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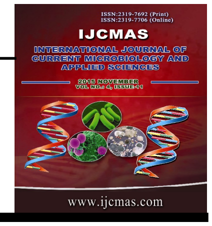

Original Research Article

Response of Growth Parameters, Forage Quality and Yield of Dual-Purpose Sorghum to Re-Growth and Different Levels of FYM and N Fertilizers in New Reclaimed Soil

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A B S T R A C T

Maximizing field crops productivity with reducing the causes of pollution aerial and soil environments is one of the important concepts of sustainable agriculture. Therefore, a field experiment of three cutting systems (S_1, S_2 and S_3) was conducted during 2009/10 seasons to determine the effect of two farmyard manure (45 and 90 m^3 FYM ha^{-1}) and three mineral nitrogen levels (70, 140 and 210 kg N ha^{-1}) on growth, forage quality and yields of the two growth periods of sorghum in each cutting system. The objectives were to identify the best combination of FYM and N fertilizer in each growth period separately under the three cutting systems to achieve acceptable forage both in quantity and quality indices aspects, also to identify the best combination of cutting system, FYM and N fertilizer that produce high productivity. Results revealed that application of FYM_2 and N_3 fertilizer as alone or in combinations significantly ($P \leq 0.05$) increased almost all growth parameters, in most cases led to significant ($P \leq 0.05$) increases forage DM% and CP% accompanied by significant ($P \leq 0.05$) decreases forage CF% and NFE% and gave the highest forage, dry and grain yield in the two growth periods of sorghum in each cutting system. Cutting systems, FYM and N levels as alone or in all possible combinations, except three-way interaction, had significant ($P \leq 0.05$) effects on forage, dry and grain yields. The highest forage yield (74.34 t ha^{-1}) recorded at S_2 while S_3 had higher dry and grain yields (19.69 and 10.13 t ha^{-1}), respectively. For that, application of S_2 with combination of FYM_2 and N_3 for the 1^{st} growth period and only N_3 for the 2^{nd} growth period may be the best option to achieve acceptable forage in quantity and quality in less time as possible compared to other cutting systems.

Keywords

Re-growth, Farmyard manure, Nitrogen fertilizer, Forage quality, Forage and grain yields, Sorghum

Introduction

Sorghum (*Sorghum bicolor* L. Moench) belonging to the family *Poaceae* is an important annual cereal crop grown for both grain and palatable green forage production. It comes at the fifth most important cereal crop in the world after wheat, maize, rice and barley in terms of importance and production. The most important global countries for grain sorghum production are Nigeria, USA and India, while Egypt has ranked fifteen in this respect (FAO, 2012). It is grown throughout the arid and semi-arid tropical regions of the world. It represents the major food for low income people in Africa, South Asia, and Central America. Grain sorghum has huge potential for wider use for human consumption, animal feeds, poultry nutrition, fuel, building materials and for some industrial products (Taylor *et al.,* 2006).

Sorghum can be grown as important dual-purpose crop for grain and forage yields in many arid and semi-arid regions of the world, due to its advantages over. These advantages include high water use efficiency and could be a good alternative to maize under limited water in the semi-arid conditions (Marsalis *et al.*, 2010). It is also of low consumption of nitrogen (Olanite *et al.,* 2010); adapted to hot and dry environments (Yan *et al.,* 2012) and high salt tolerance (Yan *et al.,* 2012; Saberi, 2013). Stable nutritive and several harvests offers sorghum as alternative silage crops compared to corn (Qu *et al.,* 2014). These features are very important particularly with increased cost of unit value of water and chemical fertilizers. In Egypt, grain sorghum is the fourth cereal crop, after wheat, maize and rice, especially after the introduction of early maturing and high yielding hybrids. Fast re-growth after cutting makes sorghum a reliable and profitable summer and autumn crop for food and feed productions. Thus, it is greatly preferred by most farmers, where it widely cultivated in middle and upper Egypt during summer and autumn in area reached 140.000 ha in 2010 season[(1)].

Source: [(1) and (2)] Economic Affairs Department, Agricultural Statistics Bulletin (2010), Ministry of Agriculture, Cairo, Egypt.

Egypt suffers from a clear lack of forage supplied especially during summer season. This problem owing to Egypt does not climatically have natural pastures, relative stability area devoted to production of green forage due to human animal competition on the cultivated area and the concentrated feed stuffs are very expensive. It is worth mentioning that in Egypt, the area devoted to summer and autumn green forage crops was 155.000 ha [(2)] in 2010 season occupy less than 10% of the cultivated area of summer crops. A shortage forage crop in Egypt was documented by Abd El-Salam *et al.,* 2013. Thus, great efforts must be paid to increase the yield of summer fodder crops on the available area devoted for them. In this respect, dual-purpose sorghum could be a strategic option for solving this problem. The present study introduces an experimental example. Sorghum owns advantages which enables us to cultivate it in newly reclaimed soils and thereby increase its productivity horizontally. Exploitation rapid re-growth after cutting for obtaining two growth periods from the same area in less time as possible with the lowest cost is a great advantage. By this way, we can increase its productivity vertically and reduce the economic cost of yield.

Undoubtedly that the low levels of organic matter and nutrient contents are the main factors facing agriculture in newly reclaimed soils. Application of manure is one of the most efficient methods for improving the physical, chemical, and biological properties of soils. The effect of farmyard manure (FYM) on the growth, forage quality as well yields of sorghum is well documented (Mohamed *et al.,* 2011). For high productivity and forage quality of sorghum, mineral N is the most important macro-nutrients (Marsalis *et al.,* 2010; Sawargaonkar *et al.,* 2013). Complementary use of organic and inorganic fertilizers as nutrients source now is necessary for reduce harmful effects on environment, reduction the total costs for profitability as well as production sustainability of soil (Patil, 2013). FYM may substitute mineral N fertilizers without reducing productivity of crops through increasing organic matter and nutrient content in new reclaimed soil. It reduce the use of chemical fertilizers which causes pollution of aerial and soil environment and have detrimental effects on human and animal health. The exorbitant price of mineral N fertilizer at the moment increases the favorable FYM usage.

Therefore, the ultimate objectives of this study were**: (i)** to determine the best combination of FYM and N fertilizer that contribute to high productivity and enhanced quality of forage of sorghum grown in the new reclaimed soil in each of the two growth periods separately under each of the tested three cutting systems and **(ii)** to determine the best combination of cutting system, FYM and N fertilizer that achieve maximum productivity and improvement the most indices of the forage quality from the same area in less time as possible with the lowest cost of yield.

Materials and Methods

Experimental site description

The present study was carried out under the condition of the new reclaimed soil at the Demo experimental farm of the Faculty of Agriculture in south-east Fayoum (29.17° N; 30.53° E), Egypt, during the 2009 and 2010 growing seasons (summer and autumn). The area has an arid and semi-arid climate, thus the region climate is hot and dry from May to October without rainfall in summer and autumn seasons and the temperatures may be reaches 40°C, as more as in 2010 season (Table 3). Experiments were carried out on a sandy- loam soil. Physical and chemical properties of the top soil (0-30cm) at the experimental location are presented in table 2. Monthly averages of relative humidity, air temperature, pan evaporation and photoperiod at Fayoum region during the two growing seasons of the study obtained from Meteorology Station of the Agricultural Management in Itsa, are reported in table 3.

Experimental design and treatments

The experimental design was split-plot in randomized complete blocks with four replications. The two investigated variables, in each growth separately under three different cutting systems each of which system includes two growths were two levels of FYM viz., 45 (FYM_1) and 90 (FYM_2) and three levels of mineral N fertilizer viz., 70 (N_1), 140 (N_2) and 210 kg ha^{-1} (N_3) in form of ammonium nitrate 33.5 % N. The FYM levels were placed in main plots and N fertilizer levels occupied the sub-plots. Each sub-plot was 3 × 4 m = 12 m^2 and consisted of five rows 60 cm apart and 4 m long. The used FYM was characterized by 16.43 and 50.99% organic matter, 1.12 and 1.96% N and 8.5/1 and 15/1 C: N ratio for 2009 and 2010 growing seasons, respectively, and added before planting.

Since, the ultimate objective was to obtain two yields from the same unit area in less time with the lowest possible cost. Consequently, the three tested cutting systems were**:** (S_1) harvesting the 1^{st} growth at booting stage for forage yield and harvesting the 2^{nd} growth at mature stage for both grain and forage yields, (S_2) harvesting the 1^{st} growth at mature stage for both grain and forage yields and harvesting the 2^{nd} growth at booting stage for forage yield and (S_3) harvesting both the 1^{st} and 2^{nd} growths at mature stage for both forage and grain yields.

Agronomic practices

The dual- purpose sorghum cultivar used in this study was the commercial hybrid (Horas). The preceding crop was sugar beet and canola in the 1st and 2nd seasons, respectively. Sorghum grains were planted on May 17th and 23rd in 2009 and 2010 seasons, respectively, in hills 20 cm interplant space. The seedlings were thinned to two per hill after 18 days from planting. For all treatments, 74 kg ha^{-1} of P_2O_5 as Calcium superphosphate was added before planting and 57 kg ha^{-1} of K_2O as potassium sulphate was top dressed before the 3rd irrigation in both seasons. Each level of N fertilizer was divided into three equal doses that were top dressed before the 2nd, 3rd and 4th irrigations in both seasons. The 1st irrigation was at 8 days after planting (DAP) and the following irrigations were at 10-12 days intervals. All other agricultural practices were done as recommended for dual-purpose sorghum in both seasons.

The above indicated practices were conducted in the 1st and 2nd growth periods of sorghum at the three cutting systems, except FYM that was added only before the 1st growths in the three cutting systems in both seasons of the study. Also, plants of the growths which were harvested at physiological maturity stage at the three cutting systems weather was the 1st or 2nd growths and also the 1st growth at the 1st cutting system S_1 were thinned at 18 (DAP) and at 10 days after harvest (DAH) the 1st growth in the 2nd growths, while the rest growth represented in the 2nd growth at the 2nd cutting system S_2 was left without thinning for forage yield. Thus, we can summarize the treatments in each cutting system in this study (Table 1).

Measurements and data analysis

First cutting system (S_1)

At booting stage in the 1st growth 65 and 73 (DAP) and at physiological maturity stage in the 2nd growth 87 and 93 (DAH) the 1st growth in 2009 and 2010 growing seasons, respectively, five representative guarded plants were chosen at random from each sub-plot and hand clipped prior harvesting. Plant height, measured from soil surface to the top of leaves in the 1st growth and measured from soil surface to the top of the panicle in the 2nd growth, stem diameter, measured at the third internode from stem base, fresh leave/stem ratio were recorded. Fresh wt. of plant and forge yield measured by sub-plots hand clipped at 7cm stubble height to allow plants to re-grow, was weighed, in kg then transferred to (t ha^{-1}). After recording the fresh wt. of sorghum plants, samples were dried to a constant wt., in an electric oven at 70°C, and DM% was estimated and then dry wt. of plant and dry yield were calculated by multiplying fresh wt. of plant and forage yield by DM%, respectively. Also, grain yield in the 2nd growth, measured by harvest the grain yield of the three inner ridges from each sub-plot, was estimated (13% wet basis) and then converted to (t ha^{-1}).

Second cutting system (S_2)

At the stage of physiological maturity, 115 and 120 (DAP) in the 1st growth and at booting stage in the 2nd growth 55 and 54 (DAH) the 1st growth in 2009 and 2010 growing seasons, respectively, five representative guarded plants chosen at random per sub-plot were hand clipped prior harvesting. Plant height, measured from soil surface to the top of the panicle in the 1st growth and measured from soil surface to the top of leaves in the 2nd growth, No. of tillers/hill in the 2nd growth, fresh leave/stem ratio, fresh wt. of tillers/hill were recorded. Forge yield, measured by sub-plots and hand clipped at 7cm stubble height to allow plants to re-grow without thinning in the 2nd growth and weighed in kg then transferred to (t ha^{-1}). Then sorghum plant samples were dried to a constant wt. and DM% was estimated and then dry wt. of tillers/hill and dry yield were calculated by multiplying fresh wt. of tillers/hill and forage yield by DM%, respectively. Also, grain yield (t ha^{-1}) in the 1st growth, measured by harvest the grain yield of the three inner ridges from each sub-plot, was estimated (13% wet basis).

Third cutting system (S_3)

At physiological maturity stage, 115 and 120 (DAP) in the 1st growth and after 100 (DAH) the 2nd growth in 2009 and 2010, respectively, five representative guarded plants per sub-plot were chosen at random and hand clipped prior harvest. Plant height and stem diameter of the 1st and 2nd growths were recorded. Leaves were separated from the stem to calculate the fresh leave/stem ratio, fresh wt. of plants and forge yield (t ha^{-1}) were calculated. Sorghum plant samples were dried to a constant wt. and DM% was estimated and then dry wt. of plant and dry yield were calculated by multiplying fresh wt. of plant and forage yield by DM%, respectively. Also, grain yield (t ha^{-1}) in the 2nd growth measured by harvest the grain yield of the three inner ridges from each sub-plot was estimated (13% wet basis).

Forage quality parameters

Representative samples of sorghum plants (comprising leave and stem) were taken from each sub-plot in each growth in all cutting systems to determine chemical composition. Dry matter (DM %), crude protein (CP %), crude fiber (CF %), ash content %, ether extract % and nitrogen free extract content (NFE %) were estimated according to (A.O.A.C 1995).

Statistical analysis

All collected data were statistically analyzed according to technique of analysis of variance for split-plot design by " GENSTAT Version 12.1 2009 " computer software package. The differences among treatment means were compared by LSD test at $P \leq 0.05$ (Gomez and Gomez 1984). Combined analysis for the two seasons of experimentation was done according to the homogeneity of experimental error variance (Bartlett, 1937). On the other side, yields of sorghum in terms of forage, dry and grain for each cutting system were combined to compare statistically among cutting systems.

Results and Discussion

Effects of FYM, N fertilizer and their interaction on the two growths in each cutting system separately

Vegetative growth parameters

There was a significant effect ($P \leq 0.05$) of FYM on all vegetative growth parameters of dual-purpose sorghum in the 1st and 2nd growths in the three cutting systems (Table 4) with the exception of few cases. Application high level of FYM_2 in the 1st and 2nd growths in the three cutting systems produced the highest vegetative growth parameters compared to FYM_1.

All vegetative growth parameters in the 1st and 2nd growths in the three cutting systems were significantly affected by N fertilizer (Table 4). However, fresh leave/stem ratio in the 2nd growth in S_2 remained statistically unchanged with all N levels tested.

The highest values of vegetative growth parameters were achieved at N_3 which was statistically similar to N_2 in terms of fresh leave/stem ratio in the 1st and 2nd growths in S_1 and stem diameter in the 1st growth in both cutting systems S_2 and S_3.

The FYM x N interaction had a significant ($P \leq 0.05$) effect on plant height, fresh wt. of plant and dry wt. of plant in the 1st growth and stem diameter, fresh wt. of plant and dry wt. of plant in the 2nd growth in S_1, as well as dry wt. of plant and fresh leave/stem ratio in the 1st growth and plant height in the 2nd growth in S_2 and fresh wt. of plant in the 1st growth and also plant height and fresh wt. of plant in S_3. However, the rest vegetative growth parameters were not significant. The maximum values of vegetative growth parameters were produced by FYM_2 x N_3 combination (Table 4).

Forage quality parameters

Sorghum plants in 1st and 2nd growths at booting stage in S_1 and S_2 system, respectively, had lower dry matter content compared to other growths at mature stage within the three systems (Table 5).

Data pertaining to forage quality in the 1st and 2nd growths in the three cutting systems (Table 5) refer to all forage quality parameters were significantly ($P \leq 0.05$) influenced by FYM except forage CP% in the 1st growth in S_1, forage CF% and NFE% in the 1st growth and forage CP%, CF% and NFE% in the 2nd growth in S_2 and forage CF% in the 1st growth in S_3.

Increasing FYM level from FYM_1 to FYM_2 led to significant ($P \leq 0.05$) increase in forage DM% in the 1st and 2nd growths in the three cutting systems and also forage CP% in the 2nd and 1st growths in S_1 and S_2, respectively, as well as in the 1st and 2nd growths in S_3. However, in same time under most circumstances, increasing FYM level led to significant decrease in forage CF% and NFE%, with the exception of forage CF% in the 1st growth and NFE% in the 2nd growth in S_2 as shown in table 5.

The application of N fertilizer significantly ($P \leq 0.05$) affected forage quality parameters i.e., DM%, CP%, CF% and NFE% in the 1st and 2nd growths in the three cutting systems (Table 5). Applying of the highest level N_3 in the 1st and 2nd growths in the three cutting systems gave the highest values of forage DM% and CP% and the lowest values of forage CF% and NFE% except the lowest forage CF% in the 1st growth in S_1 was obtained by application of N_2.

The effect of FYM x N interaction was significant ($P \leq 0.05$) on the majority of the traits. Applying of FYM_2 x N_3 combination produced the maximum values of forage DM% in the 1st and 2nd growths in both S_2 and S_3 and the minimum values of forage NFE% in the 1st growth in S_1 and forage CF% and NFE% in the 1st and 2nd growths in S_2. On the other side, applying of FYM_1 x N_3 combination produced the maximum values of forage DM% and CP% in the 1st and 2nd growths, respectively, in S_1 and forage CP% in the 2nd growth in S_2 but the minimum value of forage CF% in the 2nd growth in S_2. While, the minimum value of forage CF% in the 1st growth in S_1 was achieved by application of FYM_1 x N_3 combination (Table 5).

Forage, dry and grain yields (t ha^{-1})

The FYM had a significant ($P \leq 0.05$) effect on yields in terms of forage, dry and grain as shown in table 6. The greatest values resulted from application of highest level FYM_2 compared to lowest level FYM_1. Similar trend was observed when applying of N fertilizer, where significant increases in all yields were found at each successive increase of N fertilizer level. The greatest values of forage, dry and grain yields were recorded at applying of the highest level N_3.

The FYM x N interaction significantly ($P \leq 0.05$) affected forage yield in the 1st growth in S_1, grain yield in the 1st growth and forage and dry yields in 2nd growth in S_2 and forage, dry and grain yields in the 1st growth and forage yield in 2nd growth in S_3, where the highest values of these yields were produced at application of FYM_2 x N_3 combination (Table 6).

Effect of cutting systems, FYM, N fertilizer and their interactions on forage, dry and grain yields (t ha^{-1})

Data in table 7 refer to presence of significant ($P \leq 0.05$) differences due to cutting systems, where application of S_2 significantly was the superior system that produced the greatest value of forage yield and also application of S_3 was the best system that produced the greatest value of dry yield without significant difference with S_2. However, the lowest values of forage and dry yields were observed at application of S_3 and S_1, respectively. Also, the greatest and lowest values of grain yield were reported at application of S_3 and S_1, respectively. Also, over cutting systems increasing FYM level from FYM_1 to FYM_2 led to significant increases in both forage and dry yields. In contrast, FYM had insignificant effect on grain yield. Regardless of cutting systems and FYM levels, yields in terms of forage, dry and grain were significantly differed due to N fertilizer levels in various to N_3 which yielded the greatest values of forage, dry and grain yields compared to other levels (Table 7). Results revealed that forage yield was significantly ($P \leq 0.05$) influenced by S x FYM interaction but dry and grain yields were insignificantly influenced. Application of S_2 x FYM_2 and S_3 x FYM_1 combination produced the highest and lowest values of forage yield, respectively.

Likewise, a significant S x N interaction was observed when considering forage and grain yields. The highest values of forage and grain yields were recorded with application of S_2 x N_3 and S_3 x N_3 combinations, respectively. While, the lowest values of forage and grain yields were recorded with application of S_3 x N_1 and S_1 x N_1 combinations, respectively. A significant FYM x N interaction was also noticed with respect to forage, dry and grain yields. The combination of FYM_2 x N_3 showed to have the greatest forage, dry and grain yields while the combination of FYM_1 x N_1 showed to have the lowest yields. The interaction effect among the three factors S x FYM x N had no significant effect on forage, dry and grain yields (Table 7).

Results indicated that almost all investigated vegetative growth parameters of dual-purpose sorghum were significantly ($P \leq 0.05$) influenced by FYM in the 1st and 2nd growths in the three cutting systems in this study. These results are in line with the findings previously reported by El-Toukhy, (2008); Abd El-Samei *et al.* (2010); Ahmed *et al.* (2012); Verma *et al.* (2012). This may be explained by postulated slow release and continuous supply of available macro and micro nutrients from FYM. In addition, application of FYM plays an important role in reducing soil pH and improving soil permeability to air and water and thereby more nutrients uptake by sorghum plants required for plant growth and development (El-Toukhy, 2008; Srinivasarao *et al.*, 2012).

Application of N fertilizer significantly increased all vegetative growth parameters in the 1st and 2nd growths in the three cutting systems. These results are in conformance with those of Zhao *et al.* (2005); Almodares *et al.* (2008); Olanite *et al.* (2010); Verma *et al.* (2012); Rakić *et al.* (2013). The stimulating effects of N fertilizer on vegetative growth may be attributed to increased availability of soil N which might have beneficial effects on cell division, cell elongation and meristematic activity. It also increased photosynthetic surface which capture the incident light more efficiently, metabolic processes and hence more production and accumulation of photosynthates in plants which in turn led to increase total dry matter production and partitioning. Increased fresh leave/stem ratio with increasing N fertilizer may due to the fact that among the aerial plant parts, the leaves are more responsive to additional N supply than stems.

Table.1 Treatments in each cutting system

	The 1st growths	The 2nd growths		The 1st growths	The 2nd growths
1.	45 m^3 FYM + 70 kg N ha^{-1}	70 kg N ha^{-1}	4.	90 m^3 FYM + 70 kg N ha^{-1}	70 kg N ha^{-1}
2.	45 m^3 FYM + 140 kg N ha^{-1}	140 kg N ha^{-1}	5.	90 m^3 FYM + 140 kg N ha^{-1}	140 kg N ha^{-1}
3.	45 m^3 FYM + 210 kg N ha^{-1}	210 kg N ha^{-1}	6.	90 m^3 FYM + 210 kg N ha^{-1}	210 kg N ha^{-1}

Table.2 Selected physical and chemical properties of the top soil (0-30cm) at the experimental location during the 2009 and 2010 growing seasons

Year	Physical analysis*				Chemical analysis**						
	Sand (%)	Clay (%)	Silt (%)	Soil texture	Organic matter (%)	Ca Co_3 (%)	pH	ECe (ds/m)	N (%)	P (%)	K (%)
2009	82.60	11.70	5.70	Sandy Loam	0.68	6.70	7.80	4.02	0.13	0.36	0.35
2010	82.50	11.70	5.80	Sandy Loam	0.66	6.80	7.70	6.28	0.14	0.34	0.38

Table.3 Averages of relative humidity (%), air temperature (°C), pan evaporation (mm) and photoperiod (hr day^{-1}) at Fayoum region during the 2009 and 2010 growing seasons*

Month	RH (%)		Air temp. (°C)				Pan evaporation (mm)		Photoperiod (hr day^{-1})
	Max.		Max.		Min.				
	2009	2010	2009	2010	2009	2010	2009	2010	
May	74.73	75.93	33.81	34.14	16.64	16.71	6.90	6.90	13.37
June	73.53	74.63	38.17	38.40	20.37	21.36	8.00	7.60	13.88
July	75.21	76.73	38.45	36.59	22.66	22.34	7.80	8.60	13.53
Aug.	77.00	74.90	37.07	40.22	21.86	24.49	6.90	7.00	13.02
Sept.	76.57	76.17	35.17	36.25	20.71	21.90	6.20	6.10	12.13
Oct.	75.17	75.37	31.84	36.05	18.16	21.31	4.20	5.00	11.27
Nov.	75.10	76.93	24.97	31.25	11.68	15.99	2.50	2.30	10.42
Dec.	74.98	75.34	22.41	24.16	8.88	10.26	1.90	2.00	10.18

*The meteorology station of the Agricultural Management in Itsa - Administrative centre at Fayoum.

Table.4 Effect of farmyard manure, mineral nitrogen fertilizer and their interaction on vegetative growth parameters of dual-purpose sorghum in the 1st and 2nd growths under three various cutting systems as a combined analysis over two growing seasons

Treatments	Levels	Cutting systems (S)														
		S_1					S_2					S_3				
		1st growth at booting stage					1st growth at mature stage					1st growth at mature stage				
		Plant height (cm)	Stem diameter (cm)	Fresh wt. of plant (g)	Dry wt. of plant (g)	Fresh leave/stem ratio	Plant height (cm)	Stem diameter (cm)	Fresh wt. of plant (g)	Dry wt. of plant (g)	Fresh leave/stem ratio	Plant height (cm)	Stem diameter (cm)	Fresh wt. of plant (g)	Dry wt. of plant (g)	Fresh leave/stem ratio
Farmyard manure (FYM)	FYM_1	163.58b	1.96b	368.05b	73.75b	39.12b	151.34b	2.15a	374.38b	109.26b	20.05b	152.35a	2.13a	371.42b	107.49b	22.47a
	FYM_2	169.09a	2.05a	411.36a	86.63a	42.22a	155.25a	2.21a	405.53a	124.15a	22.75a	154.26a	2.19a	396.17a	115.56a	23.06a
	$LSD^{L.S.}$	1.26**	0.09*	5.04**	1.36**	1.15**	2.05**	NS.	12.58**	4.56**	0.82**	NS.	NS.	11.64**	4.51**	NS.
Mineral nitrogen (N)	N_1	161.97c	1.94c	364.76c	70.09c	39.44b	149.77c	2.09b	353.16c	100.18c	19.33c	149.22c	2.06b	348.81c	95.93c	20.82c
	N_2	166.12b	2.01b	380.82b	78.57b	41.24a	152.41b	2.20a	395.75b	116.39b	22.19b	153.76b	2.17a	384.00b	110.80b	22.82b
	N_3	170.91a	2.08a	423.54a	91.90a	41.33a	157.70a	2.25a	420.95a	133.55a	24.17a	156.95a	2.23a	418.56a	127.83a	24.65a
	$LSD^{L.S.}$	1.77**	0.05**	6.81**	2.40**	1.30**	2.28**	0.08**	10.59**	3.54**	0.73**	1.56**	0.09**	10.77**	3.96**	0.88**
Interaction (FYM x N)	FYM_1x N_1	155.27d	1.87a	336.77d	60.88e	38.13a	147.38a	2.03a	339.25a	94.75d	17.79d	147.31a	2.01a	328.00e	90.43a	20.72a
	FYM_1x N_2	166.10c	1.99a	366.06c	73.41d	39.39a	150.83a	2.19a	385.13a	109.87c	21.39c	153.53a	2.16a	381.25cd	107.16a	22.45a
	FYM_1x N_3	169.38b	2.04a	401.31b	86.96b	39.84a	155.80a	2.22a	398.75a	123.16b	23.96ab	156.23a	2.21a	405.00b	124.88a	24.23a
	FYM_2x N_1	168.68b	2.00a	392.74b	79.30c	40.75a	152.15a	2.14a	367.08a	105.61c	20.87c	151.13a	2.11a	369.63d	101.43a	20.91a
	FYM_2x N_2	166.15c	2.04a	395.58b	83.74b	43.09a	154.00a	2.21a	406.38a	122.91b	23.00b	154.00a	2.19a	386.75c	114.45a	23.20a
	FYM_2x N_3	172.45a	2.12a	445.77a	96.84a	42.81a	159.60a	2.28a	443.15a	143.94a	24.38a	157.67a	2.26a	432.13a	130.79a	25.08a
	$LSD^{L.S.}$	2.50**	NS.	9.62**	3.40**	NS.	NS.	NS.	NS.	5.00*	1.04**	NS.	NS.	15.23**	NS.	NS.
		2nd growth at mature stage					2nd growth at booting stage					2nd growth at mature stage				
		Plant height (cm)	Stem diameter (cm)	Fresh wt. of plant (g)	Dry wt. of plant (g)	Fresh leave/stem ratio	Plant height (cm)	No. of tillers $hill^{-1}$	Fresh wt. of tillers $hill^{-1}$ (g)	Dry wt. of tillers $hill^{-1}$ (g)	Fresh leave/stem ratio	Plant height (cm)	Stem diameter (cm)	Fresh wt. of plant (g)	Dry wt. of plant (g)	Fresh leave/stem ratio
Farmyard manure (FYM)	FYM_1	147.13a	1.91b	290.07b	81.34b	24.04a	163.32b	3.49a	539.15a	102.02b	31.26a	157.72a	1.88a	320.96b	86.29b	19.13a
	FYM_2	148.20a	2.00a	328.58a	97.24a	24.29a	166.88a	3.72a	551.36a	109.13a	31.41a	156.74a	1.93a	347.71a	97.10a	19.85a
	$LSD^{L.S.}$	NS.	0.06*	12.08**	4.34**	NS.	2.14**	NS.	NS.	3.55**	NS.	NS.	NS.	11.90**	4.99**	NS.
Mineral nitrogen (N)	N_1	144.84c	1.89c	271.74c	74.25c	23.21b	159.71c	3.27b	493.64c	88.23c	31.25a	155.90b	1.87b	318.00c	82.75c	18.51b
	N_2	147.85b	1.95b	302.18b	86.29b	24.52a	165.69b	3.52b	537.44b	101.08b	31.31a	156.57b	1.87b	325.81b	88.90b	19.00b
	N_3	150.31a	2.03a	354.06a	107.34a	24.77a	169.90a	4.02a	604.67a	127.41a	31.44a	159.21a	1.98a	359.19a	103.44a	20.97a
	$LSD^{L.S.}$	1.97**	0.06**	10.43**	3.87**	1.30*	1.61**	0.35**	7.96**	3.52**	NS.	2.17*	0.05**	7.80**	3.79**	0.96**
Interaction (FYM x N)	FYM_1x N_1	143.43a	1.84c	256.93d	67.30e	23.09a	159.38d	3.21a	488.76a	83.04a	30.94a	154.25b	1.86a	300.13e	77.05a	17.80a
	FYM_1x N_2	148.10a	1.86c	262.50d	72.99d	24.73a	163.50c	3.42a	530.39a	98.03a	31.58a	160.15a	1.83a	319.75d	84.12a	18.39a
	FYM_1x N_3	149.88a	2.04a	350.79ab	103.73b	24.30a	167.08b	3.83a	598.30a	124.99a	31.26a	158.78a	1.96a	343.00b	97.70a	21.21a
	FYM_2x N_1	146.25a	1.94b	286.56c	81.19c	23.34a	160.04d	3.33a	498.53a	93.42a	31.56a	157.55a	1.88a	335.88bc	88.44a	17.80a
	FYM_2x N_2	147.60a	2.03a	341.85b	99.58b	24.30a	167.88b	3.63a	544.50a	104.13a	31.04a	153.00b	1.91a	331.88c	93.67a	18.39a
	FYM_2x N_3	150.75a	2.02a	357.33a	110.95a	25.24a	172.71a	4.21a	611.05a	129.84a	31.63a	159.65a	2.00a	375.38a	109.19a	21.21a
	$LSD^{L.S.}$	NS.	0.08**	14.75**	5.48**	NS.	2.28*	NS.	NS.	NS.	NS.	3.06**	NS.	11.03**	NS.	NS.

Means in the same column followed by different letters differ significantly at $P \leq 0.05$ using Least Significant Different LSD test.

L.S.; Level of significance: *$P \leq 0.05$, **$P \leq 0.01$ and NS.; Non-significant.

FYM_1 and FYM_2 represent 45 and 90 $m^3 ha^{-1}$, respectively and N_1, N_2 and N_3 represent 70, 140 and 210 kg ha^{-1}, respectively.

Table.5 Effect of farmyard manure, mineral nitrogen fertilizer and their interaction on forage quality parameters of dual-purpose sorghum in the 1st and 2nd growths under three various cutting systems as a combined over two growing seasons

	Levels	Cutting systems (S)											
		S_1				S_2				S_3			
		1st growth at booting stage				1st growth at mature stage				1st growth at mature stage			
		DM%	CP%	CF %	NFE%	DM%	CP%	CF %	NFE%	DM%	CP%	CF %	NFE%
Farmyard manure (FYM)	FYM_1	20.62b	10.06a	23.97b	53.06a	30.75b	6.44b	26.05a	59.40a	30.35b	7.35b	25.84a	58.73a
	FYM_2	21.55a	10.28a	24.35a	52.33b	31.86a	6.96a	25.97a	58.69a	30.91a	7.92a	25.83a	57.92b
	$LSD^{L.S.}$	0.34**	NS.	0.31*	0.52*	0.39**	0.20**	NS.	NS.	0.52*	0.16**	NS.	0.53*
Mineral nitrogen (N)	N_1	19.84c	9.39c	24.53a	53.94a	29.60c	5.78c	26.41a	60.42a	28.87c	6.63c	26.09a	59.78a
	N_2	21.11b	10.37b	23.58b	53.07b	31.07b	6.90b	26.22a	58.67b	30.63b	7.88b	26.09a	58.09b
	N_3	22.31a	10.76a	24.37a	51.07c	33.24a	7.42a	25.40b	58.04c	32.39a	8.40a	25.33b	57.12c
	$LSD^{L.S.}$	0.36**	0.25**	0.26**	0.33**	0.42**	0.23**	0.21**	0.36**	0.36**	0.19**	0.26**	0.29**
Interaction (FYM x N)	FYM_1 x N_1	18.77d	9.32a	24.59a	54.22a	29.36e	5.52a	26.26bc	60.82a	28.82d	6.43a	26.02a	59.99a
	FYM_1 x N_2	20.64c	10.24a	23.12d	53.76ab	30.19d	6.71a	26.38ab	59.11a	30.04c	7.48a	26.23a	58.58a
	FYM_1 x N_3	22.45a	10.63a	24.19bc	51.19d	32.70b	7.09a	25.52d	58.27a	32.18a	8.14a	25.28a	57.63a
	FYM_2 x N_1	20.90c	9.45a	24.47ab	53.66b	29.84de	6.04a	26.56a	60.03a	28.92d	6.83a	26.16a	59.57a
	FYM_2 x N_2	21.59b	10.50a	24.04c	52.38c	31.96c	7.09a	26.06c	58.23a	31.22b	8.27a	25.94a	57.60a
	FYM_2 x N_3	22.18a	10.89a	24.54ab	50.96d	33.78a	7.75a	25.29d	57.81a	32.59a	8.66a	25.38a	56.61a
	$LSD^{L.S.}$	0.52**	NS.	0.37**	0.47**	0.60*	NS.	0.30*	NS.	0.51*	NS.	NS.	NS.
		2nd growth at mature stage				2nd growth at booting stage				2nd growth at mature stage			
		DM%	CP%	CF %	NFE%	DM%	CP%	CF %	NFE%	DM%	CP%	CF %	NFE%
Farmyard manure (FYM)	FYM_1	29.13b	6.56b	27.50a	57.68b	20.08b	10.46a	24.38a	52.60a	26.98b	7.40b	25.27a	59.31a
	FYM_2	30.53a	6.87a	26.11b	58.43a	20.82a	10.59a	24.38a	52.29a	28.18a	8.01a	24.81b	59.02b
	$LSD^{L.S.}$	0.45**	0.25*	0.48**	0.35**	0.24**	NS.	NS.	NS.	1.03*	0.40*	0.21**	0.19*
Mineral nitrogen (N)	N_1	28.61c	5.97c	26.99a	59.28a	19.31c	9.32c	24.68a	54.25a	25.74c	6.70c	25.57a	60.16a
	N_2	29.66b	6.76b	27.01a	57.84b	20.00b	10.44b	24.33b	52.78b	27.50b	7.94b	24.84b	59.22b
	N_3	31.22a	7.42a	26.41b	57.04c	22.04a	11.81a	24.14c	50.30c	29.50a	8.47a	24.71b	58.11c
	$LSD^{L.S.}$	0.68**	0.13**	0.45*	0.66**	0.38**	0.23**	0.14**	0.40**	0.47**	0.26**	0.20**	0.43**
Interaction (FYM x N)	FYM_1 x N_1	27.79a	5.65e	27.73a	58.87a	18.69d	9.06d	25.16a	54.03a	25.63d	6.30a	25.91a	60.18a
	FYM_1 x N_2	28.78a	6.57c	27.73a	57.61a	19.62c	10.37b	24.13c	53.18b	26.31c	7.75a	25.04a	59.40a
	FYM_1 x N_3	30.82a	7.48a	27.03a	56.55a	21.93a	11.95a	23.85d	50.60d	29.01b	8.14a	24.87a	58.36a
	FYM_2 x N_1	29.44a	6.30d	26.25a	59.69a	19.93bc	9.58c	24.20c	54.48a	25.86cd	7.09a	25.24a	60.14a
	FYM_2 x N_2	30.54a	6.96b	26.29a	58.06a	20.37b	10.50b	24.52b	52.38c	28.69b	8.14a	24.64a	59.05a
	FYM_2 x N_3	31.62a	7.35a	25.79a	57.53a	22.16a	11.68a	24.43b	50.00e	29.99a	8.80a	24.54a	57.87a
	$LSD^{L.S.}$	NS.	0.19**	NS.	NS.	0.54*	0.32**	0.19**	0.56**	0.66**	NS.	NS.	NS.

Means in the same column followed by different letters differ significantly at $P \leq 0.05$ using Least Significant Different LSD test.
L.S.; Level of significance: *$P \leq 0.05$, **$P \leq 0.01$ and NS.; Non-significant.
FYM_1 and FYM_2 represent 45 and 90 m^3ha^{-1}, respectively and N_1, N_2 and N_3 represent 70, 140 and 210 kg ha^{-1}, respectively.
DM, dry matter; CP, crude protein; CF, crude fiber; NFE, nitrogen free extract.

Table.6 Effect of farmyard manure, mineral nitrogen fertilizer and their interaction on forage, dry and grain yields (t ha^{-1}) of dual-purpose sorghum in the 1st and 2nd growths under three various cutting systems as a combined analysis over two growing seasons

Treatments	Levels	Cutting systems (S)							
		S_1		S_2			S_3		
		1st growth at booting stage		1st growth at mature stage			1st growth at mature stage		
		Forage yield (t ha^{-1})	Dry yield (t ha^{-1})	Forage yield (t ha^{-1})	Dry yield (t ha^{-1})	Grain yield (t ha^{-1})	Forage yield (t ha^{-1})	Dry yield (t ha^{-1})	Grain yield (t ha^{-1})
Farmyard manure (FYM)	FYM_1	43.23b	8.69b	37.81b	11.03b	6.75b	40.14b	11.61b	6.79b
	FYM_2	46.61a	9.80a	40.97a	12.52a	7.38a	41.81a	12.18a	7.31a
	$LSD^{L.S.}$	0.87**	0.20**	1.20**	0.46**	0.20**	0.68**	0.29**	0.19**
Mineral nitrogen (N)	N_1	38.94c	7.46c	35.73c	10.14c	6.00c	37.50c	10.28c	6.03c
	N_2	46.74b	9.62b	40.37b	11.87b	7.21b	41.20b	11.88b	7.10b
	N_3	49.08a	10.64a	42.08a	13.33a	7.99a	44.22a	13.51a	8.01a
	$LSD^{L.S.}$	1.59**	0.42**	1.41**	0.49**	0.22**	1.10**	0.46**	0.20**
Interaction (FYM x N)	FYM_1 x N_1	36.84a	6.68a	33.44a	9.36a	5.37e	35.21d	9.68e	5.59f
	FYM_1 x N_2	46.08a	9.23a	39.38a	11.23a	7.02c	42.60b	11.99c	6.92d
	FYM_1 x N_3	46.77a	10.15a	40.63a	12.52a	7.87a	42.60b	13.14b	7.85b
	FYM_2 x N_1	41.04a	8.24a	38.02a	10.92a	6.62d	39.79c	10.89d	6.47e
	FYM_2 x N_2	47.40a	10.01a	41.35a	12.51a	7.41b	39.79c	11.77c	7.29c
	FYM_2 x N_3	51.38a	11.13a	43.54a	14.15a	8.12a	45.83a	13.87a	8.18a
	$LSD^{L.S.}$	NS.	NS.	NS.	NS.	0.31**	1.55**	0.65*	0.28*

Treatments	Levels	S_1			S_2		S_3		
		2nd growth at mature stage			2nd growth at booting stage		2nd growth at mature stage		
		Forage yield (t ha^{-1})	Dry yield (t ha^{-1})	Grain yield (t ha^{-1})	Forage yield (t ha^{-1})	Dry yield (t ha^{-1})	Forage yield (t ha^{-1})	Dry yield (t ha^{-1})	Grain yield (t ha^{-1})
Farmyard manure (FYM)	FYM_1	27.50b	7.70b	4.84b	32.99b	6.22b	27.43b	7.36b	2.84b
	FYM_2	28.48a	8.42a	5.26a	36.91a	7.32a	29.58a	8.23a	3.33a
	$LSD^{L.S.}$	0.43**	0.24**	0.19**	1.32**	0.47**	0.79**	0.32**	0.17**
Mineral nitrogen (N)	N_1	25.11c	6.85c	4.17c	31.51c	5.67c	25.78c	6.66c	2.54c
	N_2	27.97b	7.96b	4.91b	34.12b	6.44b	28.86b	7.86b	3.07b
	N_3	30.88a	9.37a	6.07a	39.22a	8.19a	30.89a	8.87a	3.64a
	$LSD^{L.S.}$	0.48**	0.26**	0.21**	1.23**	0.33**	1.01**	0.35**	0.18**
Interaction (FYM x N)	FYM_1 x N_1	24.69e	6.49a	3.94a	30.73d	5.28e	25.10c	6.43a	2.27a
	FYM_1 x N_2	27.81c	7.73a	4.60a	32.71c	6.06d	28.23b	7.42a	2.80a
	FYM_1 x N_3	30.00b	8.88a	5.97a	35.52b	7.32b	28.96b	8.24a	3.44a
	FYM_2 x N_1	25.54d	7.21a	4.39a	32.29cd	6.07d	26.46c	6.89a	2.81a
	FYM_2 x N_2	28.13c	8.20a	5.22a	35.52b	6.82c	29.48b	8.31a	3.34a
	FYM_2 x N_3	31.77a	9.86a	6.16a	42.92a	9.07a	32.81a	9.51a	3.85a
	$LSD^{L.S.}$	0.67*	NS.	NS.	1.74**	0.47**	1.42*	NS.	NS.

Means in the same column followed by different letters differ significantly at $P \leq 0.05$using Least Significant Different LSD test.
L.S.; Level of significance: *$P \leq 0.05$, **$P \leq 0.01$ and NS.; Non-significant.
FYM_1 and FYM_2 represent 45 and 90 m3ha^{-1}, respectively and N_1, N_2 and N_3 represent 70, 140 and 210 kg ha^{-1}, respectively.

Table.7 Effect of cutting systems, farmyard manure, mineral nitrogen fertilizer and their interactions on combined of yields i.e. forage, dry and grain (t ha^{-1}) of dual-purpose sorghum for the 1st and 2nd growths in each cutting system

Treatments	Levels	Forage yield (t ha^{-1})	Dry yield (t ha^{-1})	Grain yield (t ha^{-1})
Cutting systems (s)	S_1	72.91b	17.30b	5.05c
	S_2	74.34a	18.55a	7.07b
	S_3	69.48c	19.69a	10.13a
	LSD$^{L.S.}$	0.85**	1.19*	1.91**
Farmyard manure (FYM)	FYM_1	69.70b	17.53b	7.07a
	FYM_2	74.79a	19.49a	7.76a
	LSD$^{L.S.}$	0.69**	0.97**	NS.
Mineral nitrogen (N)	N_1	64.86c	15.69c	6.25c
	N_2	73.08b	18.55b	7.43b
	N_3	78.79a	21.31a	8.57a
	LSD$^{L.S.}$	1.03**	0.32**	0.17**
Two-way interactions	S_1 x FYM_1	70.73c	16.39a	4.84a
	S_1 x FYM_2	75.09b	18.22a	5.26a
	S_2 x FYM_1	70.80c	17.25a	6.75a
	S_2 x FYM_2	77.88a	19.84a	7.38a
	S_3 x FYM_1	67.57d	18.97a	9.62a
	S_3 x FYM_2	71.39c	20.41a	10.64a
	LSD$^{L.S.}$	1.20**	NS.	NS.
	S_1 x N_1	64.05e	14.31a	4.17h
	S_1 x N_2	74.71b	17.58a	4.91g
	S_1 x N_3	79.96a	20.01a	6.07f
	S_2 x N_1	67.24d	15.81a	6.00f
	S_2 x N_2	74.48b	18.31a	7.21e
	S_2 x N_3	81.30a	21.53a	7.99d
	S_3 x N_1	63.28e	16.94a	8.57c
	S_3 x N_2	70.05c	19.74a	10.17b
	S_3 x N_3	75.10b	22.38a	11.66a
	LSD$^{L.S.}$	1.78**	NS.	0.29**
	FYM_1 x N_1	62.00e	14.64f	5.73f
	FYM_1 x N_2	72.27c	17.89d	7.11d
	FYM_1 x N_3	74.83b	20.08b	8.38b
	FYM_2 x N_1	67.72d	16.74e	6.76e
	FYM_2 x N_2	73.89b	19.21c	7.75c
	FYM_2 x N_3	82.75a	22.53a	8.77a
	LSD$^{L.S.}$	1.45**	0.45**	0.24**
Three-way interaction	S_1 x FYM_1 x N_1	61.52a	13.17a	3.94a
	S_1 x FYM_1 x N_2	73.89a	16.96a	4.60a
	S_1 x FYM_1 x N_3	76.77a	19.03a	5.98a
	S_1 x FYM_2 x N_1	66.58a	15.46a	4.39a
	S_1 x FYM_2 x N_2	75.52a	18.21a	5.22a
	S_1 x FYM_2 x N_3	83.16a	21.00a	6.16a
	S_2 x FYM_1 x N_1	64.17a	14.63a	5.37a
	S_2 x FYM_1 x N_2	72.08a	17.29a	7.02a
	S_2 x FYM_1 x N_3	76.15a	19.84a	7.87a
	S_2 x FYM_2 x N_1	70.31a	16.98a	6.62a
	S_2 x FYM_2 x N_2	76.88a	19.33a	7.41a
	S_2 x FYM_2 x N_3	86.46a	23.21a	8.12a
	S_3 x FYM_1 x N_1	60.31a	16.11a	7.86a
	S_3 x FYM_1 x N_2	70.83a	19.41a	9.72a
	S_3 x FYM_1 x N_3	71.56a	21.38a	11.29a
	S_3 x FYM_2 x N_1	66.25a	17.77a	9.28a
	S_3 x FYM_2 x N_2	69.27a	20.08a	10.63a
	S_3 x FYM_2 x N_3	78.65a	23.38a	12.02a
	LSD$^{L.S.}$	NS.	NS.	NS.

Means in the same column followed by different letters differ significantly at $P \leq 0.05$ using Least Significant Different LSD test.
L.S.; Level of significance: *$P \leq 0.05$, **$P \leq 0.01$ and NS.; Non-significant.
FYM_1 and FYM_2 represent 45 and 90 m^{3}ha^{-1}, respectively.
N_1, N_2 and N_3 represent 140, 280 and 420 kg ha^{-1}, respectively.

Reduced vegetative growth in the 2nd growth compared to 1st growth was highly pronounced in both S_1 and S_3 may be attributed to the short vegetative growth duration because of early panicle initiation due to shortening of daylight length in autumn coinciding with the 2nd growth period (Ellis *et al.,* 1997; Miron *et al.,* 2006).

The DM% of forage crops at harvest is one of the most important factors for successful ensilage (Miron *et al.,* 2006; Qu *et al.,* 2014). In the beginning of growing season, sorghum plants have higher nutritional value and forage quality, while they have less forage quality at the maturity stage. Thus, sorghum plants in growths at booting stage, which representing the 1st growth in S_1 and the 2nd growth in S_2, had lower DM% compared to other growths at mature stage within the three cutting systems in this study. This result was supported by (Adjei and Fianu, 1985) who proposed that according to the model, nutrients uptake is more at early growth stages accompanied with low dry matter production and then dry biomass production outstrips the nutrient uptake, then nutrients contents decline due to natural dilution processes. Fresh forage yield that harvest at booting stage may be better for feed ruminant animals directly particularly in summer and autumn seasons as in Egypt condition. However, forage yield that harvest at physiological maturity stage may be appropriate for ensilage to ensure the good fermentation during preservation of silage. Contain sufficient DM above the proposed minimum DM content (>24.7 %) demanded for ensure a margin of safety against production of effluent during ensiling (Castle and Watson, 1973).

Results clarified that forage DM% was significantly increased by increasing FYM in the 1st and 2nd growths in the three cutting systems. This result may be due to the ability of FYM to improve the soil properties and nutrients uptake which promote growth and improve meristematic and physiological activities, resulting in increasing photoassimilates and thereby enhanced dry matter content in sorghum plants. These results are supported those of (Akongwubel *et al.,* 2012).

Application of N fertilizer significantly increased forage DM% in the 1st and 2nd growths in the three cutting systems. This is in agreement with the reports of Zhao *et al.* (2005); Hugar, (2010); Saini, (2012). The increased DM%, as a result of N application, may be due to the fact that N increased leaf area development, maintenance and photosynthates efficiency (Zahid *et al.,* 2002). While this result disagrees with that of Ayub *et al.* (2009), who reported that N application didn't have effect on DM%. This contradiction may be due to the difference in soil fertility status.

For, the effect of FYM on forage CP%, results revealed that the application of FYM significantly increased forage CP%. These findings are in line with those obtained by Lubis and Kumagai (2007a); Abdalla *et al.* (2007); Amin (2010); Ahmed *et al.* (2012). Increment of forage CP% with FYM application may be ascribed to improving the nutrients availability and uptake especially N which is connected with the buildup of amino acids and also phosphorus which is main component of ATP, the energy carrier for the metabolic processes. This might have directly contributed to large photosynthetic activity and higher synthesis of protein (Khan *et al.,* 2008; Abd El-Lattief, 2011).

Application of N fertilizer significantly increased CP% in forage. Similar results have been reported by Selim (1995); Bilal *et al.* (2001); Ayub *et al.* (2002); Ayub *et al.* (2007); Rashid *et al.* (2008); Ali (2010);

Olanite *et al.* (2010); Verma *et al.* (2012); Rakić *et al.* (2013). Increase CP% with increment in N levels was due to increased absorption of N. Since N is the main constituent of amino acids, it ultimately increased CP% of plants (Ayub *et al.*, 2002; Saini, 2012).

On the other side, CP% in sorghum plants decreased as the time of harvesting was delayed. Sorghum plants in the 1st growth in S_1 and the 2nd growth in S_2 which were harvested at booting stage have higher CP % than other growths in the three cutting systems which were harvested at physiological maturity stage. Similar finding was found by Bilal *et al.* (2001). The decrease in CP% in later harvesting might be as a result that nutrient contents did not match the dry matter production at later growth stage and thus CP% is diluted. On the other side, the lower CP content in plant morphological fractions might be the result of loss of leaves blades as they are thought to contribute twice in term of CP than stems (Buxton, 1996). Therefore, the decreased CP was the result of loss of leaves mass coupled with higher proportion of stems in total biomass which are deficient in CP content (Tariq *et al.,* 2011).

It's well known that plant cell walls constituents i.e., NDF, ADF, cellulose, hemicelluloses, lignin and tannins which represent CF content in forage plant have a large influence on forage digestibility. The forage having less CF percentage is considered a good quality. Thus, sorghum plants grown in the growths which harvested at mature stage have higher CF% than plants growing in growths which harvested at booting stage. Similar result was found by Tariq *et al.* (2011); Qu *et al.* (2014). On the contrary, Atis *et al.* (2012) revealed that with prolonged maturity from booting stage to physiological maturity stage lignin content tended to increase, while NDF, ADF, cellulose and hemicellulose contents tended to decrease. The increase in forage CF% with development of growing stage may be due to increased concentration of cell walls constituents within stem and leaves as well as decreased soluble proportion of the cell (Buxton, 1996; Saini, 2012; Qu *et al.*, 2014).

Under most circumstances over all growths in the three cutting systems, forage CF% tended to decrease with increasing FYM level. This result was in agreement with those reported by Abd El-Aziz (2002); Lubis and Kumagai (2007a,b); Ahmed *et al.* (2012). While in a one occasion only in the 1st growth in S_1 sorghum forage CF% tended to increase with increasing FYM level.

In almost all cases, application of N fertilizer led to significant decreases in forage CF%. This result is in agreement with those of Ayub *et al.* (2002); Marsalis *et al.* (2010); Olanite *et al.* (2010); Tariq *et al.* (2011); Saini (2012). However, Ayub *et al.* (2007) who reported that CF% in plant increased by increasing the N fertilizer rate. The decline in forage CF% caused by FYM and/or N application may be attributed to improving the availability and uptake of macro and micro nutrients including N, the higher supply of N accompanied with the greater demand for carbon compounds for protein synthesis and the smaller proportion of carbohydrate left available for cell wall material. Increasing supply of N can decrease cell wall materials due to that the protein cell content formation is mainly from N and carbon. At high N concentration, demand of carbon for protein formation will increase, as result, proportion of carbon for cell wall decreased and consequently decrease CF% in morphological plant fractions, while concentration of organic cell content was increased (Lubis and Kumagai, 2007a,b).

Results confirmed that increasing FYM and/or N application resulted in a decrease in forage NFE% in majority of growths in the three cutting systems while only in the 2nd growth in S_1 forage NFE% tended to increase with increasing organic manure application. Decreasing forage NFE% is supported by findings of Tariq *et al.* (2011); Saini (2012); Rakić *et al.* (2013). The reason of decreasing NFE% in morphological plant fractions as a result of FYM and/or N application may be attributed to improved soil retention, availability and uptake of nutrients including N which may be used as intermediate metabolic in TCA cycle which is used for amino acids and protein synthesis. Thus forage NFE% decrease as the level of N increased. On the other hand, the lower forage NFE% at higher level of N may be due to the result of positive association with CP%, EE%, ash% and CF%. Thus, increasing N fertilizer levels decreased the forage NFE% (Tariq *et al.,* 2011; Saini, 2012).

It is worth to mention that NFE% increased by advancing maturity. Thus, findings indicated that plants growing in growths which harvested at booting stage containing NFE% lower than plants growing in growths which harvested at mature stage. These results are in agreement with those of McBee and Miller (1993). Decreasing NFE% in plants at booting stage compared to plants at mature stage could be due to the conversion of carbohydrates to build up the protective and supporting tissues in plants at booting stage. Another reason may be due to the fact that carbohydrates are the major precursors of proteins and fats.

Fresh and dry forage yields seemed to be significantly increased with increasing FYM application from FYM_1 to FYM_2 in all growths at the three cutting systems. This is in accordance with those of Ismail *et al.* (2001); El-Toukhy (2008); Ahmed *et al.* (2012). This may be due to the ability of FYM to supply the macro and micro elements (Maltas *et al.,* 2013), necessary to promote meristematic and physiological activities as well as increased photosynthetic surface and hence more total dry matter production and accumulation, thereby resulting in improving growth in terms of more plant height, stem diameter, number and area of green leaves per plant consequently higher fresh and dry forage yields (El-Toukhy, 2008; Amin, 2010).

Both fresh and dry forage yields were significantly influenced by the application of N fertilizer in all growths at the three cutting systems. These results are in agreement with other reports Ayub *et al.* (2002); Ayub *et al.* (2007); Ayub *et al.* (2009); Tariq *et al.* (2011); Saini (2012); Rakić *et al.* (2013). The increase in fresh and dry forage yields was mainly due to greater plant height, number of green leaves per plant, stem diameter, leaves area per plant and number of tillers per plant consequently production of more dry matter as a result of improved photosynthetic activity at higher level of N (Ayub *et al.,* 2009; Tariq *et al.,* 2011).

The obvious forage and dry yields reduction in the 2nd growths compared to the 1st growths at the three cutting systems. Similar result reported by Miron *et al.* (2006); Atis *et al.* (2012). This may be due to the short vegetative growth duration because of early panicle initiation as a result of diurnal asynchrony between photoperiod and thermoperiod (Escalada and Plucknett, 1975; Ellis *et al.,* 1997).

In general, results regarding dual-purpose sorghum plants harvested at physiological maturity stage in the 2nd and 1st growths in both S_1 and S_2, respectively, and also plants in the two growths in the cutting system S_3 indicated that grain yields were decreased in growths which were harvested as second growths. These grain yield decreases were more pronounced in the plants of the 2nd growth in S_3. Increasing grain yield that produced from the 1st growths compared to grain yield from the 2nd growths in the three cutting systems mainly due to the suitable growth season duration, coincidence of the different phenological stages- especially the heading and grain filling stages-with day length and temperature more favorable in addition to the higher dry matter accumulation capacity and positive influence of temperature on dynamic formation of the yield components, and ultimately, the generation of active sinks (Verma *et al.*, 2012).

The obvious grain yield reduction in the plants of the 2nd growths at physiological maturity stage in both S_1 and S_3 may be attributed to the fact that sorghum is a short-day crop and thereby the short vegetative growth duration and early panicle initiation as a result of diurnal asynchrony between short photoperiod and low temperature. These findings are in harmony with those of Escalada and Plucknett (1975) who reported that in sorghum low light intensity, short photoperiod and low temperature, resulted in rosette from of foliage with very short internodes and reduced number of leaves and thereby low grain and stover yields. Ellis *et al*. (1997) reported that the effect of diurnal asynchrony between photoperiod and thermoperiod reduced durations to panicle initiation in sorghum when the temperature warmed after lights went on and cooled after lights went off, but increased these durations when the temperature warmed before lights went on and cooled before lights went off. Also, grain yield reduction, may be due to that plants of the 1st growths allocated a higher proportion of its total above ground biomass to grain than did the plants grown in the second growths. Mathan (1989) reported that total heat unit accumulation significantly influenced the yields i.e., grain, straw and total dry matter and more heat units were available for the early crops during the flowering stage while the availability decreased progressively for the later sown crops. This may also explanation the reduction of sorghum yield in the 1st growths compared to 2nd growths.

The pronounced reduction in grain yield in plants the 2nd growth at S_3 was mainly due to unfavorable climatic conditions which were prevailed during the different phenological stages of sorghum plants particularly severe air temperature decline during the period from flowering to grain filling stages as shows from meteorological data in table 3. Thus, both seed setting and pollen fertility in grain sorghum plants were negatively affected with decline in minimum temperature down to blow 13°C. Seed setting percentage may be more affected by decline in minimum temperature compared to pollen fertility percentage which might be attributed to other factors than pollen fertility influencing seed setting percentage like pollen germination and pollen tube elongation which might be badly affected with decreasing minimum temperature (Mukri *et al.*, 2010; Awad *et al.*, 2013).

Grain yield is the final result of many complex morphological and physiological processes occurring during the growth and development of crop. Results indicated that grain yield inclined to increase with increasing FYM application. This grain yield increase may attributed to the addition of NPK and other essential nutrients through FYM application besides its favorable effect on the physical, chemical, microbial properties of soil due to enhancing soil organic carbon (Manna *et al.*, 2005; Maltas *et al.*, 2013). This will be improve availability and uptake of plant nutrients particularly in sandy loam, which tend to improve meristematic and physiological activities as well as more vigor growth. Thereby this resulted in enhancing the source efficiency (more dry matter accumulation per unit area/time) as well as more panicle length, more panicle diameter, panicle wt., more sink capacity (grain wt.), more grain yield per plant consequently increase grain yield per hectare (Khan *et al.*, 2008; Akongwubel *et al.*, 2012).

Grain yield significantly increased by increasing the N dose. This is supports several author reports (Bacci *et al*., 1999; Hamada *et al.*, 2008; Ali, 2010; Abd El-Samei *et al.*, 2010; Verma *et al.*, 2012). The grain yield increase was a reflection of the role of N in activating photosynthates and metabolism and thereby, improved plant growth and production of more dry matter and subsequently grain yield components. Hamada *et al.* (2008) reported that photosynthate among different organs of maize plants was in favor of the developing grains under high N fertilizer rates than low ones. So, grain yield increased on account of photosynthates translocated to stover or straw organs.

Results indicated that the FYM x N interaction effect significantly increased some of vegetative growth traits, forage quality indices as well as forage, dry and grain yields in the different growths at the three cutting systems. This may be due to that the combined use of organic manures and mineral N fertilizer checks N losses, conserves soil N by forming organic-mineral complexes and thus ensures continuous N availability sorghum plants (Ismail *et al.*, 2001; Abd El-Lattief, 2011; Patil, 2013) consequently greater growth, forage quality indices and productivity of forage and grain. Shisanya *et al.* (2009) reported that integration of organic and inorganic nutrient sources of N resulted in higher maize grain yields compared to sole application or organic materials. Amujoyegbe *et al.* (2007) suggested that inorganic fertilizer component of the mixture provided early nutrient to the growing crops during the early vegetative growth stage, while the organic component provided nutrients at the later stage of the crop development.

Conclusion

In general, it may be concluded that under S_2 with applying of combination FYM_2 x N_3 at the 1st growth period and highest level N_3 at the 2nd growth period could be recommended for maximizing forage yield and improving most indices of the forage sorghum quality without delaying planting time of the winter crops under Fayoum region condition. Also, using of S_3 with applying of combination FYM_2 x N_3 at the 1st growth period and highest level N_3 at the 2nd growth period may be recommended for maximizing grain and dry yields with produce sorghum forage low in nutritive value.

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