s	3.21e-l	0.0025233 b-j	0.00892d-i	4.45a	3.51d-g
	75%N + *Bacillus licheniformis* (K.95) (3	1.72s-u	3.44c-i	0.00216 c-k	0.00749d-k	2.41 klm	2.33U-W
	100%N + *Bacillus licheniformis* (K.95) (3	1.66 s-o	2.45m-s	4.00E-04 pq	0.0106d-g	4.11 abc	3.29f-j
	50%N+ *Bacillus licheniformis*(ECto3) (4)	1.66 s-o	3.62b-g	0.0031467 a-f	0.0235a	2.03m-p	3.05j-p
	75%N + *Bacillus licheniformis*(ECto3) (4)	1.66 s-o	2.92g-p	5.97E-04 m-q	0.00434i-n	2.39 klm	3j-p
	100%N + *Bacillus licheniformis***(**ECto3)(4)	3.14 abc	4.03abc	4.83E-04 opq	0.00431i-n	2.6 jkl	2.73p-t
	50%N + Mixture of strains (1+2+3+4)(5)	2.39 d-m	3.04f-o	0.0021633 c-k	0.00441i-n	2.83 ijk	3j-p
	75%N + Mixture of strains (1+2+3+4)(5)	2.01 i-q	2.92g-p	0.0024833 b-j	0.01086de	1.32s-v	2.26UVW
	100%N + Mixture of strains (1+2+3+4)(5)	2.83 a-f	3.97a-d	0.00175 f-p	0.00265j-n	1.22l	2.18VW
Red	50%N+ without biofertilizers (0)	2.21 f-o	1.98sub	4.20E-04 pq	0.00064mn	1.52q-v	3.44d-i
	75% N+ without biofertilizers (0)	2.36 e-m	2.45m-s	0.0021333 c-k	0.00092 1-n	4.28ab	4.3a
	100%N+ without biofertilizers (0)	2.10 h-p	2.86h-p	0.00144 i-q	0.00254j-n	3.06g-j	3.24g-l
	50%N +*Enterobacter cloacae* (1)	1.89 k-s	3.03f-o	0.0030567 a-g	0.00432i-n	2.77 ijk	2.85m-r
	75%N + *Enterobacter cloacae* (1)	2.83 a-f	3.15f-m	0.0013867 i-q	0.0046i-n	2.96 hij	3.37e-j
	100%N + *Enterobacter cloacae* (1)	1.93 j-s	2.69j-q	0.0026333 b-i	0.007d-k	4.26 ab	4.03abc
	50%N + Sphingomonas paucimobilis (2)	2.65 b-h	3.33c-k	9.10E-04 k-q	0.00912d-i	1.35r-v	1.22y
	75%N + Sphingomonas paucimobilis (2)	1.43 sub	2.39s-u	0.0030767 a-g	0.00736d-k	1.96m-q	3.12h-o
	100%N + Sphingomonas paucimobilis (2)	3.23 ab	4.26ab	0.00338 a-d	0.00719d-k	4.23 ab	3.76cd
	50%N+ *Bacillus licheniformis* (K.95) (3)	2.24 f-o	1.99sub	0.00367 ab	0.02026ab	4.43a	4.15ab
	75%N + *Bacillus licheniformis* (K.95) (3	2.19 g-o	2.51 1-q	0.0018867 f-o	0.00797d-j	1.17 uv	1.69X
	100%N + *Bacillus licheniformis* (K.95) (3	2.59 c-i	2.45m-s	0.00263 b-i	0.00788d-j	3.41e-h	3.79bcd
	50%N+ *Bacillus licheniformis* (ECto3) (4)	2.48 d-l	2.69j-q	0.00427 a	0.01879ab	3.56d-g	2.77n-s
	75%N + *Bacillus licheniformis* (ECto3) (4)	2.59 c-i	2.34s-o	0.00191 f-n	0.00517g-n	1.96m-q	3.19g-m
	100%N + *Bacillus licheniformis***(**ECto3)(4)	3.41 a	4.55a	0.0034333abc	0.01119de	3.28f-i	3.14g-n
	50%N + Mixture of strains (1+2+3+4)(5)	1.86 l-s	2.68j-q	0.0020967 c-l	0.00588e-m	3.23f-i	3j-p
	75%N + Mixture of strains (1+2+3+4)(5)	2.24 f-o	3.27d-k	6.97E-04 1-q	0.01035d-g	3.9b-e	3.19g-m
	100%N + Mixture of strains (1+2+3+4)(5)	3.00 a-d	3.39c-j	0.0033467 a-e	0.00386i-n	3.87b-e	3.64def
White	50%N+ without biofertilizers (0)	1.92 j-s	2.39s-u	0.00246 b-j	0.00016n	1.57p-v	2.75o-t
	75% N+ without biofertilizers (0)	2.13 h-o	2.34s-o	0.00254 b-j	0.00086 1-n	1.04V	2.41s-w
	100%N+ without biofertilizers (0)	2.65 b-h	2.51 1-q	0.0011667 j-q	0.0003n	1.63o-v	2.9k-q
	50%N +*Enterobacter cloacae* (1)	1.37 rs	1.75s	0.001993 d-m	0.01068d-g	1.81s-u	3j-p
	75%N + *Enterobacter cloacae* (1)	2.83 a-f	2.74i-p	0.0015467 i-p	0.0047h-n	1.54p-v	2.75o-t
	100%N + *Enterobacter cloacae* (1)	3.01 a-d	3.09f-n	0.00156 i-p	0.00627e-l	3.45d-h	3.29f-j
	50%N + Sphingomonas paucimobilis (2)	1.95 j-r	2.28s-d	0.0013533 i-q	0.0088d-i	1.26 tuv	2.73p-t
	75%N + Sphingomonas paucimobilis (2)	2.24 f-o	2.34s-o	0.0034533 abc	0.0122cd	1.9u-u	2.55q-v
	100%N + Sphingomonas paucimobilis (2)	1.78 m-s	2.63k-q	0.00194 f-m	0.00904d-i	1.47q-v	2.53q-w
	50%N+ *Bacillus licheniformis* (K.95) (3)	1.48 s-d	1.81rs	0.0016033 h-p	0.01249cd	4.11 abc	3.46d-h
	75%N + *Bacillus licheniformis* (K.95) (3	2.36 e-m	1.81rs	0.0025333 b-j	0.01126de	1.45r-v	2.87 1-r
	100%N + *Bacillus licheniformis* (K.95) (3	2.07 h-p	2.63k-q	0.0026867 b-i	0.01078def	1.91m-q	3.24g-l
	50%N+ *Bacillus licheniformis***(ECto3)** (4)	2.30 e-n	1.98sub	4.00E-05 q	0.0073d-k	2.16 1mn	3.27g-k
	75%N + *Bacillus licheniformis***(ECto3)** (4)	1.89 k-s	2.51l-r	0.0017567 f-n	0.00394i-n	3.61c-f	3.34e-j
	100%N + *Bacillus licheniformis***(**ECto3) (4)	2.88 a-e	3.04f-o	0.0026633 b-i	0.01037d-g	0.48W	2.16W
	50%N + Mixture of strains (1+2+3+4) (5)	2.77 b-g	2.74i-p	0.0014067 i-q	0.01202cd	1.67n-u	2.58q-u
	75%N + Mixture of strains (1+2+3+4) (5)	2.13 h-o	2.27s-d	8.13E-04 k-q	0.01017d-h	1.78n-t	3.24g-l
	100%N+ Mixture of strains (1+2+3+4) (5)	2.07 h-p	2.74i-p	0.0023467 b-j	0.01065d-g	1.96m-q	2.5r-w

- Values having the same alphabetical letter(s) did not show a significant difference at 0.05 level of significance according to Duncan's multiple range test..

Data in Table (4) shows the three-way interaction among the studied factors, indicating that the Giza Red cultivar under the *B. licheniformis* (k.95) + 50 % dose of N treatment had the highest value in the 2022/2023 season (4.43%), while under the 0 + 75 % dose of N treatment in the 2023/2024 season, the same cultivar had its maximal potassium content (4.3%). On the other hand, in 2022/2023, the Giza White cultivar treated with *S. paucimobilis* + 100 % dose of N had the lowest potassium content (0.48%), and in 2023/2024, the Giza Red cultivar treated with *S. paucimobilis* + 50 % dose of N had the lowest potassium content (1.22%). With the Giza Red cultivar demonstrating greater potassium assimilation under moderate nitrogen inputs combined with either strain *B. licheniformis* (k.95) or no microbial inoculation, these results point to a cultivar specific response to fertilization techniques. The improved root activity and membrane permeability, which are triggered by the combined effects of an ideal nitrogen supply and a good microbial presence, may be the cause of the elevated potassium levels in favorable treatments. In contrast, less than ideal combinations, especially those combining strain *S. paucimobilis* and unbalanced nitrogen levels, probably reduced microbial compatibility or root effectiveness, which in turn decreased potassium uptake. These results highlight how crucial it is to implement integrated nutrient management that is specific to cultivar traits in order to maximize nutrient use efficiency and promote sustainable onion production. The results are in agreement with **[30-31-32-33].**

Estimation of total solids TSS (*Brix*)

According to the data in Table (5), during the winter seasons of 2022–2023 and 2023–2024, cultivar type, mineral nitrogen levels, and biofertilizer application all had a substantial impact on the total soluble solids (TSS) content of onion bulbs. Because of its higher genetic ability for carbohydrate buildup and efficient sugar metabolism, Giza White consistently had the highest TSS values among the cultivars, averaging 14.31 Brix in the first season and 15.04 Brix in the second. Perhaps as a result of variations in enzyme activity, moisture content, or source sink partitioning efficiency, the Giza 6 Mohassan cultivar had the lowest TSS in 2023/2024 (13.81 Brix), while the Giza Red cultivar had the lowest in 2022/2023 (13.07 Brix). Similar results were obtained by **[34-35]** for the effect of the cultivars on the accumulation of total solids**.** According to fertilization treatments, the maximum TSS buildup occurred during the seasons when microbial (Mixture of bacterial strains (1+2+3+4)**)** was applied in combination with 50 % dose of N, reaching 14.79 Brix and 15.71 Brix, respectively. This synergistic improvement is probably due to higher phytohormonal activity (such as gibberellins, auxins, and cytokinins) that stimulate the synthesis of carbohydrates, better nitrogen assimilation, and microbial stimulation of sugar production pathways. On the other hand, TSS levels were lowest in control condition (0 + 50 % dose of N), with values of 12.46 Brix and 13.23 Brix, suggesting a lack of microbial stimulation and an inadequate nitrogen supply.

Data in Table (6) shows that the three-way interaction among nitrogen level, cultivar, and biofertilization treatment had a significant effect on TSS content as well. The highest TSS levels were achieved by the Giza White cultivar treated with (Mixture of bacterial strains (1+2+3+4)) + 50 % dose of N, which reached 16.33 Brix and 17.67 Brix during the two seasons. However, in 2022/2023, the Giza White cultivar under treatment 0 + 50 % dose of N had the lowest TSS concentration (10.45 Brix), and in 2023/2024, the Giza Red cultivar under treatment *S. paucimobilis* + 75 % dose of N had

the lowest TSS (12.33 Brix). These results demonstrate how important cultivar specific fertilization techniques and microbial compatibility are for improving bulb quality.

The enhanced microbial induced glucose metabolism, better nitrogen uptake, and effective sugar translocation into bulbs may all contribute to the superior TSS buildup seen in optimal combinations. Suboptimal treatments, on the other hand, demonstrated limited physiological activity and nutrient intake, highlighting the need for integrated nutrient management specific to cultivar genotype. Similar results were obtained by **[36-37-38]** in onion, these findings are consistent.

Estimation of total sugars.

Onion cultivars, nitrogen levels, and the use of biofertilizers all significantly affected the amount of total sugars in onion bulbs throughout the winter seasons of 2022–2023 and 2023–2024. Table (5) shows with the highest average sugar concentrations of 10.35% and 10.56% in the first and second seasons, respectively, the Giza White cultivar continuously surpassed the other cultivars under study. Along with better nitrogen uptake and microbial facilitation of photosynthesis and nutrient assimilation, this greater sugar buildup most likely reflects its enhanced genetic ability for carbohydrate synthesis and storage.

Table (5). Averages values of TSS, total sugars, dry Weigh and v.c of onion plants as affected by cultivars, N mineral and N biofertilization during the winter seasons of 2022/2023 and 2023/2024.

Treatments	TSS ,total, sugars, dry Weight and v.c estimation days after the harvest						
	TSS		total sugars		dry Weight		Vitamin C
	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023
cultivars							
Giza 6 Mohassan	14.00 ab	13.81b	10.04 a	8.15b	14.92 b	14.81b	1.02 a
Giza Red	13.07 b	14.31b	8.76 b	8.37b	13.99 c	14.21b	0.69 b
Giza White	14.31 a	15.40a	10.35 a	10.56a	17.23 a	15.82a	0.84 ab
N biofertilization							
50%N+ without biofertilizers (0)	12.46 g	13.23g	9.97 b-e	9.08bcd	14.57 cd	14.19e-h	.71 ghi
75% N+ without biofertilizers (0)	13.27 c-g	14.46a-f	8.89 efg	8.72bcd	14.77 cd	15.11c-g	1.01ab
100%N+ without biofertilizers (0)	13.81 a-f	14.47a-f	9.31 d-g	9.12bcd	14.1 de	11.48i	1.18 a
50%N +*Enterobacter cloacae* (1)	13.4 b-g	13.91fg	8.77 fg	8.59bcd	15.25 cd	16.23bc	.72 f-i
75%N + *Enterobacter cloacae* (1)	14.24 a-e	14.27c-g	8.96 efg	8.53cd	15.41 cd	15.32cde	.89 b-g
100%N + *Enterobacter cloacae* (1)	14.28 a-d	15.03a-e	9.22 d-g	9.46bcd	18.48 a	18.46a	.73 e-h
50%N + *Sphingomonas paucimobilis* (2)	13 efg	14efg	9.41 d-g	8.22d	14.39 d	1.34h	1.01 abc
75%N + *Sphingomonas paucimobilis* (2)	12.84 fg	13.91fg	9.74 c-g	8.63bcd	15.8 cd	15.41cde	.88 b-g
100%N + *Sphingomonas paucimobilis* (2)	13.25 c-g	14.2d-g	9.68 c-g	8.89bcd	15.55 cd	17.03b	.82 c-h
50%N+ *Bacillus licheniformis* (K.95) (3)	13.07 d-g	13.78fg	11.06 ab	9.97ab	15.88bcd	15.68cd	.54 i
75%N + *Bacillus licheniformis* (K.95) (3	14.23 a-e	15.36ab	9.91 b-f	9.31bcd	15.04 cd	14.76d-g	.94 bcd
100%N + *Bacillus licheniformis* (K.95) (3	14.81 a	14.81a-f	10.69 abc	9.9abc	15.48 cd	14.26e-h	.78 d-h
50%N+ *Bacillus licheniformis*(ECto3) (4)	14.46abc	14.31c-f	10.25 a-d	8.57bcd	12.53 e	12.02i	.89 b-f
75%N+ *Bacillus licheniformis*(ECto3) (4)	14.26 a-d	15.12a-d	10.22 a-d	8.84bcd	14.49 cd	13.96jh	.69 hi
100%N+ *Bacillus licheniformis* **(**ECto3) (4)	14.58 ab	15.25abc	9.35 d-g	9.02bcd	17.71 ab	16.24bc	.91 b-e
50%N + Mixture of strains (1+2+3+4) (5)	14.79 a	15.51a	11.31 a	10.91a	15.51 cd	15.22c-f	.71 f-i
75%N + Mixture of strains (1+2+3+4) (5)	13.79 a-f	15.22a-d	9.53 c-g	8.37d	16.27 bc	16.23bc	1.02 ab
100%N+ Mixture of strains (1+2+3+4) (5)	13.77 a-f	14.33b-f	8.71 g	8.40d	15.78 cd	14.07fgh	.95 bcd

- Values having the same alphabetical letter(s) did not show a significant difference at 0.05 level of significance according to Duncan's multiple range test.

Table (6). Averages values of TSS, total sugars, dry Weigh and V.c of onion plants as affected by the interaction among cultivars, N mineral and N biofertilization during the winter seasons of 2022/2023 and 2023/2024.

Treatments		TSS, total, sugars, dry Weight and v.c estimation days after the harvest						
		TSS		total sugars		dry Weight		Vitamin C
cultivars	Fertilization	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023
Yellow	50%N+ without biofertilizers (0)	13.83d-k	12.53 pq	9.86 c-p	8.98 f-m	14.78 g-s	13.4 l-t	0.75 g-o
	75% N+ without biofertilizers (0)	12.46i-m	14.13 g-q	8.97 h-q	8.23 i-o	11.56 tu	10.05 W	1.73 ab
	100%N+ without biofertilizers (0)	15.00a-g	13.6 j-q	11.00 a-h	8.87 g-n	13.47 m-u	11.25 tuvw	1.77 a
	50%N +*Enterobacter cloacae* (1)	13.66d-k	13.07 m-q	10.75 a-j	8.75 g-o	16.58 a-m	17.3 d-g	1.24 cde
	75%N + *Enterobacter cloacae* (1)	14.40a-j	12.97 m-q	9.69 c-q	8.68 g-o	17.08 a-j	18.32 cde	0.72 h-q
	100%N + *Enterobacter cloacae* (1)	15.20a-e	14.9 c-k	9.12 h-q	8.82 g-n	17.51 c-h	18.5 cd	0.92 e-k
	50%N+*Sphingomonas paucimobilis* (2)	12.90g-l	13 m-q	9.48 e-q	7.75 k-o	13.9 j-u	13.6 1-m-s	1.59 bc
	75%N+ *Sphingomonas paucimobilis* (2)	13.70d-k	13.9 h-q	10.18 c-n	7.98 j-o	15.36 b-q	14.73 i-o	1.01 c-i
	100%N+ *Sphingomonas paucimobilis* (2)	13.66d-k	13.3 k-q	9.90 c-p	7.51 1-o	16.33 b-n	17.8 def	1.06 c-i
	50%N+ *Bacillus licheniformis* (K.95) (3)	13.00e-l	13.17 k-q	11.29 a-g	9.17 f-l	16.23 b-o	16.93 d-h	0.043 q
	75%N + *Bacillus licheniformis* (K.95) (3	14.20a-j	14.67 d-n	10.44 a-m	8.49 h-o	14.85 d-r	14.25 i-p	0.84 f-n
	100%N + *Bacillus licheniformis* (K.95) (3	15.66a-d	15.43 c-i	10.52 a-l	7.5 1-o	13.15 n-u	12.75 n-u	0.87 e-l
	50%N+ *Bacillus licheniformis*(ECto3) (4)	14.43a-i	13.17 k-q	10.80 a-i	6.52 no	13.82 k-u	13.59 l-r	1.24 c-f
	75%N + *Bacillus licheniformis*(ECto3) (4)	13.26e-l	14.43 e-o	10.07 c-o	8.23 i-o	13.16 n-u	12.6 o-v	0.074 pq
	100%N + *Bacillus licheniformis***(**ECto3) (4)	15.03a-g	14.77 c-m	8.23 s-u	6.37 o	15.13 d-r	15.52 g-m	0.7 i-q
	50%N + Mixture of strains (1+2+3+4) (5)	13.86c-k	12.87 n-q	11.50 a-e	9.07 f-l	15.46 b-p	15.54 g-l	0.75 g-o
	75%N + Mixture of strains (1+2+3+4) (5)	13.00f-l	14.17 g-p	9.57 c-q	8.68 g-o	14.51 f-u	14.47 i-p	1.49 bcd
	100%N+ Mixture of strains (1+2+3+4) (5)	14.76a-h	14.67 d-n	9.39 f-q	7.23 1-o	15.85 d-p	16.08 f-j	0.59 k-q
Red	50%N+ without biofertilizers (0)	13.00f-l	14.5 e-n	8.53 k-r	7.27 1-o	11.53 u	15 h-n	0.52 m-q
	75% N+ without biofertilizers (0)	12.73h-l	14.77 c-m	8.13 s-u	8.51 h-o	14.41 g-u	19 bcd	0.47 n-q
	100%N+ without biofertilizers (0)	12.26j-m	15.83 b-g	6.33 S	6.6 mno	14 i-u	10.58 VW	0.81 f-n
	50%N +*Enterobacter cloacae* (1)	13.53d-k	12.43 pq	8.93 i-q	8.65 g-o	12.19 q-u	17 d-h	0.47 opq
	75%N + *Enterobacter cloacae* (1)	12.33i-m	13.37 k-q	8.68 j-r	8.12 i-o	12.15 r-u	12 q-w	1.03 c-i
	100%N + *Enterobacter cloacae* (1)	11.331m	12.67 opq	7.84 s-d	7.83 k-o	21.32 ab	21 ab	0.43 opq
	50%N + *Sphingomonas paucimobilis* (2)	13.33e-k	13.57 j-q	9.20 h-q	8.24 h-o	14.75 g-t	14.95 h-m	0.54 1-q
	75%N + *Sphingomonas paucimobilis* (2)	12.03klm	12.33 q	8.07 s-o	7.88 j-o	13.51 m-u	13 n-u	1.08 c-h
	100%N + *Sphingomonas paucimobilis* (2)	13.33e-l	13.83 i-q	7.78 sub	7.12 1-o	13.57 m-u	18.8 cd	0.43 pq
	50%N+ *Bacillus licheniformis* (K.95) (3)	13.00f-l	14.87 c-l	10.34 b-m	10.43 c-i	14.34 g-u	14 i-q	0.41 pq
	75%N + *Bacillus licheniformis* (K.95) (3	12.33i-m	14.93 c-k	9.58 c-q	9.48 d-l	13.09 o-u	13.9 j-r	0.81 f-n
	100%N + *Bacillus licheniformis* (K.95) (3	13.10e-l	14.83 c-l	9.28 g-q	7.67 k-o	15.29 e-r	14.56 1-j-p	0.52 n-q
	50%N+ *Bacillus licheniformis***(ECto3)** (4)	13.86c-k	14.2 f-p	9.23 g-q	7.78 k-o	11.61 stu	10.5 VW	0.7 i-q
	75%N + *Bacillus licheniformis***(ECto3)** (4)	13.23e-l	14.6 d-n	9.78 c-q	8.33 h-o	12.69 p-u	12.11 p-v	0.63 j-q
	100%N + *Bacillus licheniformis***(**ECto3) (4)	14.00c-k	15.67 c-h	8.20 s-u	8.51 h-o	16.38 a-m	13.15 m-r	1.1 c-g
	50%N + Mixture of strains (1+2+3+4) (5)	14.16b-k	16 a-f	9.97 c-o	10.68 b-h	11.51 u	11.83 r-w	0.72 h-q
	75%N + Mixture of strains (1+2+3+4) (5)	13.33e-l	14 h-q	9.47 e-q	8.98 f-m	14.74 e-t	11.9 r-w	0.85 f-m
	100%N+ Mixture of strains (1+2+3+4) (5)	13.86c-k	15.33 c-j	8.44 m-r	8.65 g-o	14.92 f-r	12.5 p-v	1.01 c-j
White	50%N+ without biofertilizers (0)	10.45m	12.67opq	11.53 a-e	11 b-g	17.39 a-h	14.19 i-p	0.86 e-m
	75% N+ without biofertilizers (0)	14.63a-h	14.5 e-n	9.59 c-q	9.44 e-l	18.33 a-e	16.27 e-i	0.82 f-n
	100%N+ without biofertilizers (0)	14.16b-k	14 h-q	10.59 a-k	11.91 bcd	14.8 g-r	12.62 o-u	0.98 d-k
	50%N +*Enterobacter cloacae* (1)	13.00f-l	16.23 a-e	6.64 rs	8.37 h-o	16.98 a-k	14.39 i-p	0.45 opq
	75%N + *Enterobacter cloacae* (1)	16.00abc	16.5 a-c	8.50 1-m	8.78 g-o	16.94 a-k	15.65 g-l	0.92 e-l
	100%N + *Enterobacter cloacae* (1)	16.33a	17.53 a-b	10.70 a-j	11.75 b-e	16.63 a-m	15.88 f-k	0.85 f-m
	50%N + *Sphingomonas paucimobilis* (2)	12.76h-l	15.43 c-i	9.53 d-q	8.68 g-o	14.54 f-u	11.48 s-w	0.88 e-l
	75%N + *Sphingomonas paucimobilis* (2)	12.80h-l	15.5 c-i	10.97 a-i	10.03 c-k	18.53 a-d	18.5 c-d	0.56 1-q
	100%N + *Sphingomonas paucimobilis* (2)	12.76h-l	15.47 c-i	11.38 a-f	12.04 b-c	16.73 a-l	14.5 1-j-p	0.99 c-j
	50%N+ *Bacillus licheniformis* (K.95) (3)	12.70h-m	13.33 k-q	11.57 a-d	10.33 c-j	17.09 a-j	16.11 f-j	0.8 g-o
	75%N + *Bacillus licheniformis* (K.95) (3	16.16ab	16.5 abc	9.68 c-q	9.98 c-k	17.13 a-i	16.15 f-i	1.17 c-f
	100%N + *Bacillus licheniformis* (K.95) (3	15.66a-d	14.17 g-p	12.28 ab	14.53 a	18.01 a-f	15.5 g-m	0.96 e-k
	50%N+ *Bacillus licheniformis***(ECto3)** (4)	15.10a-f	15.57 c-i	10.70 a-j	11.41 b-f	12.17 q-u	12 r-w	0.75 h-p
	75%N + *Bacillus licheniformis***(ECto3)** (4)	16.26ab	16.33 a-d	10.80 a-i	9.97 c-k	17.63 a-g	17.19 d-g	0.71 h-q
	100%N + *Bacillus licheniformis***(**ECto3) (4)	14.70a-h	15.33 c-j	11.61 abc	12.19 abc	21.61 a	20.08 bc	0.92 e-l
	50%N + Mixture of strains (1+2+3+4) (5)	16.33a	17.67 a	12.42 a	12.98 ab	19.55 abc	18.3cde	0.67 i-q
	75%N + Mixture of strains (1+2+3+4) (5)	15.03a-g	17.5 ab	9.56 c-q	7.45 1-o	19.55 abc	22.35 a	0.7 i-q
	100%N+ Mixture of strains (1+2+3+4) (5)	12.66h-m	13 m-q	8.25 s-u	9.33 e-l	16.59 a-m	13.65 k-s	1.26 bcd

- Values having the same alphabetical letter(s) did not show a significant difference at 0.05 level of significance according to Duncan's multiple range test.

Dry Weight.

Data in Tables (5) shows that the dry weight concentration of onion bulbs during the winter seasons of 2022–2023 and 2023–2024 was significantly impacted by the onion cultivars, mineral nitrogen level, and biofertilizer treatment, as well as their interactions. The Giza White cultivar surpassed the Giza Red and Giza 6 Mohassan cultivars among the evaluated cultivars, obtaining the greatest average dry weights in both seasons (15.82 % and 17.23 %, respectively). However, the Giza Red cultivar had the lowest values (13.99 % and 14.21 %), indicating that the capacity for dry matter buildup varies by varietal. When 100 % dose of N was added to biofertilizer treatment *Enterobacter cloacae* a strong synergistic impact was seen, resulting in the greatest overall dry weights (18.48 % in 2022/2023 and 18.46 % in 2023/2024, respectively). This enhancement is ascribed to improved photosynthetic efficiency and nutrient uptake, which are made possible by the interplay between adequate nitrogen supply and microbial activity. This leads to increased translocation to bulbs and glucose synthesis. Treatment *B. licheniformis*(ECto3) + 50 % dose of N, on the other hand, produced the lowest bulb dry weights (12.53 % and 12.02 %), indicating insufficient nitrogen delivery and/or inefficient microbial colonization that prevented biomass formation.

Data in Table (6) shows that further analysis revealed a significant effect of the interaction among cultivar, nitrogen level, and biofertilizer strain on bulb dry weight. Interestingly, the Giza White cultivar treated with *B. licheniformis*(ECto3) + 100 % dose of N had the highest dry weight in 2022/2023 (21.61 %), whereas the same cultivar treated with (Mixture of bacterial strains (1+2+3+4)) + 75 % dose of N had the highest dry weight in 2023/2024 (27.35 %). These findings highlight the Giza White cultivar genetic potential for effective nitrogen utilization under ideal fertilization conditions. Conversely, the Giza 6 Mohassan cultivar under treatment 0 + 75 % dose of N lowest in 2023/2024 (10.05%) and the Giza Red cultivar under treatment 0 + 50 % dose of N (11.53 % in 2022/2023) both showed poor performance, most likely because of inadequate nitrogen and ineffective microbial support, which restricted nutrient assimilation and absence of effective microbial support, which limited nutrient assimilation and dry matter synthesis.

Conclusively, these results validate the crucial function of the interplay among genotype, nitrogen availability, and biofertilization in augmenting the accumulation of dry matter in onion bulbs. The Giza White cultivar higher performance under high-nitrogen and biofertilizer treatments highlights how crucial it is to combine appropriate microbial inoculants with balanced mineral fertilization techniques in order to maximize bulb quality and output. These findings are consistent with previous research by **[40-41]** indicating that better nitrogen management, especially when combined with biofertilizers, greatly increases the output of dry biomass in onion crops. Similar results were obtained by **[35-38].**

Vitamin C estimation

Data in Table (5) shows the average vitamin C concentrations in onion bulbs throughout the winters of 2022–2023 and 2023–2024, as impacted by fertilization practices and cultivar type. A considerable impact of onion cultivar on vitamin C accumulation was found by statistical analysis. On average, the Giza 6 Mohassan cultivar had the highest concentration (1.02 mg/100g), followed by the Giza White cultivar (0.84 mg/100g), while the Giza Red cultivar had the lowest concentration (0.69 mg/100g). Both the cultivars' efficiency in micronutrient uptake necessary for antioxidant

formation and the enzymatic and biosynthetic pathways responsible for ascorbic acid synthesis are impacted by genotypic diversity, which accounts for these discrepancies. The agronomic benefit of choosing cultivars with naturally higher nutritional content, like Giza 6 Mohassan onions, to improve crop quality is highlighted by this. These results are consistent with the findings of **[42].**

Data in Table (6)show that vitamin C accumulation was significantly influenced by the interaction between biofertilizer application and mineral nnitrogen. Thetreatment of 100 % does of N without the addition of biofertilizer (0 + 100 % dose of N) produced the highest concentration (1.18 mg/100g), underscoring the critical role that enough nitrogen plays in promoting antioxidant production. The *B. licheniformis* (k.95) + 50 % dose of N condition, on the other hand, had the lowest concentration (0.54 mg/100g), indicating that too much biofertilizer combined with insufficient nitrogen may upset the nutritional balance and prevent the production of ascorbic acid. Significant differences in vitamin C concentration were also found in the three-way interaction between cultivar, mineral nitrogen, and biofertilizer treatment.

When the Giza 6 Mohassan cultivar was treated with 0 + 100 % dose of N, the accumulation was at its highest (1.77 mg/100g), whereas when it was treated with The *B. licheniformis* (k.95) + 50 % dose of N, it was at its lowest (0.43 mg/100g). These results demonstrate that appropriate mineral nitrogen supply is closely associated with optimal vitamin C production, especially in cultivars that are physiologically responsive to nitrogen. On the other hand, an imbalance brought on by too much biofertilizer and limited nitrogen availability could have a detrimental effect on the plant's ability to biosynthesize. All things considered, our findings demonstrate how crucial cultivar selection and exact nutrient management techniques are to raising the nutritional value of onion bulbs**. [43-44]** have also reported similar findings in work with biofertilizers.

Weight loss

Data in Table (7) summarizes the estimated weight loss percentages in onion bulbs during storage across the 2022/2023 and 2023/2024 seasons as influenced by cultivar type, fertilization regime (chemical nitrogen and biofertilizer), and storage duration. Significant variation was observed among cultivars, where the Giza 6 Mohassan cultivar exhibited the highest initial weight loss after curing (30.23% in 2022/2023 and 24.06% in 2023/2024), yet maintained superior storability, recording the lowest cumulative losses by the fifth month (49% and 43%, respectively). Conversely, the Giza White cultivar had the lowest initial loss but suffered the most severe long-term degradation (99% and 62%), indicating poor storage resilience. The Giza Red cultivar showed moderate cumulative losses (80% and 69%). Regarding fertilization, treatments integrating mineral nitrogen with biofertilizers significantly influenced bulb storability. The absence of biofertilizer (0 + 50% dose of N) led to the highest cumulative losses after five months (63.03% and 46.63%), highlighting its adverse effect on postharvest performance. In contrast, treatments such as *S. paucimobilis* + 100% % dose of N minimized post curing losses (8% and 7.12%), while *Enterobacter cloacae* + 100% dose of N yielded the lowest cumulative losses during extended storage (30.51% and 19.74%). These findings emphasize the critical importance of cultivar selection and integrated nutrient management in enhancing onion bulb quality and reducing postharvest weight loss.

Table (7). Averages values of weight loss (g) of onion plants as affected by cultivars, N mineral and N biofertilization during the winter seasons of 2022/2023 and 2023/2024.

Treatments	Weight loss (g) estimation days after the harvest							
	After curing		After One Month		After Three Month		After Five Month	
	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Cultivars								
Giza 6 Mohassan	30.23a	24.06a	30.79a	13.25b	33.63b	30.70a	49.48b	43.56b
Giza Red	22.35b	17.93b	22.27b	19.42a	37.19ab	30.63a	80.15b	69.77a
Giza White	23.43b	14.73b	29.73ab	17.16ab	49.51a	30.15a	99.36a	62.47b
N biofertilization								
50%N+ without biofertilizers (0)	20.19 a	19.1 a	20.16 ab	18.43 a	42.15 a	33.45 a	63.03 bcd	46.63 a
75% N+ without biofertilizers (0)	19.64 ab	15.16 a	12.47abcde	10.99 bcde	25.88 ab	19.69 bcd	69.03 ab	46.09 ab
100%N+ without biofertilizers (0)	14.29 abc	12.04 ab	15.49 abc	13.73 abc	30.74 abc	23.66 ab	43.46 cd	31.15 bcd
50%N +*Enterobacter cloacae* (1)	16.52 abc	11.81 ab	24.53 a	14.05 ab	36.79 bcd	19.92 bcd	66.9 abc	32.07 bcd
75%N + *Enterobacter cloacae* (1)	19.28 ab	12.05 ab	14.75 abcd	12.45 abcd	29.74 bcd	20.25 bcd	55.78 bcd	37.23 abc
100%N + *Enterobacter cloacae* (1)	14.11 abc	10.97 ab	9.71 cde	8.51 de	23.76 bcd	16.99 bcd	30.51 d	19.74 d
50%N+*Sphingomonas paucimobilis* (2)	12.53 abc	8.99 ab	10.87abcde	8.67 cde	24.72 bcd	15.89 cd	41.64 cd	24.73 cd
75%N + *Sphingomonas paucimobilis* (2)	14.06 abc	10.26 ab	9.23 de	8.72 cde	26.11 bcd	18.41 bcd	45.49 cd	29.08 cd
100%N+ *Sphingomonas paucimobilis* (2)	8 c	7.12 b	11.14abcde	9.91 cde	20.68 bcd	15.69 cd	42.28 cd	26.30 cd
50%N+ *Bacillus licheniformis* (K.95) (3)	14.66 abc	11.39 ab	12.22 bcde	9.1 cde	26.1 bcd	15.42 cd	40.09 cd	23.87 d
75%N + *Bacillus licheniformis* (K.95) (3	11.83 bc	9.26 ab	7.29 de	7.53 de	23.36 bcd	15.98 cd	84.64 a	34.90abcd
100%N + *Bacillus licheniformis* (K.95) (3	18.25 abc	14.36 ab	8.29 de	9.21 cde	23.39 bcd	18.65 bcd	43.78 cd	28.89 cd
50%N+ *Bacillus licheniformis*(ECto3) (4)	18.52 abc	12.64 ab	8.81 de	9.02 cde	23.36 bcd	17.27 bcd	51 bcd	32.99 bcd
75%N + *Bacillus licheniformis*(ECto3) (4)	21.74 a	16.17 a	11.87abcde	11.02 bcde	28.63 cd	21.67 abc	47.93 bcd	33.22 bcd
100%N+ *Bacillus licheniformis***(**ECto3) (4)	13.05 abc	10.23 ab	6.68 e	6.9 e	17.1 d	12.37 d	39.76 cd	25.33 cd
50%N + Mixture of strains (1+2+3+4) (5)	23.52 a	14.51 ab	8.18 de	7.97 de	21.4 cd	15.71 cd	37.15 cd	24.31 cd
75%N + Mixture of strains (1+2+3+4) (5)	14.71 abc	10.24 ab	10.57 bcde	8.63 de	27.61 cd	17.7 bcd	46.9 bcd	25.70 cd
100%N+ Mixture of strains (1+2+3+4)(5)	13.04 abc	10.29 ab	12.54abcde	12.21abcde	28.35 cd	21.31 bcd	41.25 cd	30.84 bcd

- Values having the same alphabetical letter(s) did not show a significant difference at 0.05 level of significance according to Duncan's multiple range test.

The results in Table (8) reveal that onion bulb weight loss was significantly influenced by the interaction between cultivar type, nitrogen fertilization level, and biofertilizer application. The Giza 6 Mohassan cultivar showed the highest post-curing losses in both seasons under treatments (Mixture of bacterial strains (1+2+3+4)) + 50% does of N and *B. licheniformis*(ECto3)+ 75% does of N (40.59% and 25.78%, respectively), while the white cultivar under *B. licheniformis* (k.95) + 75% dose of N consistently recorded the lowest (0.76% and 3.45%). After five months of storage, the highest cumulative losses were observed in the Giza White cultivar under 0 + 75% dose of N (100% dose of N) in the first season and the Giza Red cultivar under *Enterobacter cloacae* + 75% dose of N (71.79%) in the second. Conversely, the Giza 6 Mohassan cultivar under Mixture of bacterial strains (1+2+3+4)) + 75% dose of N and *B. licheniformis* (k.95) + 50% dose of N exhibited the lowest storage losses in the first and second seasons (17.66% and 15.66%, respectively). These findings highlight the critical role of genotype and integrated nutrient management in preserving bulb quality during storage. The application of biofertilizers with moderate to high nitrogen levels (e.g., *B. licheniformis* (k.95) + 75% and (Mixture of bacterial strains (1+2+3+4)+ 75%) significantly minimized weight loss, particularly in the Giza 6 Mohassan and Giza White cultivars, while the absence of biofertilization (e.g., 0 + 75% dose of N) led to severe postharvest deterioration, sometimes complete. These results are consistent with those reported by **[45-46-47],** reinforcing the importance of cultivar-specific fertilization strategies for enhancing onion storage quality and reducing postharvest losses.

Table (8). Averages values of weight loss (g) of onion plants as affected by the interaction among cultivars, N mineral and N biofertilization during the winter seasons of 2022/2023 and 2023/2024.

Treatments		Weight loss (g) estimation days after the harvest							
		After curing		After One Month		After Three Month		After Five Month	
cultivars	Fertilization	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Yellow	50%N+ without biofertilizers (0)	24.96 a-e	24.06 abc	15.54 a-k	16.02 a-d	33.63 a-g	30.7 a-d	49.48 d-n	43.56 b-g
	75% N+ without biofertilizers (0)	33.56 abc	24.51ab	2.12 k	6.52 gh	10.93 lm	16.37 c-j	17.66 n	23.89 g-k
	100%N+ without biofertilizers (0)	24.26 a-f	16.24 a-f	15.64 a-j	13.48 a-g	28.65 c-m	22.23 a-j	39.80 g-n	29.73 e-k
	50%N +*Enterobacter cloacae* (1)	28.58 a-d	17.18 a-e	30.79 ab	13.25 a-h	32.21 a-j	13.74 ij	84.82 b-d	31.82 d-k
	75%N + *Enterobacter cloacae* (1)	24.87 a-f	12.81 a-g	7.32 f-k	5.24 gh	21.1 i-m	10.29 j	32.04 h-n	14.29 k
	100%N + *Enterobacter cloacae* (1)	14.36 c-i	13.22 a-g	7.01 h-k	6.13 gh	18.26 j-m	11.11 j	31.97 i-n	17.18 i-k
	50%N+ *Sphingomonas paucimobilis* (2)	19.03 a-i	11.82 b-g	5.76 i-k	5.04 gh	20.12 i-m	11.65 ij	29.59 j-n	16.00 j-k
	75%N+ *Sphingomonas paucimobilis* (2)	15.2 c-i	11.08 c-g	11.73 b-k	9.12 c-h	24.32 d-m	15.5 f-j	61.98 c-m	34.61 c-k
	100%N+ *Sphingomonas paucimobilis* (2)	6.48 f-i	7.07 e-g	10.05 d-k	6.85 f-h	18.06 j-m	9.95 j	53.83 d-n	23.81 g-k
	50%N+ *Bacillus licheniformis* (K.95) (3)	15.85 c-i	12.25 a-g	5.92 h-k	6.9 f-h	12.9 lm	10.57 j	22.59 k-n	15.66 k
	75%N + *Bacillus licheniformis* (K.95) (3	22.93 a-h	14.22 a-g	8.01 e-k	7.82 f-h	27.92 c-m	17.33 c-j	71.10 c-i	37.97 b-j
	100%N + *Bacillus licheniformis* (K.95) (3	20.75 a-h	20.50 a-e	5.32 i-k	8.3 e-h	22.16 f-m	18.96 b-j	29.56 j-n	23.64 g-k
	50%N+ *Bacillus licheniformis***(ECto3)** (4)	20.43 a-h	14.86 a-f	7.91 e-k	8.69 c-h	18.96 j-m	14.94 g-j	28.18 k-n	20.15 h-k
	75%N + *Bacillus licheniformis***(ECto3)** (4)	38.12 ab	25.78 a	14.52 b-k	10.43 a-h	30.92 a-m	17.66 c-j	31.74 j-n	18.01 h-k
	100%N+ *Bacillus licheniformis*(ECto3) (4)	19.74 a-h	15.74 a-f	6.55 h-k	5.91 gh	21.57 g-m	11.82 ij	41.40 f-n	19.63 h-k
	50%N + Mixture of strains (1+2+3+4) (5)	40.59 a	22.20 a-d	5.74 i-k	8.49 d-h	15.88 k-m	15.34 g-j	25.08 k-n	21.55 h-k
	75%N + Mixture of strains (1+2+3+4) (5)	22.32 a-h	16.17 a-f	5.07 i-k	7.76 f-h	13.59 k-m	13.33 ij	19.91 n	17.46 h-k
	100%N+ Mixture of strains (1+2+3+4) (5)	23.08 a-g	16.79 a-e	8.36 e-k	7.21 f-h	34.07 a-f	17.95 b-j	41.66 f-n	21.12 h-k
Red	50%N+ without biofertilizers (0)	14.37 c-i	21.85 a-e	13.03 b-k	22.15 a	29.43 b-m	39.5 a	40.79 f-n	51.52 a-e
	75% N+ without biofertilizers (0)	9.09 e-i	9.41 d-g	16.1 a-j	13.03 a-h	34.51 a-e	22.79 a-i	89.44 bc	51.91 a-d
	100%N+ without biofertilizers (0)	10.96 d-i	12.98 a-g	10.36 c-k	15.09 a-e	28.31 c-m	29.58 a-e	36.59 g-n	36.25 c-j
	50%N +*Enterobacter cloacae* (1)	10.45 e-i	9.46 d-g	12.87 b-k	11.75 a-h	29.8 b-m	20.4 b-j	50.00 d-n	30.72 d-k
	75%N + *Enterobacter cloacae* (1)	22.35 a-h	16.65 a-f	17.74 a-h	21.3 ab	31.68 a-m	32.7 abc	79.44 b-f	71.79 a
	100%N + *Enterobacter cloacae* (1)	13.02 d-i	10.36 d-g	7.19 h-k	9.87 a-h	24.68 c-m	23.52 a-g	20.54 mn	20.29 h-k
	50%N + *Sphingomonas paucimobilis* (2)	7.2 f-i	8.15 e-g	11.02 b-k	11.44 a-h	24.69 c-m	20.32 b-j	41.68 e-n	31.36 d-k
	75%N + *Sphingomonas paucimobilis* (2)	7.48 f-i	8.34 e-g	7.32 g-k	10.64 a-h	22.79 e-m	22.81 a-i	33.19 h-n	30.99 d-k
	100%N + *Sphingomonas paucimobilis* (2)	12.66 d-i	9.67 d-g	8.53 e-k	11.91 a-h	17.39 j-m	19.29 b-j	21.56 k-n	22.77 g-k
	50%N+ *Bacillus licheniformis* (K.95) (3)	14.39 c-i	12.06 a-g	11.14 b-k	8.56 d-h	31.72 a-l	17.01 c-j	50.57 d-n	24.75 g-k
	75%N + *Bacillus licheniformis* (K.95) (3	11.8 d-i	10.10 d-g	6.42 h-k	6.25 gh	17.75 j-m	11.57 j	82.77 b-e	42.12 b-i
	100%N + *Bacillus licheniformis* (K.95) (3	14.85 c-i	11.23 c-g	10.95 b-k	12.23 a-h	24.99 c-m	23.19 a-h	28.46 k-n	25.89 f-k
	50%N+ *Bacillus licheniformis***(ECto3)** (4)	11.69 d-i	9.90 d-g	9.36 d-k	11.01 a-h	22.18 e-m	20.65 a-j	51.64 d-n	42.79 b-h
	75%N + *Bacillus licheniformis***(ECto3)** (4)	13.59 d-i	12.22 a-g	11.56 b-k	14.42 a-f	33.24 a-h	32.93 ab	48.29 e-n	45.78 a-f
	100%N+ *Bacillus licheniformis*(ECto3) (4)	8.99 e-i	6.69 e-g	0.18k	3.27 h	6.63 m	7.52 j	20.98 l-n	16.96 j-k
	50%N + Mixture of strains (1+2+3+4) (5)	11.41 d-i	9.87 d-g	4.83 jk	5.65 gh	21.45 h-m	15.8 e-j	30.97 j-n	21.62 g-k
	75%N + Mixture of strains (1+2+3+4) (5)	9.78 e-i	7.91 e-g	10.16 d-k	8.77 c-h	32.37 a-i	22.27 a-j	46.36 e-n	30.77 d-k
	100%N+ Mixture of strains (1+2+3+4) (5)	4.27 hi	5.45 fg	18.62 a-h	20.65 ab	31.1 a-m	32.23 abc	53.29 d-n	52.83 a-c
White	50%N+ without biofertilizers (0)	21.23 a-h	10.93 c-g	31.91 a	17.12 a-d	63.39 a	30.15 a-e	98.83 b	44.82 b-g
	75% N+ without biofertilizers (0)	16.27 b-i	12.02 b-g	19.2 a-f	13.42 a-h	32.21 a-k	19.91 b-j	100.00 a	62.47 a-b
	100%N+ without biofertilizers (0)	7.64 f-i	6.90 e-g	20.46 a-d	12.61 a-h	35.27 a-d	19.17 b-j	54.00 d-n	27.48 e-k
	50%N +*Enterobacter cloacae* (1)	10.53 d-i	8.80 d-g	29.92 abc	17.16 abc	48.35 ab	25.62 a-f	65.87 c-j	33.66 c-k
	75%N + *Enterobacter cloacae* (1)	10.62 d-i	6.69 e-g	19.2 a-g	10.82 a-h	36.43 a-d	17.77 b-j	55.87 d-n	25.62 g-k
	100%N + *Enterobacter cloacae* (1)	14.96 c-i	9.32 d-g	14.94 b-k	9.53 a-h	28.33 c-m	16.33 c-j	39.03 g-n	21.76 g-k
	50%N + *Sphingomonas paucimobilis* (2)	11.37 d-i	6.99 e-g	15.83 a-j	9.52 b-h	29.35 c-m	15.71 f-j	53.66 d-n	26.84 e-k
	75%N + *Sphingomonas paucimobilis* (2)	19.49 a-h	11.35 c-g	8.64 e-k	6.41 gh	31.22 a-m	16.93 c-j	41.30 f-n	21.63 g-k
	100%N + *Sphingomonas paucimobilis* (2)	4.85 ghi	4.62 g	14.83 b-k	10.97 a-h	26.58 c-m	17.83 b-j	51.44 d-n	32.33 d-k
	50%N+ *Bacillus licheniformis* (K.95) (3)	13.74 c-i	9.85 d-g	19.59 a-e	11.83 a-h	33.69 a-g	18.67 b-j	47.12 e-n	25.19 g-k
	75%N + *Bacillus licheniformis* (K.95) (3	0.76 i	3.45 g	7.45 e-k	8.52 d-h	24.41 c-m	19.04 b-j	33.38 g-n	24.60 g-k
	100%N + *Bacillus licheniformis* (K.95) (3	19.14 a-h	11.36 b-g	8.59 e-k	7.11 f-h	23.03 d-m	13.81 hij	73.33 c-g	37.15 b-j
	50%N+ *Bacillus licheniformis*(ECto3) (4)	23.43 a-g	13.15 a-g	9.15 e-k	7.35 f-h	28.94 c-m	16.21 c-j	73.18 c-h	36.03 c-k
	75%N + *Bacillus licheniformis*(ECto3) (4)	13.52 d-i	10.50 d-g	9.53 d-k	8.2 e-h	21.74 f-m	14.43 g-j	63.76 c-l	35.88 c-k
	100%N+ *Bacillus licheniformis*(ECto3) (4)	10.43 e-i	8.27 e-g	13.32 b-k	11.52 a-h	23.09 d-m	17.77 c-j	56.91 d-m	39.40 b-j
	50%N + Mixture of strains (1+2+3+4) (5)	18.56 b-i	11.47 b-g	13.96 b-k	9.77 a-h	26.87 c-m	15.99 d-j	55.39 d-n	29.75 d-k
	75%N + Mixture of strains (1+2+3+4) (5)	12.03 d-i	6.64 e-g	16.49 a-i	9.35 c-h	36.88 abc	17.49 c-j	65.43 c-k	28.88 e-k
	100%N+ Mixture of strains (1+2+3+4) (5)	11.78 d-i	8.62 e-g	10.64 c-k	8.78 c-h	19.89 i-m	13.76 hij	28.81 j-n	18.58 h-k

- Values having the same alphabetical letter(s) did not show a significant difference at 0.05 level of significance according to Duncan's multiple range test.

Conclusion

Under sandy soil conditions, the integration of biofertilizers with reduced nitrogen levels demonstrated a remarkable ability to enhance the quality and productivity of onion cultivars. The most effective treatment was the combination of *B. licheniformis(ECto3)* (strain 4) with 100% of the recommended nitrogen dose, which significantly improved NPK uptake and bulb weight, particularly in the Giza Red cultivar. The genetic potential of Giza White was confirmed by its consistently high accumulation of dry matter, total soluble solids, and total sugars, highlighting its superior quality traits. In terms of storability, the Giza 6 Mohassan cultivar exhibited the greatest potential for long-term storage, especially when combined with biofertilizer strains *B. licheniformis* (k.95) or (Mixture of bacterial strains (1+2+3+4)) and moderate nitrogen levels (50% or 75% does of N), resulting in the lowest cumulative weight loss during storage. Additionally, Giza 6 Mohassan achieved the highest vitamin C content. These findings demonstrate that cultivar specific, integrated nutrient management strategies can minimize excessive nitrogen use while successfully optimizing production and postharvest characteristics. It is advised that such biofertilizer-based systems be adopted for sustainable onion production, particularly in dry regions where soil health and resource efficiency are crucial. It was clearly demonstrated that strain 4 (*B. licheniformis*) led to the highest uptake of nitrogen, phosphorus, and potassium (NPK), which can be attributed to its multifunctional capabilities in promoting nutrient availability and plant uptake. These functional traits are well-supported by earlier research conducted in the Qassim Desert, where *B. licheniformis* emerged as the most dominant among the spore-forming Gram-positive isolates, representing 43.8% of the total microbial population. This remarkable strain displayed a high nitrogen-fixation capacity (>100 nmol C_2H_4/h) and produced substantial amounts of indole-3-acetic acid (IAA) ranging from 1.0 to 9.9 mg/L, both of which are key drivers of plant growth and development. Moreover, it exhibited a robust ability to solubilize phosphate and potassium, crucial for root and bulb development, and maintained tolerance to salinity stress up to 10% NaCl, highlighting its adaptability to harsh environments. Its broad enzymatic activity, as validated by API-ZYM assays, underscores its vigorous metabolic profile under desert conditions. Further molecular characterization confirmed its genetic identity with 99.87% similarity to *B. licheniformis* (GenBank accession no. OQ568846), solidifying its status as a promising bio-inoculant for enhancing crop productivity, particularly in arid and nutrient-depleted ecosystems. This conclusion was clearly supported by the data presented in reference [48-49].

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تأثير التسميد النيتروجيني الحيوي والمعدني على جودة وقابلية التخزين لثلاثة أصناف من البصل تحت ظروف المناطق الجافة

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الملخص

أُجريت هذه الدراسة في المزرعة البحثية التجريبية بكلية الزراعة والموارد الطبيعية، جامعة أسوان، جمهورية مصر العربية، خلال موسمين متتاليين 2022–2023 و2023–2024. وهدفت إلى تقييم التأثيرات المشتركة للتسميد بالنيتروجين والتلقيح الحيوي على جودة وخصائص التخزين لثلاثة أصناف من البصل المصري وهي: الجيزة 6 محسّن، الجيزة أحمر، والجيزة أبيض، تحت ظروف التربة الرملية. تم اختبار خمس سلالات بكتيرية مثبتة للنيتروجين (*Enterobacter cloacae, Sphingomonas paucimobilis, Bacillus licheniformis* (k.95), *Bacillus licheniformis*(ECto3), Mixture of bacterial strains) وثلاث مستويات من النيتروجين المعدني (50%، 75%، و100% من الكمية الموصى بها). وأظهرت النتائج أن التداخل بين السلالة *Bacillus licheniformis(ECto3)* (strain 4) مع استخدام 100% من التسميد النيتروجيني أدى إلى أعلى نسب من العناصر الغذائية (NPK) في الأبصال. وسجل صنف جيزة أبيض أعلى المحتوى في الوزن الجاف، المواد الصلبة الذائبة الكلية، السكريات الكلية .كما أن استخدام السلالة Mixture of bacterial strains مع 50% من الكمية النيتروجينية ادي الي زيادة السكريات الكلية والقدرة التخزينية . كما اظهرت النتائج تفوق صنف الجيزة 6 محسّن في محتوى فيتامين ج ,كما تفوق جيزة 6 محسن ايضا في القدرة التخزينية خلال فترة التخزين ، لا سيما عند استخدام السلالات الحيوية *Bacillus licheniformis* (k.95) أو Mixture of bacterial strains مع مستويات معتدلة من النيتروجين (50% أو 75%). وتوضح هذه النتائج أهمية التكامل بين التسميد الحيوى والمعدني لتحسين جودة وتخزين البصل.

الكلمات المفتاحية: البصل – الأسمدة الحيوية – مستويات النيتروجين – جودة البصلة – قابلة التخزين.