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Effect of Mineral and Bio Nitrogen Fertilization on Growth, Productivity and Quality of some Summer Forage Crops

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ABSTRACT

Two field experiments were conducted at El-Gemmeiza Farm, Agricultural Research Center, during 2022 and 2023 seasons to study three forage crops (millet, sudan grass and teosinte) under six levels of recommended mineral nitrogen fertilizer (RMNF) beside grain inoculation with cerealin biofertilizer (bio) on growth characters, dry matter accumulation, forage productivity and quality as well as correlation coefficient between fresh forage yield/fed and all previous characters.- The averages of three cuts, millet crop were superior to sudan grass and teosinte crops in no. of tillers and leaves/plant, leaves area, dry weights of leaves, stem and total/plant as well as fresh and dry yields/fed. However, sudan grass surpassed the rest crops in plant height. Meanwhile, Teosinte crop exceeded in protein and digestible protein% in both seasons. - Application of 100% RMNF + bio (T_5) recorded the highest significant values for all studied traits compared to the other tested N fertilization treatments during the two growing seasons. However, there were no significant differences between 75% RMNF+ bio(T_4)and100%RMNF + without bio (T_6) for all the studied traits in the three cuts during the two growing seasons.-The interaction between the two tested factors indicated that the application of T_5 generally recorded the highest values for most characters studied in the tested crops in one or more cuts in both seasons.- There were a positive and high significant phenotypic correlation between fresh forage yield/fed and all growth characters, dry matter accumulation and dry forage yield/fed as well as CP% and DCP% mostly in the three forage crops.

***Keywords*:** N Mineral, Bio fertilization, Teosinte, Sudan grass, Pearl millet

INTRODUCTION

In Egypt, the farmers really suffered from feed deficiency for their livestock's, especially during summer season because of limited cultivated area and the competition between human food and animal feed. Therefore, great efforts recently were achieved to grow many favorable annual grass forage crops such as millet, sudan grass and teosinte etc. into the Egyptian agricultural rotation and crop composition for maximizing the forage production in summer season.

Millet (*Pennisetum glaucum*), sudan grass (*Sorghum vulgare var sudanense*) and teosinte (*Euchlaena mexicana*) belongs to *poaceae* family are considered as promising summer grass forage crops. They had high efficiency for producing large amounts of biomass and vegetative canopy through many cuttings per season as well as high resistance to biotic and / or abiotic stress condition and consequently encouraged the total forage production especially in arid and semi-arid conditions. These advantages were previously reported by Osman *et al.*, (2022) and El-Gaafarey *et al.*, (2023) for sudan grass, Habib *et al.*, (2007) and Hassan *et al.*, (2022) for millet and Habiba *et al.*, (2018 a) and Fayed *et al.*, (2020) for teosinte.

Many investigations were done for using the mineral nitrogen (N) fertilization to enhance the growth, productivity and quality of some forage crops such as millet (Habib *et al.*, 2007 and Ibrahim *et al.*, 2014), sudan grass (Ikanovic, 2014 and Ziki *et al.*, 2019) and teosinte (Aboelgoud *et al.*, 2022).

Implementation of biofertilizers results in increasing forage crops production with increased sustainable and environmentally friendly productivity and soil fertility. Therefore, some researchers found an increase in the growth and total forage production of some forage crops by the inoculation with various biofertilizers including some nitrogen fixing bacteria as reported by Hassan (2017) and Swami (2020) for millet, Abd El-Rahman *et al.*, (2005) and Chahal *et al.*, (2021) for sudan grass and Ibrahim *et al.*, (2009) for teosinte. Moreover, it is well known that *Azospirillium spp* is considered non – symbiotic nitrogen fixing bacteria and has more ability to fix considerable quality of N in the rhizosphere in non-leguminous crops such as cereals, grass forage crops and etc. and consequently the chemical N fertilizer can be saved by the inoculation with such bacteria (Rani *et al.*, 2019).

Therefore, the present investigation was carried out to study the response of some grass summer crops (millet, sudan grass and teosinte) to various levels of mineral N fertilization and grain inoculation with biofertilizer namely cerealin included *Azospirillium* bacteria as well as to detect the suitable combination of them for maximizing the development and forage production and quality of the three crops.

MATERIALS AND METHODS

Two field experiments were done in the experimental farm at El-Gemmeiza Agriculture Research Station (ARC), El-Gharbia Governorate, Egypt (Latitude:

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30° 79 53 and Longitude: 31° 12 28) to study the influence of different levels of recommended mineral nitrogen fertilizer (RMNF) as well as grain inoculation with biofertilizer (cerealin) on some summer forage crops during 2022 and 2023 seasons. Each experiment included 18 treatments which were the combination of two factors as follows:

A- Three summer forage crops:

1- Millet (Shandawel 1 variety)
2- Sudan grass (Giza 2 variety)
3- Teosinte (Gemmeiza 4 variety)

B- Six nitrogen (N) fertilization treatments:

(T_1) 0 % RMNF + without cerealin inoculation (control)
(T_2) 0 % RMNF + cerealin inoculation
(T_3) 50 % RMNF + cerealin inoculation
(T_4) 75 % RMNF + cerealin inoculation
(T_5) 100 % RMNF + cerealin inoculation
(T_6) 100 % RMNF + without cerealin inoculation

At each experiment, the treatments were arranged in a split plot design with three replications. The three forage crops were allocated at random in main plots, while the six N fertilization treatments were allocated at random in sub-plots. The area of each sub plot was 12 m^2 including 4 rows (3.75 m long and 0.80 m width). The mechanical and chemical analysis for the experimental soil as well as temperature and relative humidity % of experimental area are shown in Tables 1 and 2, respectively. The grains of the tested forage crops were obtained from the Forage Crops Research Section, Field Crops Research Institute, ARC, Giza, Egypt.

Table 1. Mechanical and chemical analysis of experimental soils in 2022 and 2023 seasons

Soil properties		2022	2023
Mechanical analysis			
Sand %		22.24	22.06
Silt %		28.63	30.03
Clay %		49.13	47.91
Texture class		clay	clay
Chemical analysis			
pH		8.13	7.92
E.C. (ds/m)		1.55	0.65
Soluble cations (meq/l)	Ca^{++}	4.55	1.55
	Mg^{++}	3.80	2.05
	Na^{+}	6.54	2.52
	K^{+}	0.28	0.41
Soluble anions (meq/l)	HCO_3^-	6.88	3.09
	Cl^-	3.90	1.90
	SO_4^-	4.52	1.41
Available nutrients (ppm)	N	41.06	44.06
	P	3.49	5.81
	K	405.36	463.15

Table 2. Monthly average of temperature and relative humidity during the growing periods of forage crops in 2022 and 2023 seasons.

Month	2022 season			2023 season		
	Temperature (c°)		Relative humidity	Temperature (c°)		Relative humidity
	Max	Min	(%)	Max	Min	(%)
June	38.69	21.33	45.16	38.65	21.45	43.59
July	39.74	21.94	45.75	41.76	23.12	44.65
August	39.61	23.22	49.03	40.59	23.53	48.05
September	37.84	21.91	50.99	39.17	22.97	48.46
October	32.07	18.78	57.85	33.47	20.13	58.60

Before sowing, the grains of each crop were inoculated with biofertilizer namely cerealin included non-symbiotic nitrogen fixing bacteria, i.e. *Azospirillium brasilense*, with the exception of T_1 and T_6 treatments. The tested biofertilizer was produced by Microbiological Department, Soil, Water and Environment Research Institute, Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Arab Republic of Egypt. Grains were sown on 23th and 18th June in 2022 and 2023 seasons, respectively. Grains were hand sown in hills 20 cm apart on both sides of each row, using seeding rates of 20, 20 and 25 kg grains/fed for millet, sudan grass and teosinte, respectively. The preceding crops in this experiment were flax and Egyptian clover in the first and second seasons, respectively. Phosphorus fertilizer at a rate of 200 kg/fed calcium superphosphate (15.5 % P_2O_5) and potassium fertilizer at a rate of 50 kg/fed potassium sulphate (48% K_2O) were added at single dose for each crop during land preparation. The recommended mineral nitrogen fertilizer, i.e. 100 % RMNF (65 Kg N/ fed) was applied in the form of urea (46.5 % N). The experienced N fertilization treatments, i.e. 0, 50, 75 and 100 % RMNF were divided to three equal doses, at 21 days after sowing (DAS) and after first and second cuts. Three cuts were taken from each forage crop at 60 DAS, 40 days after the first cut and 30 days after the second cut.

Characters studied:

At each cut, the following characters were determined in every plot

1- Growth characters

Plant height (cm), number (no.) of tillers/plants, no. of leaves/plant and leaves area/ plant (cm^2) were estimated as an average of five plants.

2- Dry matter accumulation

- Leaves, stem and total dry weights/ plant (g) were estimated as an average of five plants.
- **Dry matter percentage (DM %):** it was determined by drying 100 g (as a sample), from fresh weight of five plants, until a constant weight and then DM % was estimated as follows

$$\text{DM \%} = \frac{\text{Dry weight of the sample}}{\text{Fresh weight of the sample}} \times 100$$

3-Forage production

-Fresh forage yield/ fed (ton): it was estimated from all plants grown in the two central rows at each plot (fed = 4200 m^2).

-Dry forage yield/ fed (ton): it was calculated by multiplying fresh forage yield/ fed by dry matter %.

4- Forage quality

The following chemical composition and nutritive value were determined in sample included whole plant (leaves + stem)

- **Crude protein (CP %):** Nitrogen percentage was determined according to the methods described by AOAC (2019) and then CP % was calculated by multiplying nitrogen percentage by 6.25
- **Total carbohydrate (TC %):** It was determined using hydrochloric acid method by spectrophotometer at wavelength 490 nm as described by Dubois *et al.*, (1956).
- **Digestible crude protein (DCP %):** It was calculated according to the formula by Bredon *et al.*, (1963): DCP % = (CP % X 0.9596) – 3.55

5- Correlation studies:

Simple phenotypic correlation coefficient was calculated between the fresh forage yield/fed and each of growth characters, dry matter accumulation and forage quality for each forage crop (overall means of the six fertilization treatments and three cuts) during the two seasons.

Statistical analysis:

The data, in each cut at every season, were statistically analyzed according to the methods described by Snedecor and Cochran (1989). Duncan's multiple range test (Duncan, 1955) was used to compare the treatment means. The mean values designated by the same letter (s) in each column are not significantly at 5 % level.

RESULTS AND DISCUSSION

1- Growth characters

Table 3 included the growth characters studied (plant height, no. of tillers/plant, no. of leaves/plant and leaves area/ plant) of the three tested summer forage crops (millet, sudan grass and teosinte) as affected by different mineral and biofertilization of nitrogen (N) treatments at three cuts in 2022 and 2023 seasons.

Data show that there are significant differences among the three forage crops in all growth characters studied in the three cuts in both seasons. Sudan grass crop had the highest significant values of plant height (129.78 cm) in the first season and (182.06 cm) in the second season, as an average of the three cuts. However, millet crop produced the highest significant values of no. of tillers/ plant (5.36) in the first season and (6.13) in the second season, as an average of the three cuts. In addition, millet crop was superior to the other crops in no. of leaves/ plant (25.10 and 40.11) and leaves area / plant (6028.3 and 9385.1 cm^2) in the early growth period (1st cut). Teosinte crop surpassed in no. of leaves/ plant (18.77 and 30.50) and leaves area/ plant (3335.4 and 3896.0 cm^2) in the later growth period (3rd cut) in the first and second seasons, respectively. Similar results were previously obtained by other investigators who found superiority of sudan grass crop in plant height (Hassan *et al.*, 2017, Rady, 2018 and Hassan *et al.*, 2022), millet crop in no. of tillers (Habib *et al.*, 2007, Hassan *et al.*, 2016 and Abd El-Naby *et al.*, 2016) and teosinte crop in no. and area of leaves/ plant (Mohamed, 2024) as compared with other summer grass forage crops.

Regardless of the three tested forage crops, it can be noticed that application of N element as a mineral and / or as a biofertilizer caused a significant increment in all growth characters studied herein compared to the unfertilized plants (T_1) (at the three cuts) in both seasons. Plants fertilized with 100 % of the recommended mineral N fertilizer (RMNF) and inoculated with cerealin biofertilizer (T_5) produced the highest significant values of plant height (130.51 and 172.63 cm), no. of tillers/ plant (5.45 and 5.85), no. of leaves/ plant (20.08 and 38.85) and leaves area/ plant (5907.8 and 7503.5 cm^2) in the first and second season, respectively, as an average of the three cuts. This superiority of such treatment (T_5) may be due to the positive effect of N element forms either as mineral fertilizer or biofertilizer for enhancing the activity of meristematic tissue and cell division which caused elongation in plant height and increasing in no. of tillers and leaves/ plant.

Table 3. Growth characters of some summer forage crops as affected by N mineral and bio fertilization at three cuts during 2022 and 2023 seasons.

Characters	Crops Fertilization	2022 season											
		1st cut				2nd cut				3rd cut			
		Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean
Plant height (cm)	T_1(0%+0)	104.65 ef	116.41 de	57.30 h	92.79 D	80.77 gh	96.24 e-h	71.29 h	82.77 C	71.43 gh	79.37 f	50.71 j	67.18 E
	T_2(0%+B)	127.62 cd	136.95 cd	76.40 gh	113.66 C	104.90 d-h	120.30 c-f	89.12 fgh	104.77 B	82.10 f	88.19 e	59.65 i	76.65 D
	T_3(50%+B)	137.86 cd	148.12 c	78.87 gh	121.62 BC	112.07 c-g	129.40 b-e	91.45 fgh	110.97 B	87.75 e	98.11 cd	66.82 h	84.23 C
	T_4(75%+B)	143.95 c	149.79 bc	83.80 fg	125.85 BC	132.17 bcd	156.97 ab	98.12 d-h	129.10 A	88.70 e	108.81 b	72.46 gh	89.99 B
	T_5(100%+B)	171.45 ab	191.95 a	91.50 fg	151.63 A	145.07 abc	170.37 a	109.78 d-g	141.74 A	102.25 c	116.00 a	76.19 fg	98.15 A
	T_6(100%+0)	146.78 c	151.45 bc	86.83 fg	128.35 B	131.40 bcd	165.10 a	106.45 d-g	134.62 A	95.91 d	114.63 a	78.66 f	96.40 A
	Mean	138.72 A	149.11 A	79.12 B		117.70 B	139.37 A	94.37 C		88.02 B	100.85 A	67.42 C	
No. of tillers/ plant	T_1(0%+0)	4.45 d-g	2.93 h	3.42 gh	3.60 D	4.47 c-f	2.98 g	3.50 fg	3.65 D	3.00 def	2.13 f	2.57 ef	2.57 D
	T_2(0%+B)	5.11 cde	3.67 fgh	4.17 d-h	4.32 C	5.26 bc	3.50 fg	3.89 d-g	4.22 CD	4.00 a-e	2.67 ef	3.33 c-f	3.33 CD
	T_3(50%+B)	6.15 abc	3.83 e-g	4.17 d-h	4.72 BC	5.56 bc	3.50 fg	4.56 c-f	4.54 C	4.67 abc	3.00 def	3.67 b-f	3.78 BC
	T_4(75%+B)	6.56 ab	4.50 d-g	4.33 d-g	5.13 AB	6.11 ab	4.33 c-f	5.11 bcd	5.18 B	4.33 a-d	3.33 c-f	4.33 a-d	4.00 ABC
	T_5(100%+B)	6.67 a	5.00 c-f	5.33 bcd	5.67 A	7.00 a	4.83 cde	6.22 ab	6.02 A	5.33 a	4.00 a-e	5.00 ab	4.78 A
	T_6(100%+0)	6.56 ab	4.67 d-g	5.00 c-f	5.41 AB	6.28 ab	3.67 efg	6.11 ab	5.35 B	5.00 ab	3.67 b-f	4.67 abc	4.45 AB
	Mean	5.92 A	4.10 B	4.40 B		5.78 A	3.80 C	4.90 B		4.39 A	3.13 A	3.93 A	
No. of leaves/ plant	T_1(0%+0)	20.47 cd	13.73 hi	9.85 j	14.68 D	14.13 gh	9.76 i	19.47 de	14.46 D	11.57 i	9.50 j	13.60 fgh	11.56 E
	T_2(0%+B)	24.33 b	16.75 fg	12.67 i	17.92 C	17.67 ef	11.48 hi	24.08 bc	17.74 C	12.85 h	11.32 i	17.67 c	13.95 D
	T_3(50%+B)	25.83 ab	17.69 ef	15.07 gh	19.53 B	19.33 de	13.19 gh	24.08 bc	18.87 BC	13.01 gh	12.85 h	18.67 b	14.85 C
	T_4(75%+B)	26.08 ab	19.00 de	15.33 gh	20.14 B	20.67 de	14.14 gh	25.58 ab	20.13 AB	13.96 ef	13.43 fgh	20.67 a	16.02 B
	T_5(100%+B)	27.08 a	21.25 c	16.67 fg	21.67 A	22.00 cd	15.16 fg	27.33 a	21.50 A	15.43 d	14.49 e	21.33 a	17.08 A
	T_6(100%+0)	26.83 a	19.56 cde	15.67 fgh	20.69 AB	21.00 d	14.85 fg	24.33 bc	20.06 AB	13.90 ef	13.62 fg	20.67 a	16.06 B
	Mean	25.10 A	18.00 B	14.21 C		19.13 B	13.10 C	24.15 A		13.45 B	12.53 C	18.77 A	
Leaves area/ Plant (cm^2)	T_1(0%+0)	4402.9 def	2556.0 f	2723.8 f	3227.6 C	2805.4 cde	1262.9 e	4240.1 a-e	2769.5 C	1931.5 ij	1849.6 j	2146.0 hi	1975.7 F
	T_2(0%+B)	5179.9 b-e	3194.9 ef	3321.7 ef	3898.8 C	3643.4 b-e	1683.8 de	5300.1 abc	3542.4 BC	2205.2 h	2176.0 hi	2384.5 gh	2255.2 E
	T_3(50%+B)	6101.6 a-d	4557.1 c-f	4502.5 def	5053.7 B	4844.6 ad	3042.6 cde	5878.8 abc	4588.7 AB	2651.2 f	2560.4 fg	3185.6 e	2799.1 D
	T_4(75%+B)	6685.1 abc	5243.9 b-e	5130.5 b-e	5686.5 B	5445.5 abc	3429.4 b-e	6140.4 abc	5008.4 AB	2969.5 e	3001.5 e	3683.5 cd	3218.2 C
	T_5(100%+B)	7440.0 a	7088.2 ab	6460.0 a-d	6996.1 A	7325.2 a	4688.8 a-d	6765.9 ab	6260.0 A	4563.8 a	4053.0 b	4785.0 a	4467.3 A
	T_6(100%+0)	6360.5 a-d	5600.4 a-d	5492.9 a-d	5817.9 B	6195.7 abc	3409.6 b-e	6658.5 ab	5421.3 A	3464.3 d	2933.0 e	3827.7 bc	3408.3 B
	Mean	6028.3 A	4706.8 B	4605.2 B		5045.0 A	2919.5 B	5830.6 A		2964.3 B	2762.3 C	3335.4 A	

0, 50, 75 and 100 % of recommended mineral N fertilizer (RMNF), B: grain inoculation with N biofertilizer (cerealin)

Table 3. continued.

Characters	Crops Fertilization	2023 season											
		1st cut				2nd cut				3rd cut			
		Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean
Plant height (cm)	T_1 (0% + 0)	109.00g	117.67 fg	91.67h	106.11D	129.33gh	157.33def	102.00i	129.55D	123.00b-f	99.67f	119.67 c-f	114.11 B
	T_2 (0% + B)	142.33e	194.33bc	102.00gh	146.22C	135.33fg	176.00cd	112.00hi	141.11C	133.67b-f	156.00abc	97.33f	129.00AB
	T_3 (50 % + B)	171.33d	198.33b	111.00 g	160.22B	136.33fg	189.33bc	141.33efg	155.67B	136.67b-f	155.00a-d	101.33 ef	131.00AB
	T_4 (75 % + B)	181.67cd	203.33b	112.00fg	165.67B	139.33efg	190.33bc	150.00efg	159.45B	140.00b-f	159.67abc	113.33c-f	137.67AB
	T_5 (100 % +B)	188.00bc	256.67a	127.33ef	190.67A	146.67efg	216.33a	161.33 de	174.78A	150.33a-e	189.33a	117.67c-f	152.44A
	T_6(100 %+0)	142.00e	247.67a	113.33fg	167.67B	141.67efg	203.67ab	133.00g	159.89B	141.67a-f	171.33ab	105.33def	139.45AB
	Mean	155.72B	203.00A	109.56C		138.11B	188.83A	133.28B		137.56B	155.17A	109.11C	
No. of tillers/ plant	T_1 (0% + 0)	6.67bcd	2.67i	3.67ghi	4.34D	3.67f	3.67f	4.67def	4.00D	3.33Cd	2.67de	2.00e	2.67C
	T_2 (0% + B)	7.33abc	3.33hi	5.00efg	5.22C	5.67cde	4.33ef	4.67def	4.89C	3.33cd	3.33cd	2.67de	3.11B
	T_3 (50 % + B)	7.67ab	4.33fgh	5.00efg	5.67BC	6.67bc	4.33ef	5.00def	5.33BC	3.67bc	3.33cd	3.33cd	3.44B
	T_4 (75 % + B)	7.67ab	5.30def	6.00cde	6.32AB	7.33b	4.64def	5.64cde	5.87B	4.33ab	3.67bc	3.67bc	3.89A
	T_5 (100 % +B)	8.67a	5.67 def	5.33def	6.56A	9.67a	4.67def	6.00cd	6.78A	4.33ab	3.67bc	4.67a	4.22A
	T_6 (100 %+0)	8.67a	5.33def	5.33def	6.44AB	7.67b	4.67def	5.67cde	6.01B	4.00abc	3.67 bc	4.33ab	4.00A
	Mean	7.78 A	4.44 B	5.06B		6.78A	4.38C	5.27B		3.83A	3.39B	3.44B	
No. of leaves/ plant	T_1 (0% + 0)	33.67 def	29.00 e-h	26.67h	29.78D	30.33gh	20.00j	34.00efg	28.11C	21.33h	21.33h	24.67ef	22.44D
	T_2 (0% + B)	34.33 cde	29.33 e-h	27.33gh	30.33D	31.00gh	22.67ij	36.33b-g	30.00C	23.67fgh	22.00gh	25.33def	23.67D
	T_3 (50 % + B)	40.00abc	33.33d-g	28.00fgh	33.78C	41.33a-d	27.33hi	38.33a-f	35.66B	27.67d	23.33fgh	32.00bc	27.67C
	T_4 (75 % + B)	43.67 ab	40.00abc	29.67e-h	37.78B	42.00abc	32.67fgh	36.00c-g	36.89B	25.67def	27.00de	32.00bc	28.22BC
	T_5 (100 % +B)	46.00a	41.00ab	38.33bcd	41.78A	42.33abc	40.00a-e	41.33a-d	41.22A	33.67ab	31.67bc	35.33a	33.56A
	T_6 (100 %+0)	43.00ab	40.33ab	30.67e-h	38.00B	42.67ab	35.00d-g	43.33a	40.33A	30.33c	24.00fg	33.67ab	29.33B
	Mean	40.11A	35.50 B	30.11C		38.29A	29.61B	38.22A		27.06B	24.89C	30.50A	
Leaves area/ Plant (cm^2)	T_1 (0% + 0)	6265.8def	2187.1h	1447.6h	3300.2D	3172.0efg	1474.2g	4142.9d-g	2929.7D	2279.1gh	1108.6i	2590.5gh	1992.7E
	T_2 (0% + B)	7509.9cde	3795.4fgh	2995.8gh	4767.1C	3423.2efg	1933.9fg	4213.1d-g	3190.1D	2765.8fgh	2183.6h	2625.0fgh	2524.8D
	T_3 (50 % + B)	10030.3bc	4783.4efg	5652.4 ef	6822.0B	4444.0def	3465.0efg	4784.5de	4231.2CD	3396.9def	3574.6 de	3046.7efg	3339.4C
	T_4(75 % + B)	10555.5ab	5307.5efg	6124.2def	7329.1AB	5134.8cde	4885.4 de	5567.3cde	5195.8C	4035.1d	3825.2 de	3393.9def	3751.4C
	T_5 (100 % +B)	9241.2bc	8695.4bcd	6402.3def	8453.2A	9732.5a	6047.0cde	9338.6 ab	8372.8A	5441.7b	4803.6bc	6808.0a	5684.4A
	T_6 (100 %+0)	12708.0a	6367.9def	6283.8def	8113.0B	6838.8bcd	5303.8cde	7861.1abc	6667.9B	5098.3b	4156.3cd	4911.6b	4722.1B
	Mean	9385.1A	5189.5B	4817.7B		5457.5AB	3851.6B	5984.6A		3836.2A	3275.3B	3896.0A	

0, 50, 75 and 100 % of recommended mineral N fertilizer (RMNF), B: grain inoculation with N biofertilizer (cerealin)

In this concern, many researchers found that application of N fertilizer either as mineral fertilizer of as biofertilizer caused an increase in plant height, no. of tillers/plants, no. of leaves/plants and leaves area/ plant of sudan grass crop (Abd El-Rahman *et al.,* 2005) and millet crop (Hassan, 2017) as well as plant height of teosinte crop (Ibrahim *et al.,* 2009) compared to unfertilized plants. On the other hand, plants fertilized with 100 % RMNF only (T_6) as well as those fertilized with 75 % RMNF and inoculated with cerealin biofertilizer (T_4) took the second and third rank, respectively, for increasing all abovementioned growth characters without significant differences between them, in most cuts, in both seasons. This means that seed inoculation with N biofertilizer (cerealin) combined with application of moderate level of N mineral fertilizer (75 % RMNF) produced the same significant values of growth characters obtained by the application of high level of N mineral fertilizer (100 % RMNF) alone without N biofertilizer, indicating that using N biofertilizer had beneficial and additive effect to N mineral fertilizer for improving the growth characters of the tested forage crops. This beneficial effect maybe due to promoting some growth regulators such as indole acetic acid (IAA), cytokinin and gibberellic acid beside N_2 fixation by some nitrogen fixing bacteria. In this respect Jain and Patriquin (1985), Kennedy and Tchan (1992), Mikhailouskaya and Bogdevitch (2009) and Vishnu *et al.,* (2022) came to the same conclusion.

The interaction between the two experienced factors (3 forage crops and 6 fertilization treatments) had a significant effect on all growth characters studied in the three cuts during both seasons. The behavior of growth characters for the tested forage crops to the interaction treatments was fluctuated from crop to another at three cuts. Significantly highest values were observed for plant height by sudan grass (at three cuts), no. of tillers/ plant by millet (at three cuts), no. of leaves/ plant by millet (at 1st cut) and by teosinte (at 2nd and 3rd cuts) and leaves area/ plant by millet (at 1st and 2nd cuts) and by teosinte (at 3rd cut) when they were fertilized with 100 % RMNF and inoculated with cerealin biofertilizer (T_5), mostly in both seasons. Nevertheless, it can be noticed that there are no significant differences among the plants fertilized with 50 or 75 % RMNF beside cerealin inoculation (T_3 or T_4) and those fertilized with 100 % RMNF only (T_6) in all growth characters studied herein at each tested forage crop (mostly at three cuts) in both seasons. This means that the grain inoculation with N biofertilizer in combination with mineral N fertilization at medium levels are able to complement each other and so make better use of N resources than when they were added separately. Similar results were obtained by many investigators who found that application of N as mineral and biofertilization together was more effective for promoting the growth and development of plant height and no. of tillers/ plant (Ibrahim *et al.,* 2013 and Hassan, 2017) as well as no. and area of leaves/ plant (Habiba *et al.,* 2018 b) for some forage crops as compared with their individual application.

Additionally, it can be noticed that the mean values of all growth traits studied herein for each of millet and sudan grass crops were decreased gradually with successive cuts from the early cut (1st cut) up to the later one (3rd cut) in both seasons. Reversely, such growth traits for teosinte crop were increased up to the 2nd cut and then decreased another time up to 3rd cut in the two seasons. These results were previously supported by Habiba *et al.,* (2018 a) for teosinte crop, Hassan (2017) and El-Gaafarey *et al.*, (2023) for millet crop and Mohamed (2024) for sudan grass crop.

2- Dry matter accumulation:

Dry matter accumulation is an important yield contributing characters that may affect the forage production of forage crops. Results of dry matter accumulation/ plant (leaves, stem and total dry weight/ plant as well as dry matter %) are significantly affected by the three tested forage crops and six fertilization treatments and their interaction at most cuts in both seasons as shown in Table 4.

In comparison among the three tested forage crops, it can be noticed that the distribution of dry matter accumulation in different plant organs for tested forage crops varied from cut to another. Leaves dry weight/ plant of millet crop was superior at 1st cut (27.83 g), but the superiority of such trait was recorded by teosinte crop at 2nd and 3rd cuts (26.52 and 16.29 g), respectively, as an average of both seasons. Reversely, the highest values of stem and total dry weight/ plant at 1st cut were obtained by sudan grass (37.95 and 60.65 g) in the first season but by millet crop (40.74 and 69.60 g) in the second season for the same respective traits without significant differences between the two crops, mostly, in both seasons. However, at the later cut, millet crop produced the highest values of stem dry weight (25.07 and 25.88 g) and total dry weight/ plant (38.00 and 44.10 g) in the first and second season, respectively. The superiority of total dry weight for sudan grass crop (at early cut) and for millet crop (at later cut) may be due to the increase in plant height for sudan grass, as well as no. of tillers and leaves/ plant and leaves area/plant of millet crop at such cuts as shown previously in Table 3

Nevertheless, teosinte crop produced the lowest values of stem and total dry weight/ plant at three cuts compared to the rest tested forage crops in both seasons. However, there are no significant differences among the three tested forage crops in their dry matter %, mostly, at three cuts in both seasons. These results were supported by other investigators who found variation among some summer grass forage crops in their stem dry weight in favor of sudan grass crop (Silungwe, 2011 and Machado *et al.*, 2018) as well as leaves and total dry weight/ shoot in favor of millet crop (Mohamed, 2024)

Regarding the influence of N mineral and biofertilization treatments, data registered significant differences among N treatments, overall, the three forage crops, for the dry matter accumulation traits studied at all cuts in both seasons. It is evident that application of the highest N level, i.e. 100 % RMNF, beside inoculation with cerealin biofertilizer (T_5) accumulated the highest amounts of dry matter/ plant for leaves (27.83, 27.97 and 20.99 g), stem (39.86, 35.26 and 26.59 g), total plant (67.68, 63.23 and 47.57 g) and dry matter % (20.38, 21.61 and 26.72 %) at the first, second and third cuts, respectively, as an average of both seasons. Nevertheless, there are no significant differences between the application of medium N level (75 % RMNF) beside cerealin inoculation (T_4) and the application of highest N level (100 % RMNF) alone (T_6) for the dry matter accumulation in the leaves, stem and total plant, mostly, at three cuts in both seasons. This indicated that N biofertilizer can be relatively compensate the decline in the mineral N fertilization level that used in T_4 treatment (75 % RMNF).

Table 4. Dry matter accumulation of some summer forage crops as affected by N mineral and bio fertilization at three cuts during 2022 and 2023 seasons.

Characters	Crops Fertilization	2022 season											
		1st cut				2nd cut				3rd cut			
		Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean
Leaves dry weight/ plant (g)	T_1(0% + 0)	22.52bc	15.74ef	13.10f	17.12C	18.13fg	14.27g	17.41fg	16.61C	9.31f	8.35g	10.39e	9.35E
	T_2(0% + B)	27.81a	19.93cd	17.24de	21.66B	21.59c-f	19.29ef	24.04a-e	21.64B	10.46e	9.94ef	12.08d	10.83D
	T_3(50 % + B)	26.47a	21.39c	18.29de	22.05B	20.06def	21.34def	27.65ab	23.02AB	12.52d	10.39e	12.90d	11.94C
	T_4(75 % + B)	28.00a	26.58a	21.80c	25.46A	23.44b-e	22.22c-f	28.51a	24.72A	15.03bc	14.80bc	15.15b	14.99A
	T_5(100 %+B)	28.06a	27.13a	25.05ab	26.75A	25.10a-d	21.21def	28.78a	25.03A	15.60ab	14.06c	16.16a	15.27A
	T_6(100 %+0)	27.88a	25.40ab	22.88bc	26.73A	23.54b-e	20.43def	26.41abc	23.46AB	14.67bc	12.38d	14.76bc	13.94B
	Mean	26.79A	22.70B	19.73C		21.98B	19.79C	25.46A		12.93A	11.65B	13.57A	
Stem dry weight/ plant (g)	T_1(0% + 0)	21.78fgh	22.42fgh	11.82h	18.67C	17.84d	18.95d	16.85d	17.88B	19.05de	12.74gh	11.49h	14.42E
	T_2(0% + B)	27.66def	28.38def	13.28gh	23.11BC	19.58d	23.39cd	18.12d	20.63B	22.68bc	15.16fg	14.55fgh	17.46D
	T_3(50 % + B)	32.54c-f	33.87b-f	13.32gh	26.57B	28.83abc	34.63a	20.13d	27.86A	24.78b	19.04de	15.49efg	19.77C
	T_4(75 % + B)	36.39b-e	48.41a	24.37fg	36.39A	29.90abc	35.78a	23.11cd	29.60A	24.00bc	21.33bcd	16.42ef	20.58C
	T_5(100 %+B)	36.88bcd	49.78a	24.87efg	37.18A	28.47abc	32.54ab	28.43abc	29.81A	31.38a	24.31bc	20.68cd	25.46A
	T_6(100 %+0)	41.42abc	44.86ab	23.73fg	36.67A	32.22ab	32.38ab	24.33bcd	29.64A	28.55a	23.41bc	16.58ef	22.84B
	Mean	32.78B	37.95A	18.56C		26.14A	29.61A	21.83A		25.07A	19.33B	15.87C	
Total dry weight/ plant (g)	T_1(0% + 0)	44.30fg	38.16gh	24.92i	35.79C	35.97fg	33.22g	34.26fg	34.48C	28.36fgh	21.09j	21.88ij	23.78E
	T_2 (0% + B)	55.47def	48.31efg	30.52hi	44.77B	41.17efg	42.68c-f	42.16d-g	42.00B	33.14de	25.10hi	26.63gh	28.29D
	T_3(50 % + B)	59.01ce	55.26def	31.61hi	48.63B	48.89a-e	55.97ab	47.78b-e	50.88A	37.30c	29.43fg	28.39fgh	31.71C
	T_4(75 % + B)	64.39bcd	74.99ab	46.17fg	61.85A	53.34ab	58.00a	51.62abc	54.32A	39.02c	36.13cd	31.57ef	35.57B
	T_5(100 %+B)	64.94bcd	76.91a	49.92efg	63.92A	53.57ab	53.75ab	57.21ab	54.84A	46.98a	38.37c	36.84c	40.73A
	T_6(100 %+0)	69.30abc	70.26abc	46.61fg	62.06A	55.76ab	52.81ab	50.74a-d	53.10A	43.22b	35.79cd	31.34ef	36.78B
	Mean	59.57A	60.65A	38.29B		48.12A	49.41A	47.30A		38.00A	30.99B	29.44B	
Dry matter %	T_1(0% + 0)	14.32ef	15.34cde	12.08f	13.91C	17.04ab	15.57b	15.53b	16.05B	14.42i	16.68hi	17.15hi	16.08D
	T_2(0% + B)	15.83b-e	15.52b-e	14.05ef	15.13C	17.51ab	17.44ab	16.69ab	17.22AB	16.62hi	17.69h	17.35hi	17.22D
	T_3(50 % + B)	15.89b-e	15.30cde	14.51def	15.23C	17.94ab	16.75ab	18.05ab	17.58AB	19.34gh	19.17gh	21.89efg	20.14C
	T_4(75 % + B)	17.31a-e	17.74a-d	17.32a-e	17.46B	19.04ab	19.54ab	17.65ab	18.74AB	23.20def	20.85fg	24.12de	22.72B
	T_5(100 %+B)	18.35abc	20.16a	20.02a	19.51A	19.34ab	22.11a	19.43ab	20.29A	32.44a	21.93efg	28.03bc	27.46A
	T_6(100 %+0)	17.80a-d	18.80ab	18.76ab	18.46AB	20.33ab	20.53ab	19.33ab	20.06A	30.86ab	21.25efg	25.61cd	25.91A
	Mean	16.58A	17.14A	16.12A		18.53A	18.66A	17.78A		22.81A	19.59B	22.36A	

0 75 ,50 ,and 100 % of recommended mineral N fertilizer (RMNF), B: grain inoculation with N biofertilizer (cerealin)

Table 4. continued.

Characters	Crops Fertilization	2023 season											
		1st cut				2nd cut				3rd cut			
		Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean
Leaves dry weight/ plant (g)	T_1 (0% + 0)	23.79d-g	16.67 h	15.01 h	18.49 C	18.74ghi	14.05 i	17.86 hi	16.88 E	10.19 f	11.47 ef	10.56 f	10.74 D
	T_2 (0% + B)	29.44 ab	21.05 fg	20.84 g	23.78 B	22.66d-h	18.77ghi	24.91b-h	22.11 D	13.70def	14.16def	12.88 ef	13.58 D
	T_3 (50 % + B)	28.34abc	22.87efg	24.20def	25.14 B	21.58e-h	19.86 f-i	29.38a-d	23.61CD	16.67cde	16.25cde	16.39 cde	16.44 C
	T_4 (75 % + B)	30.45 a	26.72bcd	24.21def	27.13 A	26.07a-g	23.80c-h	30.30abc	26.72BC	21.51 bc	19.13bcd	20.14 bc	20.26 B
	T_5 (100 %+B)	31.16 a	29.43 ab	26.13cde	28.91 A	32.23 ab	27.47a-e	33.04 a	30.91 A	23.77 b	22.98 b	33.34 a	26.70 A
	T_6 (100 %+0)	29.97 ab	28.25abc	25.52cde	27.91 A	27.01 a-f	26.20a-f	29.97a-d	27.73AB	23.48 b	22.89 b	20.69 bc	22.35 B
	Mean	28.86 A	24.17 B	22.65 B		24.72 A	21.69 B	27.58 A		18.22 A	17.81 A	19.00 A	
Stem dry weight/ plant (g)	T_1 (0% + 0)	22.59 ij	21.89 j	11.89 k	18.79 E	19.51 de	20.08 de	17.53 e	19.04D	19.54c-h	14.09 gh	12.02 h	15.22 D
	T_2 (0% + B)	28.96 g	28.04 g	13.52 k	23.51 D	24.45 de	23.19 de	19.06 e	22.23D	23.32 b-f	16.48e-h	14.86 fgh	18.22 CD
	T_3 (50 % + B)	35.31 ef	33.31 f	13.71 k	27.44 C	34.80abc	35.83abc	22.87 de	31.17C	25.57a-d	20.55b-h	16.14 e-h	20.75 BC
	T_4 (75 % + B)	49.16 b	37.46 de	25.13 h	37.25 B	36.39 ab	40.41 a	26.64cde	34.48BC	24.97a-e	22.89b-g	17.21 d-h	21.69 BC
	T_5 (100 %+B)	57.23 a	43.82 c	26.53 gh	42.53 A	41.48 a	43.64 a	36.98 ab	40.70A	32.55 a	27.93abc	22.66 b-g	27.71 A
	T_6 (100 %+0)	51.22 b	38.00 d	24.92 hi	38.05 B	37.29 ab	43.08 a	29.17bcd	36.51AB	29.35 ab	26.12a-d	17.59 d-h	24.35 AB
	Mean	40.74 A	33.75 B	19.28 C		32.32 A	34.37 A	25.37 B		25.88 A	21.34AB	16.75 B	
Total dry weight/ plant (g)	T_1 (0% + 0)	46.38g	38.56h	26.90j	37.28E	38.25hi	34.13i	35.39hi	35.92E	29.73efg	25.56fg	22.58g	25.96E
	T_2 (0% + B)	58.40e	49.09fg	34.36i	47.28D	47.11e-h	41.96ghi	43.97f-i	44.35D	37.02def	30.64efg	27.74fg	31.80DE
	T_3 (50 % + B)	63.65d	56.18e	37.91h	52.58C	56.38de	55.69def	52.25d-g	54.77C	42.24b-e	36.80def	32.53efg	37.19CD
	T_4 (75 % + B)	79.61b	64.18d	49.34fg	64.38B	62.46a-d	64.21a-d	56.94cde	61.20B	46.48a-d	42.02b-e	37.35def	41.95BC
	T_5 (100 %+B)	88.39a	73.25c	52.66f	71.43A	74.52a	71.11ab	69.21abc	71.61A	56.32a	50.91abc	56.00a	54.41A
	T_6 (100 %+0)	81.19b	66.25d	50.44f	65.96B	64.30a-d	69.28abc	59.14b-e	64.24B	52.83ab	49.01a-d	38.28c-f	46.71B
	Mean	69.60A	57.92B	41.94C		57.04A	56.06A	52.95B		44.10A	39.16AB	35.75B	
Dry matter %	T_1 (0% + 0)	14.07j	16.04hi	13.38j	14.50F	15.73i	15.97hi	13.21k	14.97F	20.46jk	15.41m	20.56ijk	18.81F
	T_2 (0% + B)	15.94hi	17.11g	14.26j	15.77E	15.34ij	18.89ef	13.68k	15.97E	21.88gh	17.89l	21.42hij	20.40E
	T_3 (50 % + B)	17.34fg	17.78efg	15.25i	16.79D	17.20gh	19.47de	14.16jk	16.95D	22.90efg	19.67k	21.93gh	21.50D
	T_4 (75 % + B)	18.20ef	19.84d	16.79gh	18.28C	20.09de	20.62cd	17.82fg	19.51C	22.88efg	21.73ghi	22.63fgh	22.41C
	T_5 (100 %+B)	21.53ab	22.34a	19.85d	21.24A	23.46a	23.49a	21.81bc	22.92A	26.83a	25.20bc	25.91ab	25.98A
	T_6 (100 %+0)	21.06bc	20.42cd	18.68e	20.05B	21.70bc	22.58ab	18.73ef	21.00B	24.34cd	24.08cde	23.31def	23.91B
	Mean	18.02A	18.92A	16.37A		18.92A	20.17A	16.57A		23.21A	20.66A	22.63A	

0, 50, 75 and 100 % of recommended mineral N fertilizer (RMNF), B: grain inoculation with N biofertilizer (cerealin)

Moreover, it can be noticed that the plants inoculated with cerealin biofertilizer alone (T_2) significantly increased the dry matter accumulation traits studied (leaves, stem and total plant) more than the unfertilized plants (T_1) at three cuts in both seasons. However, the inoculation with cerealin biofertilizer alone was not sufficient to reach the maximum productivity of dry matter accumulation compared to when its combination with mineral N fertilizer at any level. In this respect, many investigators found that application of N element either as a mineral and / or as a biofertilizer caused an increment in total dry weight/ plant of some forage crops such as sudan grass (Abd El-Rahman *et al.,* 2005, Ziki *et al.,* 2019 and Chahal *et al.,* 2021), forage sorghum (Afzal *et al.,* 2013 and Rathore, 2016) and millet (Habiba *et al.,* 2018 b and Swami *et al.,* 2020).

The interaction between the tested forage crops and N fertilization treatments on dry matter accumulation of leaves, stem and total plant were significant at all cuts in both seasons. Generally, it can be noticed that plants fertilized with 100 % RMNF and inoculated with cerealin biofertilizer (T_5) produced the highest values of leaves dry weight, especially by millet crop (at 1st cut), and teosinte (at 2nd and 3rd cuts) in both seasons. Moreover, the highest values of stem and total dry weight/ plant as well as dry matter % were recorded by sudan grass (at 1st and 2nd cuts) and by millet (at 3rd cut) when they were fertilized with the same treatment (T_5) in the first season. However, in the second season, sudan grass or millet crops were superior in stem, total dry weight/ plant and dry matter % (at 1st and 2nd cuts), while millet crop was superior in such traits (at 3rd cut) when they were fertilized mostly with (T_5). Noticeably, there are non-significant effect among the application of 50 or 75 % RMNF beside inoculation with cerealin biofertilizer (T_3 or T_4) and the application of 100 % RMNF only without inoculation (T_6) for most dry matter accumulation studied at the three cuts in both seasons. This reflect the impact role of N biofertilizer which promoting plant growth characters compared to the mineral N fertilization alone, as shown in Table 3. This advantage may be attributed to the adequate supply of many macro and micro elements and some growth regulators which were released around the plant roots with biofertilizer application.

Observably, the values of dry matter accumulation/ plant (leaves, stem and total dry weight/ plant) for millet and sudan grass crops recorded the highest values in the early growth period (1st cut) and then the values were gradually decline with age progress up to the later period (3rd cut). However, teosinte crop recorded the highest values of those traits in the medium period (2nd cut) and then decreased up to 3rd cut where produced the lowest ones in the two seasons. Oppositely, at later cut (3rd cut) the values of dry matter % recorded the highest amounts, while the lowest ones were recorded at early cut (1st cut) in the three tested forage crops in both seasons. These results may be due to the increase in the fiber and/ or carbohydrate in such forage crop canopy at their later growth stage. Similar conclusions were obtained also by Abd el-shafy (1991), Marei (1992) and Mohamed (2024).

3- Forage production:

Forage production (fresh and dry forage yields/ fed) of the tested forage crops (millet, sudan grass and teosinte) under different N levels of mineral and biofertilization and their interaction at the three cuts and total of them in both seasons are presented in Table 5.

Significant variation was detected among the three tested forage crops in their forage production in favor of millet crop which produced the highest values of fresh and dry forage yields/ fed (18.201 and 3.207 ton) at the 1st cut, (15.618 and 4.969 ton) at the 2nd cut and (43.156 and 8.395 ton) at the total of three cuts, respectively, as an average of the two seasons. Reversely, teosinte crop significantly outyielded the rest crops mostly in the 3rd, where it produced the maximum values of fresh yield/ fed (11.519 ton) and dry forage yield/ fed (2.637 ton), as an average of the two growing seasons. From these results, it can be suggested that the superiority of millet crop in its total forage production/ fed compared to the other crops may be attributed to the clear increment of its growth characters (plant height, no. of tillers/plants, no. of leaves/plants and leaves area/ plant), as shown in Table 3 and total dry matter accumulation/ plant, as shown in Table 4 at one or more cut during the two growing seasons. In this respect, Hassan *et al.,* (2016), Hassan *et al.,* (2022) and Mohamed (2024) found also that millet crop was superior to sudan grass and teosinte in its forage production per fed

Overall means of the three tested forage crops, the data indicated that application of N element either as a mineral fertilizer and / or as a biofertilizer (cerealin) caused an increase in fresh and dry forage yields/ fed at three cuts and their total compared to unfertilized plants in both seasons. The relative increase in total fresh yield/ fed amounted to 17.15, 31.63, 51.67, 78.03 and 65.66 % as well as that of total dry yield/ fed amounted to 26.16, 50.12, 89.86, 154.25 and 124.42 % for total dry yield/ fed when the plants were fertilized with T_2, T_3, T_4, T_5 and T_6 treatments, respectively more than the unfertilized plants (T_1), as an average of both seasons. From these results, it can be observed that the maximum pronounced relative increase % occurred herein were obtained by application of 100 % RMNF accompanied with cerealin biofertilizer inoculation (T_5). The superiority of all growth characters studied and dry matter accumulation/ plant that recorded by the application of T_5 treatment as previously discussed in Tables 3 and 4 may be contributed to high productivity of forage crops/ fed under such treatment compared to the other treatments.

However, there are no significant differences between the application of 100 % RMNF alone (T_6) and the application of 75 % RMNF combined with cerealin biofertilizer inoculation (T_4) for both fresh and dry forage yields/ fed at most cuts in both seasons. These results indicated to the importance of inoculation with cerealin biofertilizer for saving about 25 % of mineral N fertilizer level as well as producing the same significant yields/ fed obtained by high level of mineral N fertilizer alone. These results were supported by Ibrahim *et al.,* (2013), Hassan (2017) and Habiba *et al.,* (2018 b) who suggested that integration of mineral N fertilizer with N biofertilizer, containing N fixing bacteria, showed a considerable improvement of forage production per unit area of millet crop.

Table 5. Fresh and dry forage yields of some summer forage crops as affected by N mineral and bio fertilization at three cuts and their total during 2022 and 2023 seasons.

Cuts	Crops	2022 season									
		Fresh forage yield/ fed (ton)					Dry forage yield/ fed (ton)				
	Fertilization	Millet	Sudan	Teosinte	Mean	Relative Increase%	Millet	Sudan	Teosinte	Mean	Relative Increase %
1st cut	T_1 (0% + 0)	11.885gh	11.033 hij	7.242 k	10.053C	-	1.714 fgh	1.679 fgh	0.873 i	1.422 D	-
	T_2 (0% + B)	13.956d-g	13.293e-h	9.052j k	12.100B	20.36	2.225 def	2.047 efg	1.269 hi	1.847 C	29.89
	T_3 (50 % + B)	17.327 bc	13.584d-h	9.193 ijk	13.368B	32.98	2.755 b-e	2.082 ef	1.334 ghi	2.057 C	44.66
	T_4 (75 % + B)	19.680 ab	14.685 c-f	11.628ghi	15.391A	53.10	3.413 ab	2.631 cde	2.014 efg	2.686 B	88.89
	T_5 (100 % +B)	20.390 a	16.000 cd	12.475fgh	16.286A	62.00	3.733 a	3.175 abc	2.493 cde	3.134 A	120.39
	T_6 (100 %+0)	20.266 a	15.329cde	12.025 gh	15.873A	57.89	3.609 a	2.879 bcd	2.299 def	2.929AB	105.98
	Mean	17.250 A	14.017 B	10.269 B			2.908 A	2.415 A	1.714 B		
2nd cut	T_1 (0% + 0)	8.656 cd	6.265 d	7.738 d	7.553 D	-	1.497 fg	0.964 g	1.199 g	1.220 E	-
	T_2 (0% + B)	11.098 cd	8.582 cd	10.317 cd	10.000 D	32.40	1.972 d-g	1.479 fg	1.719 fg	1.723DE	41.23
	T_3 (50 % + B)	16.657 ab	10.571 cd	10.771 cd	12.667 C	67.71	2.998 a-e	1.828 fg	1.885 efg	2.237CD	83.36
	T_4 (75 % + B)	17.017 ab	12.799 bc	10.864 cd	13.560BC	79.53	3.223 abc	2.460 c-f	1.926 efg	2.536BC	107.87
	T_5 (100 % +B)	19.009 a	18.245 a	15.762 ab	17.672 A	133.97	3.524 abc	4.060 a	3.053 a-d	3.546 A	190.66
	T_6 (100 %+0)	17.711 ab	17.618 ab	13.320 bc	16.216AB	114.70	3.572 abc	3.620 ab	2.552 b-f	3.248AB	166.23
	Mean	15.024 A	12.347 A	11.462 A			2.798 A	2.402 A	2.056 A		
3rd cut	T_1 (0% + 0)	4.955 hij	3.245 j	7.717 d-g	5.306 D	-	0.698 k	0.542 k	1.323 ghi	0.854 E	-
	T_2 (0% + B)	5.969 ghi	3.817 j	8.769 cde	6.185 CD	16.57	0.969 ijk	0.676 k	1.521 fgh	1.055 DE	23.54
	T_3 (50 % + B)	6.480 fgh	4.197 ij	9.489 bcd	6.722 C	26.69	1.261 g-j	0.803 jk	2.077 cde	1.380CD	61.59
	T_4 (75 % + B)	6.807 fgh	5.859 ghi	10.077abc	7.581 B	42.88	1.580 fgh	1.223 hij	2.420 bc	1.741BC	103.86
	T_5 (100 % +B)	7.050 efg	8.762 cde	11.481 a	9.098 A	71.47	2.286 cd	1.926 def	3.211 a	2.474 A	189.70
	T_6 (100 %+0)	6.980 efg	8.058 def	10.701 ab	8.580AB	61.70	2.147 cde	1.724 efg	2.745 b	2.206AB	158.31
	Mean	6.374 B	5.656 B	9.706 A			1.490 B	1.149 C	2.216 A		
Total	T_1 (0% + 0)	25.496i	20.543k	22.697j	22.912E	-	3.909ijk	3.185k	3.395jk	3.496F	-
	T_2 (0% + B)	31.023g	25.692i	28.138h	28.284D	23.45	5.166gh	4.202h-k	4.509hij	4.626E	32.31
	T_3 (50 % + B)	40.464d	28.352h	29.453h	32.756C	42.97	7.014de	4.713hi	5.296fgh	5.674D	62.31
	T_4 (75 % + B)	43.504c	33.523f	32.569f	36.532B	59.44	8.216bc	6.314efg	6.360ef	6.963C	99.18
	T_5 (100 % +B)	46.449a	43.003c	39.715d	43.056A	87.92	9.543a	9.161ab	8.757abc	9.154A	161.83
	T_6 (100 %+0)	44.957b	41.005d	36.046e	40.669A	77.50	9.328ab	8.223bc	7.596cd	8.382B	139.77
	Mean	38.649A	32.020A	31.436A			7.196A	5.966A	5.986A		

0, 50, 75 and 100 % of recommended mineral N fertilizer (RMNF), B: grain inoculation with N biofertilizer (cerealin)

Table 5. continued.

Cuts	Crops Fertilization	2023 season									
		Fresh forage yield/ fed (ton)					Dry forage yield/ fed (ton)				
		Millet	**Sudan**	**Teosinte**	**Mean**	**Relative Increase%**	**Millet**	**Sudan**	**Teosinte**	**Mean**	**Relative Increase%**
1st cut	T_1 (0% + 0)	16.708de	10.491 g	6.791 h	11.452 E	-	2.402ghi	1.673 K	0.907 l	1.661 E	-
	T_2 (0% + B)	17.075de	13.203 f	7.832 h	12.581D	9.86	2.670 fg	2.271 hi	1.118 l	2.020 D	21.61
	T_3 (50 % + B)	18.026cd	15.723 e	7.987 h	13.912C	21.48	3.133 de	2.794 ef	1.219 l	2.382 C	43.41
	T_4 (75 % + B)	20.717 b	17.445 d	10.251 g	16.138B	40.92	3.775 bc	3.468 cd	1.717 jk	2.987 B	79.83
	T_5 (100 % +B)	23.072 a	20.609 b	12.645 f	18.775A	63.95	4.974 a	4.627 a	2.506fgh	4.036 A	142.99
	T_6 (100 %+0)	19.303bc	19.215 bc	10.946 g	16.488B	43.97	4.075 b	3.887 b	2.045 ij	3.336 B	100.84
	Mean	19.151A	16.114 B	9.409 C			3.505 A	3.120 A	1.585 B		
2nd cut	T_1 (0% + 0)	13.753d-g	8.680 i	10.894 hi	11.109D	-	2.166fgh	1.392 i	1.437 i	1.665 E	-
	T_2 (0% + B)	13.890d-g	11.553 gh	11.509 ef	12.317CD	10.87	2.124fgh	2.196fgh	1.574 hi	1.965DE	18.02
	T_3 (50 % + B)	13.367d-h	13.347d-h	12.594e-h	13.103 C	17.95	2.299 fg	2.593ef	1.783ghi	2.225 D	33.63
	T_4 (75 % + B)	15.658 cd	17.330 bc	14.501 de	15.831 B	42.51	3.136 de	3.568 cd	2.582 ef	3.095 C	85.89
	T_5 (100 % +B)	19.443 ab	20.546 a	14.239def	18.076A	62.71	4.555 ab	4.871 a	3.103 e	4.176 A	150.81
	T_6 (100 %+0)	21.160 a	17.285 bc	12.565e-h	17.003AB	53.06	4.558 ab	3.988 bc	2.355 fg	3.634BC	118.26
	Mean	16.212 A	14.790AB	12.717 B			3.140 A	3.101 A	2.139 A		
3rd cut	T_1 (0% + 0)	7.025 fg	6.012 g	11.378cde	8.139C	-	1.456hij	0.933 j	2.337fgh	1.576 E	-
	T_2 (0% + B)	9.563 ef	7.155 fg	10.683de	9.134C	12.23	2.112ghi	1.279 ij	2.300fgh	1.897DE	20.37
	T_3 (50 % + B)	11.395cde	7.241 fg	11.098cde	9.911C	21.77	2.560efg	1.448 ij	2.449efg	2.152 D	36.55
	T_4 (75 % + B)	14.169abc	9.038efg	13.415bcd	12.207B	49.98	3.287cde	1.908ghi	3.031def	2.766 C	75.51
	T_5 (100 % +B)	16.847a	10.862cde	16.591ab	14.767A	81.44	4.592 a	2.727efg	4.313 ab	3.877 A	146.00
	T_6 (100 %+0)	14.806ab	9.557ef	16.824a	13.729AB	68.68	3.682bcd	2.320fgh	3.918abc	3.307BC	109.84
	Mean	12.300A	8.311B	13.331A			2.948 A	1.781 B	3.058 A		
Total	T_1 (0% + 0)	37.854f	25.184h	29.063gh	30.700F	-	6.024ij	3.998m	4.681lm	4.901F	-
	T_2 (0% + B)	40.161ef	31.911g	30.024g	34.032E	10.85	6.906hi	5.746jk	4.992kl	5.881E	20.00
	T_3 (50 % + B)	42.788de	36.310f	31.679g	36.926D	20.28	7.992fg	6.835hi	5.451jkl	6.759D	37.92
	T_4 (75 % + B)	50.545c	43.813de	38.166f	44.175C	43.89	10.198c	9.017de	7.329gh	8.848C	80.54
	T_5 (100 % +B)	59.362a	52.017bc	43.474de	51.618A	68.14	14.121a	12.225b	9.922cd	12.089A	146.67
	T_6 (100 %+0)	55.269b	46.058d	40.335ef	47.220B	53.81	12.315b	10.195c	8.318ef	10.276B	109.67
	Mean	47.663A	39.216B	35.457C			9.593A	8.003B	6.782B		

0, 50, 75 and 100 % of recommended mineral N fertilizer (RMNF), B: grain inoculation with N biofertilizer (cerealin)

The interaction between the two tested factors was found to be significant for each of fresh and dry forage yields at three cuts and their totals in both seasons. Application of 100 % RMNF combined with grain inoculation of cerealin biofertilizer (T_5) produced the maximum significant values of fresh and dry forage yields/ fed by millet at 1st cut (21.731 and 4.354 ton), sudan grass at 2nd cut (19.396 and 4.466 ton), teosinte at 3rd cut (14.153 and 4.262 ton) and millet at total of three cuts (52.906 and 11.832 ton), respectively, as an average of the two seasons compared to the other N fertilization treatments. The variation among the three tested forage crops in their forage productivity/ fed during the three cuts, from cut to another, may be attributed to the diversity in their growth habit and development rate of plant organs along their growth stages as previously discussed in Tables 3 and 4. Nevertheless, it can be observed that the plants fertilized with 100 % RMNF separately (T_6) insignificantly outyielded those fertilized with 75 % RMNF in combination with cerealin biofertilizer inoculation (T_4), for each tested forage crop, mostly, at the three cuts and their total in both seasons. This indicated the importance role of addition N biofertilization combined with N mineral fertilization at a medium N level, i.e. 75 % RMNF (T_4) for promising the total forage productivity of the tested forage crops and equal approximately with that obtained by the single application of N mineral fertilization at recommended level, i.e. 100 % RMNF (T_6).

For the seasonal changes of the two growing seasons, as an overall means of the three tested forage crops and six fertilization treatments, it can be noticed that, the total fresh and dry forage yields/ fed recorded 34.035 and 6.382 ton/ fed in the first season ,while 40.778 and 8.126 ton/ fed in the second season, respectively. This means that the values obtained from the 1st season were inferior to that obtained from the 2nd season. The reduction in the forage productivity occurred at the 1st season may be owing to the increase in the values of PH, EC and soluble cations and anions as well as the decrease in N, P and K available in the experimental soil at the 1st season compared to the 2nd one as shown in Table 1. Therefore, such soil chemical properties may be caused a harmful effect in most growth characters and dry matter accumulation/ plant, as previously discussed, and consequently decreased the forage productivity at the 1st season compared to the 2nd one.

4- Forage quality:

Forage quality characters, i.e. crude protein % (CP %), total carbohydrates % (TC %) and digestible crude protein % (DCP %) in whole plant (stem and leaves) in the three summer forage crops as affected by N mineral and biofertilization treatments at three cuts during two seasons are presented in Table 6.

There are significant variation among the three forage crops for CP % and DCP % at 1st and 2nd cuts in both seasons, regardless of the N fertilization treatments. However, there are no significant differences among the three tested forage crops in such traits at 3rd cut in both seasons. Moreover, it can be noticed that teosinte plants had the highest values of CP % and DCP % (10.28 and 6.31 %)

in the first season and (11.16 and 7.16 %) in the second season, as an average of the three cuts followed by millet and sudan grass in a descending order in the three cuts at both seasons. The superiority of CP % and DCP % in teosinte crop obtained herein may be attributed to the increase in its leaves dry weight/ plant as shown previously in Table 4 and consequently led to an enhancement in its nutritive values in most cuts, compared to the other forage crops. On the other hand, it can be found that the differences among the tested forage crops did not reach the significance level for TC % at three cuts in both seasons. Nevertheless, sudan grass plants recorded the highest values of TC %, while teosinte plants produced the lowest one in most cases. In this respect, other investigators found also that teosinte forage crop was superior to millet and sudan grass crops in CP % as reported by Hassan *et al.*, (2022) and DCP as recorded by by Mohamed (2024).

Table 6. Forage quality of some summer forage crops as affected by N mineral and bio fertilization at three cuts during 2022 and 2023 seasons.

Characters	Crops Fertilization	2022 season											
		1st cut				2nd cut				3rd cut			
		Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean
Crude protein % (CP %)	T_1 (0% + 0)	9.30 gh	9.00 h	9.96 c-h	9.45 C	8.71 c	8.70 c	9.50 bc	8.97 C	8.30 a	8.00 a	9.25 a	8.52 B
	T_2 (0% + B)	9.40 fgh	9.15 h	10.25 b-f	9.60 C	9.00 c	9.00 c	10.15 abc	9.38 BC	8.50 a	8.25 a	9.50 a	8.75 B
	T_3 (50 % + B)	9.50 e-h	9.25 h	10.50 bcd	9.75 C	9.30 c	9.10 c	10.20 abc	9.53 BC	9.00 a	8.50 a	9.60 a	9.03 B
	T_4 (75 % + B)	10.39 b-e	9.63 d-h	10.75 bc	10.26 B	10.02 abc	9.30 c	10.30 abc	9.87 BC	9.10 a	8.75 a	9.75 a	9.20 B
	T_5 (100 % +B)	12.00 a	10.20 b-g	12.07 a	11.42 A	11.25 ab	9.95 abc	11.39 a	10.86 A	10.80 a	9.85 a	10.45 a	10.37 A
	T_6 (100 %+0)	10.85 bc	10.00 c-h	11.00 b	10.62 B	10.35 abc	9.50 bc	10.45 abc	10.10 AB	9.30 a	8.85 a	9.90 a	9.35 AB
	Mean	10.24 A	9.55 B	10.76 A		9.77 AB	9.26 B	10.34 A		9.17 AB	8.70 B	9.74 A	
Carbohydrates %	T_1 (0% + 0)	75.31 a	76.42 a	74.41 a	75.38 A	75.50 a	76.73 a	74.72 a	75.65 A	76.24 a	77.24 a	75.34 a	76.27 A
	T_2 (0% + B)	74.41 a	75.52 a	73.51 a	74.48 A	74.53 a	75.82 a	73.82 a	74.72 A	75.73 a	76.34 a	74.43 a	75.50 A
	T_3 (50 % + B)	73.51 a	74.61 a	72.60 a	73.58A	73.62 a	74.92 a	73.02 a	73.86 A	74.74 a	75.23 a	73.53 a	74.50 A
	T_4 (75 % + B)	72.61 a	73.71 a	70.70 a	72.67A	72.72 a	74.02 a	72.01 a	72.92 A	73.83 a	74.53 a	72.63 a	73.67 A
	T_5 (100 % +B)	71.70 a	71.80 a	70.70 a	71.07 A	70.81 a	72.32 a	70.81 a	71.31 A	72.02 a	72.73 a	70.93 a	71.89 A
	T_6(100 %+0)	71.90 a	72.11 a	70.70 a	71.57A	72.10 a	72.92 a	71.01 a	72.01 A	72.93 a	73.63 a	71.72 a	72.76 A
	Mean	73.08 A	74.03A	72.27 A		73.21 A	74.46A	72.57 A		74.25A	74.95 A	73.10 A	
Digestible crude protein (DCP %)	T_1 (0% + 0)	5.38 gh	5.18 h	6.01 c-h	5.52 C	4.81 c	4.80 c	5.57 bc	5.05 C	4.42 a	4.13 a	5.33 a	4.63 B
	T_2 (0% + B)	5.47 fgh	5.23 h	6.29 b-e	5.66 C	5.08 c	5.09 c	6.19 abc	5.45 BC	4.61 a	4.37 a	5.57 a	4.85 B
	T_3(50 % + B)	5.57 e-h	5.33 h	6.53 bcd	5.81 C	5.38 c	5.18 c	6.24 abc	5.60 BC	5.09 a	4.61 a	5.66 a	5.12 B
	T_4(75 % + B)	6.42 b-e	5.69 d-h	6.77 bc	6.29 B	6.06 abc	5.38 c	6.33 abc	5.92 BC	5.18 a	4.85 a	5.80 a	5.28 B
	T_5 (100 % +B)	7.97 a	6.24 b-g	8.03 a	7.41 A	7.25 ab	6.00 abc	7.38 a	6.87 A	6.82 a	5.90 a	6.48 a	6.40 A
	T_6(100 %+0)	6.86 bc	6.05 c-h	7.01 b	6.64 B	6.38 abc	5.57 bc	6.48 abc	6.14 AB	5.37 a	4.94 a	5.95 a	5.42 AB
	Mean	6.28 A	5.62 B	6.78 A		5.82 AB	5.33 B	6.36 A		5.25 AB	4.80 B	5.80 A	

0, 50, 75 and 100 % of recommended mineral N fertilizer (RMNF), B: grain inoculation with N biofertilizer (cerealin)

Table 6. continued.

Characters	Crops Fertilization	2023 season											
		1st cut				2nd cut				3rd cut			
		Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean	Millet	Sudan	Teosinte	Mean
Crude protein % (CP %)	T_1 (0% + 0)	9.86b-e	9.40 e	11.02a-e	10.09 A	9.39def	8.50 f	10.92a-d	9.60 B	8.64 a	7.82 a	10.00 a	8.82 A
	T_2 (0% + B)	9.96a-e	9.58 de	11.13a-e	10.22 A	9.46def	8.68ef	11.13a-d	9.76 AB	8.87 a	8.04 a	10.25 a	9.05 A
	T_3 (50 % + B)	10.00a-e	9.75cde	11.50a-d	10.42 A	9.75b-f	9.25def	11.25a-d	10.09AB	9.00 a	8.25 a	10.40 a	9.22 A
	T_4 (75 % + B)	11.00a-e	9.92a-e	11.75abc	10.89 A	10.50a-e	9.50c-f	11.50abc	10.50AB	9.50 a	8.50 a	10.50 a	9.50 A
	T_5 (100 % +B)	11.24a-e	10.14a-e	11.96 a	11.11 A	10.69a-d	9.94a-f	11.86 a	10.83A	10.13a	8.97 a	11.13 a	10.08 A
	T_6 (100 %+0)	11.25a-e	9.96a-e	11.84 ab	11.02 A	10.63a-e	9.49c-f	11.65 ab	10.59AB	9.91 a	8.75 a	11.08 a	9.92 A
	Mean	10.55AB	9.79 B	11.53 A		10.07 B	9.23 B	11.39 A		9.34 A	8.39 A	10.56 A	
Carbohydrates %	T_1 (0% + 0)	75.66 a	76.54 a	74.66 a	75.62 A	76.50 a	77.55 a	75.56 a	76.54 A	77.52 a	78.97 a	76.96 a	77.81 A
	T_2 (0% + B)	74.61 a	75.56 a	73.45 a	74.54 A	76.01 a	76.83 a	75.54 a	76.13 A	76.97 a	77.53 a	75.49 a	76.67AB
	T_3 (50 % + B)	73.76 a	74.46 a	72.95 a	73.72 A	75.58 a	75.50 a	73.58 a	74.89 A	75.53 a	76.88 a	74.96 a	75.79 A
	T_4 (75 % + B)	72.59 a	73.97 a	71.58 a	72.71 A	74.44 a	74.52 a	72.56 a	73.84 A	74.78 a	75.44 a	73.51 a	74.58 A
	T_5 (100 % +B)	70.61 a	71.61 a	70.6 a	70.94 A	71.43 a	72.70 a	70.78 a	71.64 A	72.82 a	73.57 a	71.92 a	72.77 A
	T_6 (100 %+0)	71.59 a	72.61 a	70.51 a	71.57 A	72.79 a	73.76 a	71.44 a	72.67 A	73.50 a	74.74 a	72.42 a	73.55 A
	Mean	73.14 A	74.12 A	72.29 A		74.46 A	75.14A	73.24 A		75.19A	76.19 A	74.21 A	
Digestible crude protein (DCP %)	T_1 (0% + 0)	5.91b-e	5.47e	7.02a-e	6.14 A	5.46cde	4.61 e	6.93abc	5.67 B	4.74 a	3.95 a	6.05 a	4.91 A
	T_2 (0% + B)	6.01a-e	5.64de	7.13a-e	6.26 A	5.53cde	4.78de	7.13abc	5.82 AB	4.96 a	4.17 a	6.29 a	5.14 A
	T_3 (50 % + B)	6.05a-e	5.80cde	7.49a-d	6.45 A	5.81b-e	5.32cde	7.25abc	6.13 AB	5.09 a	4.37 a	6.43 a	5.30 A
	T_4 (75 % + B)	7.01a-e	5.97a-e	7.73abc	6.90 A	6.53a-d	5.57cde	7.49 ab	6.53 AB	5.56 a	4.61 a	6.53 a	5.57 A
	T_5 (100 % +B)	7.23a-e	6.18a-e	7.93 a	7.11 A	6.71abc	5.99a-e	7.83 a	6.84 A	6.17 a	5.06 a	7.13 a	6.12 A
	T_6 (100 %+0)	7.24a-e	6.01a-e	7.81 a	7.02 A	6.65a-d	5.56cde	7.63 ab	6.61 AB	5.96 a	4.84 a	7.08 a	5.96 A
	Mean	6.58AB	5.85 B	7.52 A		6.12 B	5.31 B	7.38 A		5.41 A	4.50 A	6.58 A	

0, 50, 75 and 100 % of recommended mineral N fertilizer (RMNF), B: grain inoculation with N biofertilizer (cerealin)

With regard to the effect of N fertilization treatments, the data showed that the values of CP % and DCP % were increased with application treatments of N either as mineral or as biofertilizer as compared with the unfertilized plants (T_1). These results are fairly true in the three cuts at both seasons. In comparison among the N fertilization treatments, the plants fertilized with 100 % RMNF and inoculated with biofertilizer (T_5) produced the highest values of CP % (10.88

and 10.67 %) and DCP % (6.89 and 6.69 %) in the first and second season, respectively (as an average of the three cuts). In this respect, other investigators reported also that CP % in some summer forage crops was increased by application of N element as mineral fertilization (Awad *et al.*, 2014; Mut *et al.*, 2017 and Ziki *et al.*, 2019) and / or as biofertilization (Abd El-Rahman *et al.*, 2005; Ibrahim *et al.*, 2009 and Chahal *et al.*, 2021). Reversely, the values of TC % took an opposite direction with that of CP % and DCP %, where the unfertilized plants with N element (T_1) produced TC % more than that obtained by plants fertilized by N fertilization treatments (T_2: T_6) without significant differences among them in both seasons. In this respect, other investigators found that application of nitrogen fertilizer led to a decrease in total carbohydrate in some forage crops such as sorghum (Marei, 1992), millet (Buso *et al.*, 2016) and teosinte (Mohan *et al.*, 2017).

The interaction effect of the two tested factors was significant for CP % and DCP % in the 1st and 2nd cuts during both seasons. on the otherwise, TC % was not significantly affected by such interaction in the three cuts during both seasons. Based on the significant interaction, teosinte plants fertilized by 100 % RMNF and inoculated with cerealin biofertilizer (T_5) produced the highest values of CP % (12.07 and 11.39 %) in the first season and (11.96 and 11.86 %) in the second season, as well as DCP % (8.03 and 7.38 %) in the first season and (7.93 and 7.83 %) in the second season at the 1st and 2nd cuts respectively compared to the other treatments. This indicates to the importance of nitrogen fertilization for maximizing the nutritive values of forage summer crops especially teosinte crop.

5- Correlation studies:

Simple phenotypic correlation coefficient (r) between fresh forage yield/ fed and all traits studied herein for each tested forage crops, overall nitrogen fertilization treatments and cuts, during 2022 and 2023 seasons, are presented in Table 7. The data showed that fresh forage yield/ fed was positively and highly significant correlated with growth characters (plant height, no. of tillers and leaves/ plant and leaves area/ plant), dry matter accumulation (leaves, stem and total dry weights/ plant) and dry forage yield/ fed as well as forage quality (CP % and DCP %) for each of tested forage crops ,i.e. millet, sudan grass and teosinte during one and / or both seasons. According to the highest positive significant values of simple correlation coefficient (r) in both seasons, it can be found that the fresh forage yield/ fed recorded the highest values of r with each of plant height (0.944 and 0.866), no. of leaves/ plant (0.895 and 0.933), leaves area/ plant (0.933 and 0.873) and dry forage yield/ fed (0.962 and 0.961) and CP % (0.862 and 0.934) and DCP % (0.862 and 0.934) for sudan grass and leaves dry weight/plant (0.915 and 0.936) for millet, as well as dry matter % (0.409 and 0.700) for teosinte in the first and second seasons, respectively.

Table 7. Simple correlation coefficient (r) between fresh forage yield/ fed and growth characters, dry matter accumulation and forage quality for each tested forage crop (overall means of N fertilization treatments and cuts) during 2022 and 2023 seasons.

Crops	2022 season			2023 season		
Characters	**Millet**	**Sudan**	**Teosinte**	**Millet**	**Sudan**	**Teosinte**
Growth characters						
plant height	0.940**	0.944**	0.865**	0.648**	0.866**	0.508**
No. of tillers/ plant	0.897**	0.822**	0.919**	0.824**	0.874**	0.158
No. of leaves/ plant	0.693**	0.895**	0.794**	0.804**	0.933**	0.192
Leaves area/ plant	0.745**	0.933**	0.900**	0.707**	0.873**	0.471**
Dry matter accumulation						
Leaves dry weight/ plant	0.915**	0.868**	0.742**	0.936**	0.914**	0.494**
Stem dry weight/ plant	0.742**	0.823**	0.914**	0.809**	0.958**	0.512**
Total dry weight/ plant	0.912**	0.848**	0.858**	0.901**	0.960**	0.528**
Dry matter %	0.303-	0.195	0.409*	0.020	0.405*	0.700**
Dry forage yield/ fed	0.928**	0.962**	0.824**	0.823**	0.961**	0.917**
Forage quality						
CP %	0.723**	0.862**	0.758**	0.931**	0.934**	0.093
TC %	-0.692**	-0.715**	-0.871**	-0.889**	-0.869**	-0.345
DCP %	0.723**	0.863**	0.758**	0.931**	0.934**	0.091

*** = significant at probability of 0.05 % (r = 0.325) and ** = highly significant at probability of 0.01 % (r = 0.418).**

From these results, it can be concluded that such characters which having the highest r values are considered the most effective in contributing to maximize fresh forage yield/ fed and play an important role in determining the productivity for the abovementioned forage crops. Reversely, there are negative and significant correlation between fresh yield/ fed and carbohydrate % for three tested forage crops in the first season and for millet and sudan grass in the second season. In this concern, many investigators found significant and positive correlation between fresh forage yield/ ha and each of plant height, no. of tillers and leaves/ plant and protein % for sudan grass crop (Taha *et al.*, 2019) and with plant height and dry forage yield/ ha for millet (Imran *et al.*, 2010) as well as fresh yield/ fed with each of plant height, no. and area of leaves/ plant, dry forage yield/ fed and dry matter % for teosinte crop (Habiba *et al.*, 2018 a).

CONCLUSION

Finally, it can be concluded that the maximum values of growth, dry matter accumulation, forage productivity and quality of the tested forage crops occurred in this study were obtained by application of 100 % RMNF accompanied with cerealin biofertilizer inoculation (T_5). Moreover, N biofertilizer inoculation with N mineral fertilization at a medium N level, i.e. 75 % RMNF (T_4) gave total forage productivity equal approximately with that obtained by the single application of N mineral fertilization at recommended level, i.e. 100 % RMNF (T_6), indicating that using N biofertilizer had beneficial and additive value to N mineral fertilizer, and they are able to complement each other and so make better use than their using separately, for improving the growth, dry matter accumulation, forage productivity and quality of the tested forage crops.

REFERENCES

Abd El-Naby, Zeinab M.; Hafez, Wafaa A.; El-Tohamy, S. A. and Mohamed, Nabila A. (2016). Environmental management of salt affected soils and its effect on yield and quality of summer forage grasses in North Sinai. Egypt. J. Agron. 38 (1), 79 – 98.

Abd El-Rahman, S.M.; El Shouny, K.A.; Ashoub, M.A.; Abd El-Gawad, M.A. and Abd El-Maaboud, M. Sh. (2005). Effect of salinity and nitrogen bio-fertilization on some sudan grass (*Sorghum sudanense* L.) MOENCH) varieties at Ras Sudr. Arab Univ. J. Agric. Sci., Ain Shams Univ., Cairo, 13 (3), 755-769.

Abdel-Shafy, A.S.A. (1991). Studies on some forage crops in Egypt. Ph.D. Thesis, Fac. Agric, Menoufia University. Egypt.

Aboelgoud, S. A.; Mosaad, I. S. M. and Awad, H. A. (2022). Effect of water irrigation amounts and nitrogen fertilizer levels on teosinte productivity and optimal economic n-rates under salinity stress. Annals of R.S.C.B., 26 (1), 1057-1076.

Afzal. M.; Ahmad, A. U. H.; Zamir, S. I.; Khalid, F.; Mohsin, A. U. and Gillani, S. M. W. (2013). Performance of multicut forage sorghum under various sowing methods and nitrogen application rates. J. Anim. Plant Sci. 23(1), 232-239.

AOAC (2019). Official Methods of Analysis. 21st Ed. Association of Official Analytical Chemists, Inc., Gaithersburg, MD.

Awad, A.; Hafiz, S. I.; Hammada, M. S.; El-Hendawy, S.; Ali1, E. A. and El-Nouby, Azza M. A. M. (2014). Influence of phosphorous, nitrogenous fertilizers and seeding rates on green forage yield and its quality of sudangrass (*Sorghum vulgare* var. *Sudanense* (Piper) Stapf) under Ismailia governorate conditions – Egypt Journal of Plant Production Sciences; Suez Canal University. (2), 15-22

Bredon, R.M.; Harker, K.W. and Marshall, B. (1963). The nutritive value of grasses grown in Uganda when fed to Zebu cattle. 1- The relation between the percentage of crude protein and other nutrients. J. Agric. Sci., 61 (1), 101-104.

Buso, W.H.D.; França, A.F.S.; Miyagi, E.S.; Ferreira, R.N. and Corrêa, D.S. (2016). Effects of nitrogen fertilizer on carbohydrate and protein fractions in pearl millet (*Pennisetum glaucum*) cultivars. Tropical Grasslands –Forrajes Tropicales (4), 47-53.

Chahal, A.; Sharma, G. D.; Kumar, N.; Sankhyan, N. K.; Katoch, R., Rana, M. C., and Chandel, R. S. (2021). Impact of different nutrient sources on forage yield, nutritive value and economics of sorghum sudan grass hybrid-Oat cropping system. Journal of Plant Nutrition, 44 (9), 1223–1240.

Dubois, M.; Gilles, K.A.; Hamilton, J.K.; Robers, P.A. and Smith, F. (1956). Colorimetric method for determination of sugar and related substances. Analytical Chemistry, 28 (3), 350-356.

Duncan, B. (1955). Multiple Range and Multiple F. test. Biometrics, (11), 1-42.

El-Gaafarey, T. G.; Elsayed, Samar, S. A. and El-Nahrawy Shereen M. (2023). Assessing of some summer forage crops to infection by common smut and downy mildew diseases for forage and silage production. J. Agric. Ecol. Res. Int., 24 (1),29-42.

Fayed, Eman A.; Abo El-Goud, Sh. A. and Mostafa, El-Shimaa E. I. (2020). Agromorphologic characterization and molecular markers of some teosinte (*Zea mexicana*) Genotypes. J. of Plant Production, Mansoura Univ., 11(8), 755-760.

Habib, G.; Akmal, M.; Luqman, Z. and Ahmad, N. (2007). Biomass production and feed quality of three summer fodder species planted under two nitrogen levels. Sarhad J. Agric. 23 (4), 1144 – 1150.

Habiba, Hend E.; Bondok, A. T. and Abdel-Aal, M. S. (2018 a). Evaluation of some promising teosinte genotypes for morphological and genetic parameters under Egyptian conditions. Alexandria Science Exchange Journal, 9 (2):307-332.

Habiba, Hend E.; Salama, Heba S.A. and Bondok, A. T. (2018 b). Effect of the integrated use of mineral- and bio-fertilizers on yield and some agronomic characteristics of fodder pearl millet (*Pennisetum glaucum* L.). Alexandria Science Exchange Journal, 39 (2). April- June ,282-294.

Hassan, Hend H. M.; El-sobky, E. E. A.; Mansour, E.; El-kholy, A. S. M.; Awad, M. F.; Ullah, H. and Datta, A. (2022). Influence of preceding crop and tillage system on forage yield and quality of selected summer grass and legume forage crops under arid conditions. Journal of Integrative Agriculture, 21(11), 3329–3344.

Hassan, Hend H.M. (2017). Impact of mineral, organic and biofertilization on growth, yield and quality of fodder pearl millet. Am-Euras. J. Agric. & Environ. Sci., 17 (6), 450-457

Hassan, Hend H.M.; Sayed, Mervat R.I. and Mousa, Walaa M.E. (2017). Effect of intercropping patterns on forage yield and land use efficiency of some summer fodder crops. Zagazig J. Agric. Res., 44 (6A), 2007-2020.

Hassan, Kh. H.; Abd El-Maaboud, M. Sh.; Draz, M. and El Shaer, H. (2016). Performance of sorghum and pearl millet forage crops productivity by using different agricultural managements under salinity conditions. J. Plant Production, Mansoura Univ., 7 (2), 311 – 316.

Ibrahim, Hoda I. M.; Hamed, N.M.; Kandil, B.A.A. and Sultan, Fadia M. (2013). Productivity and quality of forage millet as affected by nitrogen and bio fertilization under new valley conditions. J. Plant Production, Mansoura Univ., 4 (12), 1897 – 1912

Ibrahim, Hoda I. M.; Kandil, B.A.A. and Hamed, N.M. (2009). Influence of mineral and biofertilizer on forage yield and quality traits of teosinte. J. Agric. Sci. Mansoura Univ., 34 (6), 6515 – 6530.

Ibrahim, Y. M.; Idris, A. E. and Marhoum, M. A. E. (2014). Effect of nitrogen fertilizer on irrigated forage pearl millet (*Pennisetum americanum* L.K. *Shcum*). Universal Journal of Agricultural Research 2 (2), 56-60.

Ikanović, J.; Janković, S.; Popović, V.; Rakić, S.; Dražić, G.; Živanović, Lj. and Kolarić, Lj. (2014). The effect of nitrogen fertilizer rates on green biomass and dry matter yield of *sorghum* sp. at different growth stages. Biotechnology in Animal Husbandry 30 (4), 743-749.

Imran, M.; Hussain, A.; Khalid, R.; Khan, S.; Zahid, M. S.; Gurmani, Z. A.; Bakhsh, A. and Baig, D. (2010). Study of correlation among yield contributing and quality parameters in different millet varieties grown under and hwar conditions. Sarhad J. Agric 26 (3), 365-368.

Jain, D.K and Patriquin, D.G. (1985). Characterization of a substance produced by *Azospirillum* which causes branching of wheat root hairs. Can. J. Microbiol., 31: 206-210.

Kennedy, I.R and Tchan, Y.T. (1992). Biological nitrogen fixation in non-leguminous field crops. Recent Advances. Plant and Soil, 141, 93-118.

Machado, R. G. -; Saccol-de Sá, E. L.; Hahn, L. and Sant´Ana, W. L. P. (2018). Inoculation of plant growth promoting rhizobia in Sudan grass (Sorghum × *sudanense* (*Piper*) *Stapf cv. Sudanense*) and millet (*Pennisetum glaucum* (L.) R.Br. cv. BRS1501). Acta Agron. 67 (1), 133-139.

Marei, Z. M. A. (1992). Effect of irrigation and nitrogen fertilization on the productivity of sorghum forage crop. Ph.D. Thesis, Fac. Agric, Menoufia University, Egypt.

Mikhailouskaya, N and Bogdevitch, I. (2009). Effect of biofertilizers on yield and quality of long – fibered flax and cereal grains. Agronomy Research 7(Special issue I), 412-418.

Mohamed, Y. M. SH. (2024). Studies on intercropping some summer forage crops with maize. Ph.D. Thesis, Fac. Agric, Menoufia University, Egypt.

Mohan, S.; Dar, E. A. and Singh M. (2017). Fodder quality of teosinte fodder as influenced by nitrogen, phosphorus and zinc application. Int. J. Pure App. Biosci. 5 (3), 596-604.

Mut, H.; Gulumser, E.; Dogrusoz, M.C. and Basaran, U. (2017). Effect of different nitrogen levels on hay yield and some quality traits of sudan grass and sorghum X sudan grass hybrids. Animal Nutrition and Feed Technology, (17), 269-278

Osman, M. A.; Ibrahim, A. M. S.; El-Naggar, H. M. M. and Seif, S. A. (2022). Potentiality assessment of annual forage crops and fertilization in allway pattern. Annals of Agric. Sci., Moshtohor, 60 (1), 9-24.

Rady, H.Y. (2018). Genotypic and environmental interaction effects on forage yield and its related traits of some summer forage crops. J. Plant Production, Mansoura Univ., Vol. 9 (10): 815 – 820.

Rani, K. S., Satish, P., Rani, C. S. and Sudhakar, C. (2019). Effect of liquid biofertilizers on growth and yield of rabi sorghum (*Sorghum bicolor* L.). Chem Sci Rev Lett 8 (32), 190-194.

Rathore, SK. (2016). Integrated nutrient management in kharif sorghum under rainfed Condition. M.Sc. (Agri.) Thesis, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya College of Agriculture, Indore (M.P).

Silungwe, D. (2011). Evaluation of forage yield and quality of sorghum, Sudan grass and pearl millet cultivars in Manawatu. M.Sc. Thesis, Massey University, Palmerston North, New Zealand.

Snedecor, G.W. and Cochran, W.G. (1989). Statistical Methods. 8th Edition, Iowa State University Press.

Swami, S. (2020). Soil health management under organic production system. IJCS. (2):330-339.

Taha, A. M.; Salem, Azza Kh. and Mekhaile, N. E. G. (2019). Maximizing land and water productivity of sudan-grass under sprinkler irrigation in sandy soil. J. Soils and Crops 29 (2), 207-217.

Vishnu, P.; Yasasvi, B. and Tarate, S. B. (2022). Influence of biofertilizers on millet production. The Pharma Innovation Journal 11 (2), 950-953.

Ziki, S. J. L.; Zeidan, E. M. I.; El-Banna, A. Y. A., and Omar, A. E. A. (2019). Influence of cutting date and nitrogen fertilizer levels on growth, forage yield, and quality of sudan grass in a semiarid environment. International Journal of Agronomy. 2019 (1), 1-9.

تأثير التسميد النيتروجيني المعدني والحيوي على نمو وإنتاجية وجودة بعض محاصيل العلف الأخضر الصيفية

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الملخص

أجريت تجربتان حقليتان بمزرعة محطة البحوث الزراعية بالجميزة مركز البحوث الزراعية خلال موسمي الزراعة 2022 و 2023 لدراسة استجابة ثلاث محاصيل علف أخضر صيفية (الدخن، حشيشة السودان، الذرة الريانة) لست معاملات من التسميد النيتروجيني المعدني والتسميد الحيوى بمخصب السيريالين: (م1) صفر% تسميد معدني + صفر تسميد حيوى،(م2) صفر% تسميد معدني + تسميد حيوى،(م3) 50% تسميد معدني + تسميد حيوى،(م4) 75% تسميد معدني + تسميد حيوى،(م5) 100% تسميد معدني + تسميد حيوى،(م6) 100% تسميد معدني + صفر تسميد حيوى وأثرها على صفات النمو (طول النبات، عدد الفروع وعدد الأوراق ومساحة الأوراق/النبات) والمادة الجافة (الوزن الجاف للأوراق والسيقان والكلي للنبات ونسبة المادة الجافة %) والإنتاجية (محصول العلف الأخضر والجاف/فدان) والجودة (النسبة المئوية للبروتين والكربوهيدرات والبروتين المهضوم) وكذلك دراسة معامل الإرتباط البسيط بين محصول العلف الأخضر/فدان وكل من الصفات السابقة لكل من المحاصيل الثلاثة على حدة ويمكن تلخيص أهم النتائج المتحصل عليها على النحو التالي :1- تشير النتائج الي تفوق محصول الدخن على محصولي حشيشة السودان والذرة الريانة في صفات عدد الفروع والأوراق ، مساحة الأوراق ، الوزن الجاف لكل من الأوراق والساق والنبات الكلي ومحصولي العلف الأخضر والجاف للفدان بينما تفوق محصول حشيشة السودان في طول النبات ومحصول الذرة الريانة في النسبة المئوية للبروتين والبروتين المهضوم كمتوسط للحشات الثلاث خلال موسمي الزراعة2- سجلت معاملة التسميد النيتروجيني المعدني بمعدل 100% تسميد معدني + تسميد حيوى(م5) أعلى قيم معنوية في كل الصفات المدروسة، بينما لم تكن هناك أي فروق معنوية بين معاملة 75% تسميد معدني + تسميد حيوى(م4) ومعاملة 100% تسميد معدني + صفر تسميد حيوى(م6) في كل الصفات المدروسة فى الحشات الثلاث خلال موسمي الزراعة 3- تشير نتائج التفاعل إلى أن إستخدام التسميد النيتروجيني بمعدل 100% تسميد معدني + تسميد حيوي(م5) قد أعطى أعلى قيم معنوية بصفة عامة لمعظم الصفات المدروسة في المحاصيل الثلاثة المختبرة في حشة أو أكثر خلال موسمي الزراعة 4- أظهرت النتائج وجود إرتباط موجب عالي المعنوية بين محصول العلف الأخضر/الفدان ومعظم صفات النمو والمادة الجافة ومحصول العلف الجاف/فدان وصفات الجودة لكل محصول على حدة من محاصيل العلف الثلاث المختبرة خلال موسمي الزراعة