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Effect of N fertilizer rates and biofertilizer on productivity and quality of fodder sorghum

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Abstract

A field experiment was conducted at Farm of the Agricultural Faculty, Al-Azhar University, Assiut Governorate, Egypt, during successive summer seasons of 2022 and 2023 to study the effect of four nitrogen fertilizer rates (N1=30, N2= 60, N3= 90, N4= 120 kg N/feddan) (feddan = 4200 m² = 0.420 hectares = 1.037 acres) and biofertilizer (B0= without biofertilizer and B1= with Nitrobine as a biofertilizer) on productivity and quality of fodder sorghum (*Sorghum bicolor* L. Moench). A randomized complete block design (RCBD) in a split plot arrangement with four replications. The important results could be summarized as follows:

- Increasing nitrogen fertilizer rate from 30 up to120 kg N/feddan led to a significant increase in plant height, number of leaves/plant, number of tillers/plant, leaf area index (LAI) and fresh and dry forage yield t/feddan in the three cuts during the two studying seasons, as well as crude protein percentage in the first cut at both seasons and in the third cut of the second season only.
- The use of Nitrobine as a biofertilizer resulted in a significant increase in plant height, number of leaves/plant, number of tillers/plant, leaf area index (LAI) and fresh and dry forage yield t/feddan in the three cuts during the two studying seasons, as well as crude protein percentage in the first and the second cut at both seasons and also in the third cut of the second season only, this is compared to without biofertilizer.
- The results during the two studying seasons showed significant effects of the interaction between nitrogen fertilizer rates and biofertilizer on most of the traits studied and the best results were with nitrogen fertilization at rate 120 kg N/feddan with biofertilizer Nitrobine.

From the results, the study concluded that the biofertilizer Nitrobine used with nitrogen fertilization at rate 120 kg N/feddan led to increased productivity and quality of fodder sorghum.

Keywords: fodder sorghum, biofertilizer, crude protein, nitrogen fertilizer.

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1. Introduction

Forage crops play an important role in animal production. Egyptian farmers depend on feeding their animal on green forage crops *i.e.* sweet sorghum, pearl millet, Sudan grass, teosinte, corn plants and cow pea in summer after the end of clover season. Shahin *et al.* (2013) reported that the problem in Egypt for livestock production is the deficiency in forage crops during the summer season. So, increasing productivity per unit area in forage crop during the summer season to resolve this problem is considered the main aim. The increased shortage of green forage needs more attention to increase the forage yield of fodder sorghum. This will be achieved in part through improving the cultural practices of fodder sorghum; among which nitrogen fertilization and biofertilizer. Nitrogen fertilizers are very important for forage crop production and increase plant growth, yield and quality of forage crops. Mahmoud *et al.* (2013) stated that increasing nitrogen rate up to 120 kg/ feddan significantly increased stalk length and leaf area index (LAI) of sweet sorghum. Ibrahim *et al.* (2015) found that plant height and number of tillers/m^2 of pearl millet as affected by the application of nitrogen fertilizers. Bhumika *et al.* (2020) indicated that application of 80 kg N/ha. Recorded significantly highest plant height, number of leaves/plant and green and dry fodder yield of fodder sorghum. Patil *et al.* (2023) showed that application of 125% RDF to fodder sorghum produced significantly higher plant height, number of leaves/plant, leaf area index (LAI) and green forage yield, but number of tillers/plant was not affected significantly. Ismaeil *et al.* (2024) revealed that application of 120 kg N/ha. recorded significantly highest plant height, number of leaves/plant, fresh and dry forage yield and crude protein % at harvest of forage sorghum compared to the other treatment *i.e.* zero, 43, 86 and 120 kg N/ha. Sobhy Aburia *et al.* (2024) observed that increasing nitrogen rates from zero, 20, 30 up to 40 kg N/feddan recorded significantly increases in plant height, number of leaves/plant and number of tillers/plant of forage sorghum hybrid. Biofertilizers are substantial for increasing fertility of the soil where they play a central role in the increasing availability of nitrogen and crop productivity. Kumar and Sharma (2002) noticed that the increase in green and dry forage yield of forage sorghum due to Azospirillum inoculation, but its inoculation had no effect on crude protein percentage. Agrawal *et al.* (2005) proposed that the grains inoculation with Azospirillum obtained higher green fodder as well as dry matter yield of fodder sorghum over uninoculated treatment. Sheoranand Rana (2006) detected that significantly higher green and dry matter yield of forage sorghum was affected with the inoculation of Azotobacter over no biofertilizer treatment. Ahmed *et al.* (2010) indicated that there were significant differences of plant height and leaf area index (LAI) obtained when sorghum were applied by biofertilizer. Meena *et al.* (2010) recorded that the grains inoculation of forage sorghum with Azospirillum obtained significant increase in green forage and dry matter yield as compared to the grains uninoculated. Sardeood *et al.* (2013)

found that the highest forage yield obtained by application of 100% chemical fertilizer with biofertilizers of forage sorghum. Ibrahim *et al.* (2015) observed that mean plant height and number of tillers/m^2 as affected by the application of bio-N-fertilizers at harvest of forage pearl millet. Tandel *et al.* (2020) showed that biofertilizer significantly highest plant height, number of leaves/plant, green and dry fodder yield and crude protein percentage were recorded with inoculation of grains with biofertilizer over grains uninoculated. The main objective of this research was to study the effect of nitrogen fertilizer rates and biofertilizer on productivity and quality of fodder sorghum as an attempt to improve green fodder during the summer season under Assiut governorate conditions, Egypt.

2. Materials and methods

A field experiment was conducted at Farm of the Agricultural Faculty, Al-Azhar University at Assiut governorate, Egypt, during successive summer seasons of 2022 and 2023 to study the effect of nitrogen fertilizer rates (N1= 30, N2= 60, N3= 90, N4= 120 kg N/feddan) and biofertilizer (B0= without biofertilizer and B1= with Nitrobineas a biofertilizer) on productivity and quality of fodder sorghum. Soil physical and chemical properties of the experimental site were presented in Table (1).

2.1 Experimental design

A randomized complete block design (RCBD) in a split plot arrangement with four replications was used in both seasons. Nitrogen fertilizer rates were assigned to the main plots and biofertilizer was located in the sub plots. The sub plot area was 10.5 m^2 including 5 ridges, each 3.5 m long and 0.6 m wide. Grains of fodder sorghum (local hybrid 102) were provided by the Forage Research Division, Field Crops Research Institute, Giza, Ministry of Agricultural and Land Reclamation, Egypt. Before sowing, the grains of fodder sorghum were divided in two equal parts; the first part was uninculated as a control and the second part inoculated with 400 g/feddan of Nitrobine (*Azospirillium brasilense*) as a biofertilizer. The biofertilizer was produced by the Ministry of Agricultural and Land Reclamation, Egypt. Phosphorus fertilizer as calcium super phosphate (15.5% P_2O_5) was added before sowing with soil preparation at a rate of 100 kg/feddan in every season. Fodder sorghum grains were sown by hand in hills 20 cm apart, on two sides of ridges with 18 kg grains/feddan on 5 and 11 June in 2022 and 2023 seasons, respectively. Irrigation applied just after sowing and then irrigation was done every 15 days in the two seasons. The nitrogen fertilizer rates in the form of ammonium nitrate (33.5% N) were applied in three equal doses where, the first one was applied after 15 and 30 days (half and half), the second was applied after the first cut and the third was applied after the second cut. The three cuts were taken in the first season, also in the second season, the first cut was after

50 days from sowing date, the second cut was after 30 days from the first cut and the third cut was after 30 days from the second cut in the two seasons. The preceding winter crop was wheat (*Triticum aestivum* L.) in both seasons.

Table (1): Soil physical and chemical analysis of the experimental site.

Physical analysis	2022	2023	Chemical analysis	2022	2023
Sand (%)	26.22	26.50	Organic matter (%)	1.03	1.16
Silt (%)	38.25	37.12	Available N (ppm)	81.40	76.55
Clay (%)	35.53	36.38	Available P (ppm)	10.36	9.80
Soil texture	Clay loam		Available K (ppm)	365.23	352.34
			pH	7.79	7.93
			E.C. (ds./m)	1.13	1.16
			Total $CaCo_3$ (%)	2.82	2.64

2.2 Studied characters

2.2.1 Vegetative characters

At cutting time, a sample of five plants was randomly collected from each plot of the four replicates to measure the following characters at the three cuts:

- Plant height (cm)
- Number of leaves/plant
- Number of tillers/plant
- Leaf area index

2.2.2 Forage yield

Fresh forage yield (t/feddan): At cutting time, an area of 4.2 m^2 was cut (2 inner ridges, 3.5 m long) and fresh forage yield/feddan was calculated. Dry forage yield (t/feddan): Samples of 250 g fresh forage were dried oven at 70^o C up to constant weight and dry forage yield t/feddan was calculated.

2.2.3 Crude protein (CP %)

Total nitrogen content was determined by using the modified Kjeldahl method according to the A.O.A.C. (1980), crude protein was calculated by multiplying the total nitrogen by 6.25.

2.3 Statistical analysis

The collected data were statistically analyzed according to Gomez and Gomez (1984) using the computer MSTAT-C statistical analysis package by Freed *et al.* (1989). The least significant differences (LSD) test at probability level of 0.05 was manually calculated compared to the differences among means.

3. Results and Discussion

3.1 Vegetative characters

3.1.1 Plant height (cm)

Result presented in Table (2) observed that plant height (cm) of fodder sorghum was significantly increased with nitrogen fertilizer rates increased from 30 to 120 kg

N/feddan at 1st, 2nd and 3rd cut in 2022 and 2023 season. The highest values of plant height (152, 141 and 123 cm) and (149, 142 and 128 cm) at 1st, 2nd and 3rdcut in the first and the second season, respectively were obtained when nitrogen fertilizer was applied at rate of 120 kg N/feddan These results may be due to the role of nitrogen stimulating growth of fodder sorghum plant and increase in the number and length of internodes which result increase in plant height. These results are in harmony with those recorded by Ibrahim *et al.* (2015), Bhumika *et al.* (2020), Patil*et al.* (2023), Ismaeil *et al.* (2024) and Sobhy Aburia *et al.* (2024).

Table (2): Plant height (cm) of fodder sorghum as influenced by nitrogen fertilizer rates and biofertilizer and their interactions at 1st, 2nd and 3rd cut in 2022 and 2023 seasons.

Treatment	Plant height (cm)					
	1st Cut		2nd Cut		3rd Cut	
	2022	2023	2022	2023	2022	2023
Nitrogen fertilizer rates						
N1	116	110	100	102	76	81
N2	128	119	114	114	84	92
N3	138	131	124	121	88	99
N4	152	149	141	142	123	128
F-test	*	*	*	*	*	*
LSD at 5%	3.24	6.89	7.62	12.11	10.70	9.18
Biofertilizer						
B0	126	119	112	114	88	89
B1	141	134	127	126	98	111
F-test	*	*	*	*	*	*
Interactions						
N1 × B0	108	103	95	99	76	72
N1 × B1	124	116	105	105	76	90
N2 × B0	123	114	110	109	84	81
N2 × B1	133	124	119	120	85	102
N3 × B0	136	126	118	118	88	94
N3 × B1	140	136	130	124	89	104
N4 × B0	136	135	126	129	103	109
N4 × B1	168	162	156	156	143	148
F-test	*	*	N.S	*	*	N.S
LSD at 5%	6.89	6.35	----	10.42	9.58	----

* = significant at 0.05 probability level. N.S = non-significant difference. N1= nitrogen fertilizer at a rate of 30 kg N/feddan, N2= 60 kg N/feddan, N3= 90 kg N/feddan and N4= 120 kg N/feddan B0= without biofertilizer and B1= with biofertilizer.

The results in the same Table reveal that plant height was significantly affected by biofertilizer at 1st, 2nd and 3rd cut in both seasons. Generally, the highest values of plant height (141, 127 and 98 cm) and (134, 126 and 111 cm) at 1st, 2nd and 3rd cut in the first and the second season, respectively were recorded when inoculated with Nitrobine was used in both seasons. These results may be due to

the availability of nitrogen with applied biofertilizer which encourages cell division and elongation resulting in increased plant height. These results are in agreement with those obtained by Ahmed *et al.* (2010), Ibrahim *et al.* (2015) and Tandel *et al.* (2020). The interaction between nitrogen fertilizer rates and biofertilizer was significantly on plant height at 1st cut in the first and the second season, 2nd cut in the second season only and 3rd cut in the first season only. The tallest plant 168 and 162 cm at 1st cut in the first and the second season respectively, 156 cm at 2nd cut in the second season only and 143 cm at 3rd cut in the first season only were obtained when the nitrogen fertilizer was applied at rate of 120 kg N/feddan with biofertilizer.

3.1.2 Number of leaves/plant

Data presented in Table (3) indicated that number of leaves/plant of fodder sorghum was significantly increased with nitrogen fertilizer rates increased from 30 to 120 kg N/feddan at 1st, 2nd and 3rd cut in 2022 and 2023 seasons.

Table (3): Number of leaves/plant of fodder sorghum as influenced by nitrogen fertilizer rates and biofertilizer and their interactions at 1st, 2nd and 3rd cut in 2022 and 2023 seasons.

Treatment	Number of leaves/plant					
	1st Cut		2nd Cut		3rd Cut	
	2022	2023	2022	2023	2022	2023
Nitrogen fertilizer rates						
N1	8.65	9.18	9.48	9.53	8.43	8.91
N2	9.10	9.75	9.65	9.95	9.00	9.63
N3	9.48	10.11	9.96	10.31	9.63	10.20
N4	10.70	11.48	11.25	11.26	11.08	11.48
F-test	*	*	*	*	*	*
LSD at 5%	0.42	0.30	0.48	0.48	0.42	0.34
Biofertilizer						
B0	8.91	9.55	9.45	9.60	9.24	9.67
B1	10.05	10.70	10.71	10.92	9.83	10.44
F-test	*	*	*	*	*	*
Interactions						
N1 × B0	8.00	9.00	8.96	8.96	8.23	8.86
N1 × B1	9.30	9.36	10.00	10.10	8.63	8.96
N2 × B0	8.80	9.13	9.46	9.56	9.20	9.46
N2 × B1	9.40	10.36	9.83	10.33	8.80	9.80
N3 × B0	9.13	9.73	9.63	9.83	9.53	10.13
N3 × B1	9.83	10.50	10.30	10.80	9.73	10.26
N4 × B0	9.73	10.36	9.76	10.06	10.00	10.23
N4 × B1	11.66	12.60	12.73	12.46	12.16	12.73
F-test	*	*	*	*	*	*
LSD at 5%	0.51	0.76	0.44	0.65	0.53	0.46

* = significant at 0.05 probability level. N.S = non-significant difference. N1= nitrogen fertilizer at a rate of 30 kg N/feddan, N2= 60 kg N/feddan, N3= 90 kg N/feddan and N4= 120 kg N/feddan B0= without biofertilizer and B1= with biofertilizer.

The highest values of number of leaves/plant (10.70, 11.25 and 11.08) and (11.48, 11.26 and 11.48) at 1st, 2nd and 3rd cut in the first and the second season, respectively were recorded when nitrogen fertilizer was applied at rate of 120 kg N/feddan This increase in number of leaves due to nitrogen fertilizer encouraged the plant height of fodder sorghum plants and subsequently the leaves were increased. Similar results were found by Bhumika *et al.* (2020), Patil *et al.* (2023), Ismaeil *et al.* (2024) and Aburia *et al.* (2024). Also, the result presented in the same Table showed that number of leaves/plant had a significant effect by biofertilizer at 1st, 2nd and 3rd cut in both seasons. Generally, the highest values of number of leaves/plant (10.05, 10.71 and 9.83) and (10.70, 10.92 and 10.44) at 1st, 2nd and 3rd cut in the first and the second season, respectively. These results may be due to the vital role of biofertilizer which led to increase in nitrogen fixation and encourage cell division and elongation resulting in increased plant height and then number of leaves/plant were increased. These results are in full agreement with this obtained by Tandel *et al.* (2020). Concerning the interaction between nitrogen fertilizer rates and biofertilizer, the data revealed that there were significant effects on number of leaves/plant at 1st, 2nd and 3rd cut in both seasons. where the highest values of number of leaves/plant (11.66, 12.73 and 12.16) and (12.60, 12.46 and 12.73) at 1st, 2nd and 3rd cut in the first and the second season, respectively were obtained when the nitrogen fertilizer was applied at rate of 120 kg N/feddan with biofertilizer.

3.1.3 Number of tillers/plant

The obtained results in Table (4) pointed that number of tillers/plant of fodder sorghum was significantly increased with nitrogen fertilizer rates increased from 30 to 120 kg N/feddan at 1st, 2nd and 3rd cut in the first and the second season. Where the highest values of number of tillers/plant (4.15, 4.02 and 3.76) and (4.00, 3.91 and 4.16) at 1st, 2nd and 3rd cut in the first and the second season, respectively were recorded when nitrogen fertilizer was applied at rate of 120 kg N/feddan This may be attributed to the fact that increasing nitrogen fertilization leads to increased activity of the basal buds, leading to their growth and therefore increasing the number of tillers of plants. In general, the obtained results are in agreement with those recorded by Ibrahim *et al.* (2015), Bhumika *et al.* (2020), Ismaeil *et al.* (2024) and Sobhy Aburia *et al.* (2024). Results listed in Table (4) showed that number of tillers/plant was significantly influenced by biofertilizer at 1st, 2nd and 3rd cut in both seasons, where the highest values of number of tillers/plant (3.40, 3.23 and 3.53) and (3.29, 3.15 and 4.00 cm) at 1st, 2nd and 3rd cut in the first and the second season, respectively were recorded when inoculated with Nitrobine was applied in both seasons. These results may encourage the availability of nitrogen with

applied biofertilizer which encourages growth of plant and lead to an increase in the basal buds which effect in increasing number of tillers. These results are in line with those reported by Ibrahim *et al.* (2015).

Table (4): Number of tillers/plant of fodder sorghum as influenced by nitrogen fertilizer rates and biofertilizer and their interactions at 1st, 2nd and 3rd cut in 2022 and 2023 seasons.

Treatment	Number of tillers/plant					
	1st Cut		2nd Cut		3rd Cut	
	2022	2023	2022	2023	2022	2023
Nitrogen fertilizer rates						
N1	2.61	2.58	2.23	2.58	2.58	3.16
N2	2.83	2.55	2.56	2.76	2.81	3.31
N3	3.10	3.11	3.11	3.00	3.26	3.71
N4	4.15	4.00	4.02	3.91	3.76	4.16
F-test	*	*	*	*	*	*
LSD at 5%	0.32	0.45	0.46	0.36	0.19	0.34
Biofertilizer						
B0	2.95	2.83	2.73	2.97	2.68	3.18
B1	3.40	3.29	3.23	3.15	3.53	4.00
F-test	*	*	*	*	*	*
Interactions						
N1 × B0	2.46	2.40	2.26	2.56	2.43	2.66
N1 × B1	2.76	2.76	2.20	2.60	2.73	3.66
N2 × B0	2.70	2.70	2.56	2.76	2.76	2.80
N2 × B1	2.96	2.40	2.56	2.76	2.86	3.83
N3 × B0	2.96	2.93	2.86	3.03	2.66	3.56
N3 × B1	3.23	3.30	3.36	2.96	3.86	3.86
N4 × B0	3.66	3.30	3.23	3.53	2.86	3.70
N4 × B1	4.63	4.70	4.80	4.30	4.66	4.63
F-test	*	*	*	*	*	N.S
LSD at 5%	0.34	0.69	0.56	0.35	0.50	----

* = significant at 0.05 probability level. N.S = non-significant difference. N1= nitrogen fertilizer at a rate of 30 kg N/feddan, N2= 60 kg N/feddan, N3= 90 kg N/feddan and N4= 120 kg N/feddan B0= without biofertilizer and B1= with biofertilizer.

The interaction between nitrogen fertilizer rates and biofertilizer was significant on number of tillers/plant at all cut in both seasons, except in the 3rd cut at the second season was no significant. The highest values of number of tillers/plant (4.63, 4.80 and 4.66) at 1st, 2nd and 3rd cuts in the first season and (4.70 and 4.30) at 1st and 2nd cuts in the second season, respectively were obtained when the nitrogen fertilizer was applied at rate of 120 kg N/feddan with biofertilizer.

3.1.4 Leaf area index

The data presented in Table (5) indicated that Leaf area index of fodder sorghum was significantly increased with nitrogen fertilizer rates increased from 30 to 120 kg N/feddan at 1st, 2nd and 3rd cut in the first and the second season. Where the highest values of number of Leaf area index (7.96,

8.04 and 8.06) and (7.99, 8.00 and 7.97) at 1st, 2nd and 3rd cut in the first and the second season, respectively were recorded when nitrogen fertilizer was applied at rate of 120 kg N/feddan This result could be due to the fact that nitrogen enhances photosynthetic of plant which increase vegetative growth of fodder sorghum. These results are in confirming the finding of Mahmoud *et al.* (2013) and Patil *et al.* (2023). The recorded data in Table (5) showed that leaf area index was significantly influenced by biofertilizer at 1st, 2nd and 3rd cut in both seasons, where the highest values of Leaf area index (7.71, 7.76 and 7.76) and (7.62, 7.69 and 7.63) at 1st, 2nd and 3rd cut in the first and the second season, respectively were recorded when inoculated with Nitrobine was applied in both seasons.

Table (5): Leaf area index of fodder sorghum as influenced by nitrogen fertilizer rates and biofertilizer and their interactions at 1st, 2nd and 3rd cut in 2022 and 2023 seasons.

Treatment	Leaf area index					
	1st Cut		2nd Cut		3rd Cut	
	2022	2023	2022	2023	2022	2023
Nitrogen fertilizer rates						
N1	7.24	7.27	7.42	7.29	7.16	7.18
N2	7.42	7.26	7.47	7.26	7.35	7.38
N3	7.54	7.33	7.47	7.53	7.50	7.49
N4	7.96	7.99	8.04	8.00	8.06	7.97
F-test	*	*	*	*	*	*
LSD at 5%	0.22	0.28	0.29	0.18	0.32	0.31
Biofertilizer						
B0	7.37	7.30	7.44	7.35	7.27	7.38
B1	7.71	7.62	7.76	7.69	7.76	7.63
F-test	*	*	*	*	*	*
Interactions						
N1 × B0	7.08	7.19	7.28	7.28	6.90	7.02
N1 × B1	7.40	7.34	7.55	7.30	7.43	7.35
N2 × B0	7.25	7.14	7.45	7.10	7.21	7.26
N2 × B1	7.59	7.88	7.50	7.42	7.49	7.51
N3 × B0	7.55	7.22	7.40	7.40	7.43	7.41
N3 × B1	7.54	7.43	7.55	7.67	7.57	7.57
N4 × B0	7.61	7.65	7.62	7.61	7.55	7.83
N4 × B1	8.30	8.33	8.46	8.39	8.56	8.11
F-test	*	*	*	*	*	N.S
LSD at 5%	0.31	0.30	0.26	0.32	0.29	----

* = significant at 0.05 probability level. N.S = non-significant difference. N1= nitrogen fertilizer at a rate of 30 kg N/feddan, N2= 60 kg N/feddan, N3= 90 kg N/feddan and N4= 120 kg N/feddan B0= without biofertilizer and B1= with biofertilizer.

This result may be attributed to the biofertilizer which works to increase the biological activity in the plant which leads to an increase in vegetative growth in plant which is reflected in its effect in leaf area and Leaf area index. A similar result was recorded by Ahmed *et al.* (2010). The interaction between nitrogen fertilizer

rates and biofertilizer was significant on leaf area index at all cuts in both seasons, except in the 3rd cut at the second season was no significant. The highest values of Leaf area index (8.30, 8.46 and 8.56) at 1st, 2nd and 3rd cut in the first season and (8.33 and 8.39) at 1st and 2nd cuts in the second season, respectively were obtained when the nitrogen fertilizer was applied at rate of 120 kg N/feddan with biofertilizer.

3.2 Forage yield

3.2.1 Fresh forage yield (t/feddan)

The results as shown in Table (6) indicated that fresh forage yield of fodder sorghum was significantly increased with nitrogen fertilizer rates increasing up to 120 kg N/feddan at 1st, 2nd and 3rd cut in the first and the second season. Where the highest values of fresh forage yield (26.94, 26.53 and 25.85t/feddan) and (25.95, 26.53 and 24.00t/feddan) at 1st, 2nd and 3rd cut in the first and the second season, respectively were recorded when nitrogen fertilizer was applied at rate of 120 kg N/feddan Increase fresh forage yield with increase nitrogen fertilizer rates has been mainly due to increase in growth parameter *i.e.* plant height, leaf area, number of leaves per plant and number of tillers per plant.

Table (6): Fresh forage yield (t/feddan) of fodder sorghum as influenced by nitrogen fertilizer rates and biofertilizer and their interactions at 1st, 2nd and 3rd cut in 2022 and 2023 seasons.

Treatment	Fresh forage yield (t/feddan)					
	1st Cut		2nd Cut		3rd Cut	
	2022	2023	2022	2023	2022	2023
Nitrogen fertilizer rates						
N1	18.85	19.13	18.89	18.59	18.00	17.13
N2	22.00	20.83	21.99	20.48	20.59	17.84
N3	23.78	21.57	22.33	21.37	22.26	18.80
N4	26.94	25.95	26.53	26.53	25.85	24.00
F-test	*	*	*	*	*	*
LSD at 5%	1.61	0.98	2.49	2.33	2.41	2.04
Biofertilizer						
B0	21.38	20.96	20.86	20.95	20.39	18.35
B1	24.94	22.78	24.01	22.54	22.96	20.53
F-test	*	*	*	*	*	*
Interactions						
N1 × B0	16.69	18.74	16.25	17.36	17.58	16.46
N1 × B1	21.01	19.53	21.53	19.83	18.43	17.79
N2 × B0	20.69	20.68	21.15	19.85	19.48	17.32
N2 × B1	23.31	20.99	22.83	21.11	21.71	18.36
N3 × B0	23.44	21.58	21.66	20.60	21.76	18.95
N3 × B1	24.11	21.56	23.00	22.14	22.77	18.66
N4 × B0	24.69	22.86	24.39	25.99	22.74	20.67
N4 × B1	29.19	29.04	28.66	27.07	28.95	27.33
F-test	N.S	*	N.S	N.S	N.S	*
LSD at 5%	----	1.30	----	----	----	2.38

* = significant at 0.05 probability level. N.S = non-significant difference. N1= nitrogen fertilizer at a rate of 30 kg N/feddan, N2= 60 kg N/feddan, N3= 90 kg N/feddan and N4= 120 kg N/feddan B0= without biofertilizer and B1= with biofertilizer.

These results are largely consistent with those obtained by Bhumika *et al.* (2020), Patil *et al.* (2023) and Ismaeil *et al.* (2024). Generally, the results in the same Table show that fresh forage yield was significantly affected by biofertilizer at 1st, 2nd and 3rd cut in both seasons, where the highest values of fresh forage yield (24.94, 24.01 and 22.96 t/feddan) and (22.78, 22.54 and 20.53 t/feddan) at 1st, 2nd and 3rd cut in the first and the second season, respectively were recorded when inoculated with Nitrobine was applied in both seasons. Biofertilizer application might have enhanced N fixation to be utilized by plants of fodder sorghum and ultimately increased the fresh forage yield. Similar results were recorded by Kumar and sharma (2002), Agrawal *et al.* (2005), Sheoran and Rana (2006), Meena *et al.* (2010) and Tandel *et al.* (2020). The interaction between nitrogen fertilizer rates and biofertilizer was significant on fresh forage yield at 1st and 3rd cut in the second season only. The highest values of fresh forage yield 29.04 and 27.33 t/feddanat 1st and 3rd cut in the second season only were obtained when the nitrogen fertilizer was applied at a rate of 120 kg N/feddan and biofertilizer was applied.

3.2.2 Dry forage yield (t/feddan)

Data illustrated in Table (7) revealed that dry forage yield of fodder sorghum was significantly increased with nitrogen fertilizer rates increasing up to 120 kg N/feddan at 1st, 2nd and 3rd cut in the first and the second season. Where the highest values of dry forage yield (3.78, 3.91 and 4.06 t/feddan) and (3.73, 4.13 and 4.14 t/feddan) at 1st, 2nd and 3rd cut in the first and the second season, respectively were recorded when nitrogen fertilizer was applied at rate of 120 kg N/feddan These results may be due to the vital role of nitrogen in building amino acids and cell membranes which together contribute to increasing plant height, number of leaves and tillers which led to high dry forage yield. These results are in harmony with those obtained by Bhumika *et al.* (2020) and Ismaeil *et al.* (2024). Here too, The data in Table (7) showed that dry forage yield was significantly influenced by biofertilizer at 1st, 2nd and 3rd cut in both seasons, where the highest values of dry forage yield (2.75, 2.86 and 2.84 t/feddan) and (2.74, 2.92 and 3.09 t/feddan) at 1st, 2nd and 3rd cut in the first and the second season, respectively were recorded when inoculated with biofertilizer was applied in both seasons. Similar results were recorded by Kumar and sharma (2002), Agrawal *et al.* (2005), Sheoran and Rana (2006), Ahmed *et al.* (2010), Meena *et al.* (2010) and Tandel *et al.* (2020). The interaction between nitrogen fertilizer rates and biofertilizer was significant on dry forage yield at 1st and 3rd cut in the second and the first season, respectively. The highest values of dry forage yield 4.22 and 4.68 t/feddan at 1st and 3rd cut in the second and the first season, respectively were obtained when the nitrogen fertilizer was applied at a rate of 120 kg N/feddan and biofertilizer was applied.

Table (7): Dry forage yield (t/feddan) of fodder sorghum as influenced by nitrogen fertilizer rates and biofertilizer and their interactions at 1st, 2nd and 3rd cut in 2022 and 2023 seasons.

Treatment	Dry forage yield (t/feddan)					
	1st Cut		2nd Cut		3rd Cut	
	2022	2023	2022	2023	2022	2023
Nitrogen fertilizer rates						
N1	1.28	1.21	1.37	1.29	1.33	1.36
N2	2.25	2.24	2.19	2.28	2.28	2.62
N3	3.00	3.08	3.22	3.29	2.99	3.68
N4	3.78	3.73	3.91	4.13	4.06	4.14
F-test	*	*	*	*	*	*
LSD at 5%	0.31	0.14	0.227	0.26	0.39	0.22
Biofertilizer						
B0	2.40	2.39	2.48	2.57	2.49	2.81
B1	2.75	2.74	2.86	2.92	2.84	3.09
F-test	*	*	*	*	*	*
Interactions						
N1 × B0	1.12	1.18	1.18	1.18	1.28	1.32
N1 × B1	1.44	1.24	1.55	1.40	1.38	1.41
N2 × B0	2.22	2.22	2.14	2.21	2.17	2.55
N2 × B1	2.27	2.25	2.24	2.35	2.40	2.70
N3 × B0	2.95	2.91	3.16	3.16	3.08	3.64
N3 × B1	3.04	3.25	3.28	3.42	2.90	3.73
N4 × B0	3.31	3.23	3.44	3.73	3.45	3.76
N4 × B1	4.26	4.22	4.39	4.53	4.68	4.52
F-test	N.S	*	N.S	N.S	*	N.S
LSD at 5%	----	0.40	----	----	0.47	----

* = significant at 0.05 probability level. N.S = non-significant difference. N1= nitrogen fertilizer at a rate of 30 kg N/feddan, N2= 60 kg N/feddan, N3= 90 kg N/feddan and N4= 120 kg N/feddan B0= without biofertilizer and B1= with biofertilizer.

3.3 Crude protein (CP %)

Data in Table (8) showed that crude protein % of fodder sorghum was significantly affected with nitrogen fertilizer rates increased from 30 to 120 kg N/feddan at 1stcut in the first and the second season and 3rd in the second season only, where the highest values of crude protein (10.60 and 11.52 %) at 1st cut in the first and the second season, respectively and (10.46 %) at 3rd in the second season only, were recorded when nitrogen fertilizer was applied at rate of 120 kg N/feddan increase in crude protein % with increment in nitrogen rates was due to increased absorption of nitrogen. These results are in agreement with obtained by Ismaeil *et al.* (2024). The results collected in Table (8) showed that crude protein % of fodder sorghum was significantly influenced by biofertilizer at 1st and 2nd cut in both seasons and at 3rd cut in the second season only, where the highest values of crude protein (10.24 and 10.86 %) and (9.47 and 9.83 %) at 1st and 2nd cut in the first and the second season, respectively and (9.51 %) at 3rd cut in the second season, only were recorded when inoculated with Nitrobine was applied in

both seasons. Biofertilizer might have enhanced N fixation to be utilized by fodder sorghum plants and ultimately increased the protein percentage. A similar result was found by Tandel *et al.* (2020).

Table (8): Crude protein (%) of fodder sorghum as influenced by nitrogen fertilizer rates and biofertilizer and their interactions at 1st, 2nd and 3rd cut in 2022 and 2023 seasons.

Treatment	Crude protein (CP%)					
	1st Cut		2nd Cut		3rd Cut	
	2022	2023	2022	2023	2022	2023
Nitrogen fertilizer rates						
N1	8.92	9.26	8.68	8.57	8.19	8.78
N2	9.31	10.11	8.70	8.99	8.37	9.02
N3	9.51	10.08	8.79	9.12	8.48	9.19
N4	10.60	11.52	10.65	10.47	10.27	10.46
F-test	*	*	N.S	N.S	N.S	*
LSD at 5%	0.82	0.87	----	----	----	1.18
Biofertilizer						
B0	8.92	9.62	8.94	8.75	8.47	9.21
B1	10.24	10.86	9.47	9.83	9.18	9.51
F-test	*	*	*	*	N.S	*
Interactions						
N1 × B0	8.36	8.90	8.48	8.22	7.91	8.68
N1 × B1	9.48	9.62	8.88	8.93	8.48	8.88
N2 × B0	8.78	9.40	8.59	8.41	8.08	9.04
N2 × B1	9.84	10.82	9.98	9.56	8.66	9.00
N3 × B0	9.11	9.66	8.62	8.64	8.11	9.17
N3 × B1	9.91	10.51	8.79	9.61	8.84	9.22
N4 × B0	9.46	10.52	10.07	9.73	9.80	9.97
N4 × B1	11.74	12.51	11.24	11.21	10.75	10.96
F-test	N.S	N.S	N.S	N.S	N.S	*
LSD at 5%	----	----	----	----	----	0.17

* = significant at 0.05 probability level. N.S = non-significant difference. N1= nitrogen fertilizer at a rate of 30 kg N/feddan, N2= 60 kg N/feddan, N3= 90 kg N/feddan and N4= 120 kg N/feddan B0= without biofertilizer and B1= with biofertilizer.

The interaction between nitrogen fertilizer rates and biofertilizer was significant on crude protein % at 3rd cut in the second season only. The highest values of crude protein (10.96 %) at 3rd cut in the second season only were obtained when the nitrogen fertilizer was applied at a rate of 120 kg N/feddan and biofertilizer was applied.

4. Conclusion

From the two seasons experiment, it can be concluded that Nitrobine as a biofertilizer used with nitrogen fertilizer at a rate of 120 kg N/feddan increased productivity and quality of fodder sorghum.

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