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MAXIMIZING LAND USE EFFICIENCY BY INTERCROPPING SOME SUMMER FORAGE CROPS WITH MAIZE

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ABSTRACT: The present study was carried out at the Experimental Farm, Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt during 2019 and 2020 summer seasons to study the influence of intercropping three summer grass forage crops, i.e. pearl millet, sudan grass and teosinte at 100% from their recommended seeding rate with maize at three densities of maize, i.e. 50, 75 and 100% of the recommended plant density (24000 plants/fed) on their productivity and quality as well as the land use efficiency and the competitive relationships. The treatments were arranged in a randomized complete blocks design with four replications. The obtained results could be summarized as follows:

1-Intercropping forage crops with maize decreased most growth characters (No. of shoots/m^2, total chlorophyll, No. of leaves /shoot, leaf area/shoot and total dry weight/shoot, forage yield (fresh and dry forage yields/fed), chemical composition (protein% and ash %) as well as nutritive value (digestible protein "DP" % and total digestible nutrients "TDN" %), but increased plant height and fiber % of forage crops compared to their sole croppings. Sudan grass surpassed other forage crops in plant height and fiber%, while millet crop recorded the highest values of No. of shoots/m^2, total dry weight/shoot, fresh and dry forage yields/fed. Teosinte crop exceeded millet and sudan grass in total chlorophyll, No. of leaves/shoot and leaf area/shoot as well as chemical composition (protein % and ash %) and nutritive values (DP% and TDN %). Increasing plant density of maize from 50% to 100% intercropped with forage crops increased plant height of forage crops, but caused a reduction in growth characters, forage yield as well as nutritive values of forage crops.

2-Intercropping maize with forage crops decreased yield and its attributes of maize (No. of ears/plant, No. of grains/ear, 100-grain weight, ear weight, grain yield/plant, grain and stover yields/fed, protein % and carbohydrates % in grains of maize, but increased oil %. Moreover, increasing plant density of maize up to 100% intercropped with forage crops increased grain and stover yields/fed as well as oil %, but decreased grain yield/ plant and its attributes, protein and carbohydrates % of maize.

3-The aggressivity results showed that the values of maize were positive (dominant), while the values of the three fodder crops were negative (dominated). Increasing the plant density of the maize from 50% to 100% intercropped with fodder crops also led to a decrease in the aggressivity value of the maize. The value of the competitive ratio for maize was greater than that of fodder. Increasing plant density of maize led to a decrease in the competitive ratio for maize but an increase in the competitive ratio for fodder crops. The values of the relative crowding ratio and land use efficiency were increased more than one compared to sole cultivation. The best intercropping system for obtaining the highest grain units was obtained when 100% maize was intercropped with millet or teosinte.

Key words: Forage crops, maize, intercropping patterns, plant density, Competitive relationships

INTRODUCTION

Nowadays, Egypt faces a severe shortage in green fodder estimated by 90% during the summer (Zohry and Ouda, 2018). The feed and fodder contributes the major share 60 % of the total maintenance cost of livestock production (Kumawat *et al.*, 2014). The area devoted to the summer forage crops is very limited due to the big competition with the economical crops such as rice, maize and cotton, which leads to the difficulty in providing the nutritional need of animals. Recently, many efforts are focused to increase the productivity of forage crops to fill the gap between production and consumption in summer season. For raising the productivity of

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unit area, this is done through vertical or horizontal expansion. As a result of the many problems facing horizontal expansion, it is necessary to increase forage productivity through vertical expansion by other agricultural methods such as agriculture intensification. This is achieved by intercropping as one of the pattern of agricultural intensification. The intercropping system allows to growing two or more crops at the same time on the same land. Hence, intercropping can provide many beneficial through increasing efficiency of land utilization, sunlight absorption, water and nutrients, controlling weeds, insects, and diseases and increasing the length of production cycles. In this respect, Shahwan *et al.* (2013) indicated that the intercropping system is consider an important agriculture issue, particularly for small-holder farmers, aiming at sustainable agriculture under the Egyptian conditions of limited land and water resources. Li *et al.* (2023) found that intercrops outperform sole crops when the objective is to achieve a diversity of crop products on a given land area.

Sowing promising grasses forage crops, i.e. pearl millet (*Pennisetum glaucum,* L.), sudan grass (*Sorghum sudanense*, L.) and teosinte (*Euchlaena maxicana,* L.) are the most popular cereal fodder crop belonging to the Poaceae family. They are drought and heat tolerant and has a considerable ability to grow in sandy, infertile and saline soils under arid, hot and dry climates in the region as reported by Jukanti *et al.*(2016) and Salem (2020) for millet Abo-Zeid *et al.* (2017) for sudan grass and Devkota *et al.* (2015) and Seadh *et al.* (2022) for teosinte.

Maize or corn (*Zea mays,* L.) is considered one of the most important food grain crops of strategic importance in Egypt after wheat and rice. Maize is very essential for the human consumption, livestock and poultry nutrition as well as common ingredient for several industrial purposes such as maize oil extraction, starch manufacture (Koriem, 2023). The arable land allocated to maize cultivation in Egypt included roughly 1.027 million hectares (2.536 million feddan) with an average grain yield 2.957 ton/fed giving an output of 7.500 million metric tons (FAO, 2021). The local production of maize dose not sufficient to meet the excessive demand especially the yellow grains. In addition to converting corn for the purpose of producing grain into silage production. Thus, Egypt imports about 6.9 million tons of maize grains (FAO, 2021). Therefore, this study was done to evaluate the influence of intercropping three summer grass forage crops, i.e. pearl millet, sudan grass and teosinte with three densities of maize on their productivity and quality as well as land use efficiency and competitive relationships.

MATERIALS AND METHODS

A field experiment was carried out at the Experimental Farm, Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt (latitude 30°31'42"N, longitude 31°04'08"E) during 2019 and 2020 summer seasons to study the effect of intercropping three summer grass forage crops (pearl millet, sudan grass and teosinte) at 100% of their recommended seeding rates with maize at three plant densities ,i.e. 50, 75 and 100% of its recommended density beside their sole croppings on the productivity, quality, the competitive relationships and land use efficiency of those crops. The experienced treatments were arranged in a randomized complete blocks design with four replications.

Agronomic practices

The preceding crop in this experiment was Egyptian clover in both seasons. The area of each experimental plot was 14.7 m^2 including 3 beds (3.5 m long and 1.4m width for each). Maize and forage crops grains were sown at the same time on May 10 and 5 in 2019 and 2020 seasons, respectively. Maize grains (Single Hybrid Yellow 2066 variety) were handly sown in the two sides of the beds for maize sole cropping using seeding rate at 10 kg grains/fed for producing the recommended plant density (24000 plants/fed), but in one side of the beds for the intercropping treatments at three plant densities (50%, 75% and 100%) of the recommended plant density of maize. The population densities, distances between hills and number of plants/hill of maize plants at each tested plant density % are presented in Table (1). Forage crop grains were handly drilled on the top of the bed at 3 rows, 30 cm apart, using 100% from their recommended seeding rate/fed, i.e. 20, 20 and 30 kg grains/fed for millet (Shandawel 1 variety), sudan grass (Giza 2 variety) and teosinte (local variety), respectively.

The tested intercropping patterns of forage crops with maize and their sole croppings are illustrated in Fig (1).

Table (1): The population densities, distances between hills and number of plants/hill of maize plants in intercropping and sole cropping treatments.

Population densities % of maize plants	Population densities (plants/fed)	Distances between hills (cm)	Number of plants/hill (after thinning 21 DAS)
Intercropping 50%	12000	25	1
Intercropping 75%	18000	16.6	1
Intercropping 100%	24000	12.5	1
Sole cropping 100%	24000	25	1

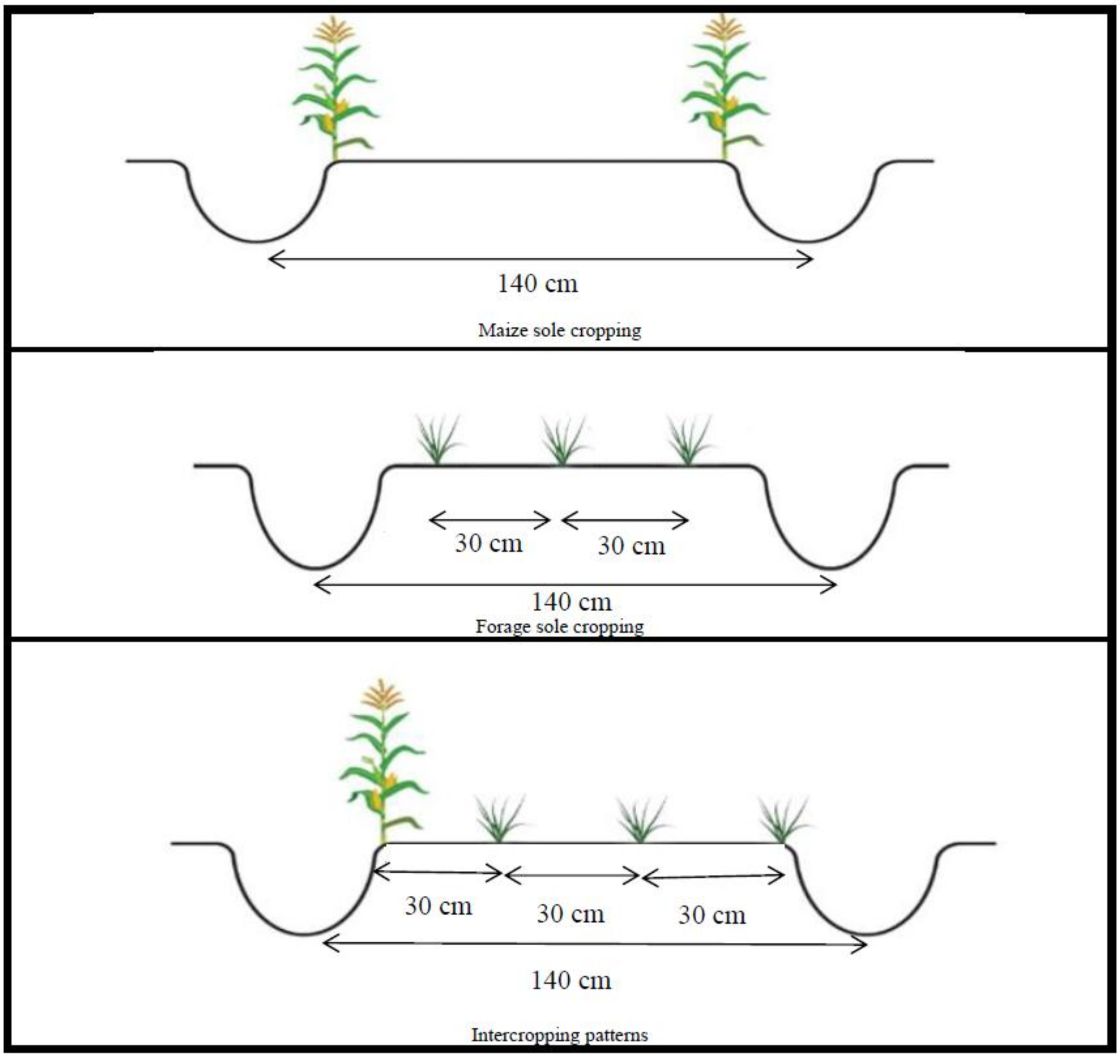

Fig. (1): The tested intercropping patterns of forage crops with maize and their sole croppings.

Phosphorus and potassium fertilizers were added as single dose during land preparation at a rate of 200 kg/fed calcium superphosphate (15.5 % P_2O_5) and 50 kg/fed potassium sulphate (48% K_2O) for both crops. Weed control was done chemically by foliar application of Atrazine at a rate of 750g/fed as a pre-emergence herbicide. For forage crops, nitrogen fertilizer was applied at a rate of 75 kg N/fed using urea fertilizer (46.5%N) which divided to three equal doses at 21days after sowing (DAS), after the first and second cuts as broadcasting on the top of the bed. For maize plants, 90 kg N/fed was applied beside the hills in two equal doses, before the first and second irrigations. Three cuts were taken from each forage crop, the first cut was done after 45 DAS, the second cut at 40 days from the first cut and the third cut at 35 days after the second cut. Maize plants were harvested 120 DAS in both seasons for grain production.

Experimental site description

Soil samples were randomly collected from the experimental site before sowing from depths of 0-30 using an auger for estimating some mechanical and chemical properties of soil as presented in Table (2).

The traits studied

1-Forage crops

1-1 Growth characters

Five shoots (tillers) were taken randomly from each experimental plot to determine the following growth characters: plant height, number of shoots/m^2, number of leaves/shoot, leaf area/shoot (cm^2) and total dry weight/ shoot.

1-2 Photosynthetic pigments

At each cut, upper leaves samples from the five shoots were taken from each experimental plot to determine the total chlorophyll (Chl. a +b) using SPAD meter (SPAD-502, Minolta, Tokyo, Japan).

1-3 Forage production

At cutting time, an area of 4.9 m^2 (3.5 m^2 length x 1.4 m^2 width) from central beds were cut and weighted, then the fresh forage yield/fed (ton) was calculated either in intercropping treatments or sole cropping. Samples (250 g) of total plants fresh weight were dried in air-oven at 70˚C until a constant, and then dry weight and dry forage yield/fed (ton) was calculated.

1-4 Chemical composition of whole shoot

At each cut, samples of whole shoots (leaves +stem) were dried in air-oven at 70˚C to constant weight and then they were finely ground to pass through a 0.5 mm sieve. The samples were chemically analyzed to determine the following chemical composition, i.e. crude protein (CP %), ash % and crude fiber (CF %), where they were determined according to the methods described by AOAC (2019).

1-5 Nutritive values

Nutritive values of whole shoot (stem +leaves) for each tested forage crop were determined as shown in Table (3).

Table (2): Some physical and chemical properties of the experimental sites during 2019 and 2020 seasons.

Soil properties	Season		Methods (References)
	2019	2020	
Soil texture	Clay loam	Clay loam	Particle size distribution (Black,1965)
pH	7.8	7.1	1 soil:2.5 water (Jackson,1973)
Ec (dS/m)	0.80	0.71	
O.M. (%)	1.78	2.00	Walkley-black method (Black,1965)
Available N (ppm)	29.22	32.50	Micro-Kjeldahl (Jackson,1973)
Available P (ppm)	8.50	9.50	Spectrophotometer (Olsen *et al*.,1954)
Available K (ppm)	286.33	300	Flame photometer (Chapman and Pratt,1978)

Table (3): The nutritive values studied in the forage crops as well as their formula and references

Nutritive value	Formula	Reference
1-Digestible protein (DP %)	DP % = 0.9596 CP % – 3.55	Bredon *et al.*, (1963)
2-Total digestible nutrients (TDN %)	TDN % = 50.41 + 1.04 CP % – 0.07 CF%	Adams *et al.*, (1964)

2- Maize crop

2-1 Yield and yield attributes

At maturity, ten guarded plants were randomly taken from each plot to determine the following grain yield attributes: number of ears/plant, number of grains/ear, ear weight (g), 100-grain weight (g), grain weight/plant (g), grain yield/fed (ton) and stover yield/fed (ton).

2-2 Grain quality

1- Protein (%): Nitrogen % was determined according to AOAC (2019) and then protein % was calculated by multiplying the N % by factor 5.75.

2- Carbohydrate %: it was determined using hydrochloric acid method by spectrophotometer at wavelength 490 nm methods as described by Dubois *et al.* (1956).

3- Oil (%): it was determined according to AOAC (2019) using soxhlet apparatus and petroleum ether (40-60 ^{o}C) as a solvent

3- Competitive relationships and yield advantage

In order to assess the nature and degree of competition between maize (m) and forage (f) plants as well as the land use efficiency, the following parameters were determined as presented in Table (4).

Table (4): The parameters of competitive relationships and land use efficiency as well as their formula and references.

Competitive relationships and land use efficiency	Formula	References
1- Aggressivity (A)	$A_m = \frac{Y_{mf}}{Y_{mm} \times Z_{mf}} - \frac{Y_{fm}}{Y_{ff} \times Z_{fm}}$ $A_f = \frac{Y_{fm}}{Y_{ff} \times Z_{fm}} - \frac{Y_{mf}}{Y_{mm} \times Z_{mf}}$	McGilchrist (1965)
2- Relative crowding coefficient (RCC)	$RCC_m = \frac{Y_{mf} \times Z_{fm}}{(Y_{mm} - Y_{mf}) \times Z_{mf}}$ $RCC_f = \frac{Y_{fm} \times Z_{mf}}{(Y_{ff} - Y_{fm}) \times Z_{fm}}$ $RCC = RCC_m \times RCC_f$	De Wit (1960) and Hall (1974)
3-Competitive ratio (CR)	$CR_m = \frac{LER_m}{LER_f} \times \frac{Z_{fm}}{Z_{mf}}$ $CR_f = \frac{LER_f}{LER_m} \times \frac{Z_{mf}}{Z_{fm}}$	Willey and Rao (1980)
4- Land equivalent ratio (LER)	$L_m = \frac{Y_{mf}}{Y_{mm}}$ & $L_f = \frac{Y_{fm}}{Y_{ff}}$ $LER = L_m + L_f$	Willey and Osiru (1972)
5- Cereal units (CU) Cereal units of maize grains Cereal units of maize stover Cereal units of forage straw Cereal units of total	 Cu_m : each 100 kg grain = 1.0 Cu Cu_s : each 100 kg stover = 0.15 Cu Cu_f : each 100 kg straw = 0.15 Cu $Cu_t = Cu_m + Cu_s + Cu_f$	Könnecke (1963)

The aforementioned symbols used herein in the competitive relationships studied are shown in Table (5).

Statistical analysis

All measurements data during each season in this study were analyzed according to the methods described by Snedecor and Cochran (1980). Duncan's multiple range test (Duncan, 1955) was used to compare between the treatments means at 5% probability. The mean values within each column followed by same letters are not significantly different. Statistical analysis was done using the CoStat package program, version 6.311 (Cohort software, USA).

Table (5): The abbreviations of competitive relationships used in this study.

Abbreviation	Competitive relationships
A_m	Aggressivity of maize
A_f	Aggressivity of forage
RCC_m	Relative crowding coefficient of maize
RCC_f	Relative crowding coefficient of forage
RCC	Relative crowding coefficient of mixture (RCC_m X RCC_f)
CR_m	Competitive ratio of maize
CR_f	Competitive ratio of forage
L_m	Land equivalent ratio of maize
L_f	Land equivalent ratio of forage
LER	Total land equivalent ratio ($L_m + L_f$)
Y_{mm}	Pure stand yield of maize
Y_{ff}	Pure stand yield of forage
Y_{mf}	Mixture yield of maize (in combination with forage)
Y_{fm}	Mixture yield of forage (in combination with maize)
Z_{mf}	Sown proportion of maize (in mixture with forage)
Z_{fm}	Sown proportion of forage (in mixture with maize)
Cu_m	Cereal unit of maize grains
Cu_s	Cereal unit of maize stover
Cu_f	Cereal unit of forage straw
Cu_t	Cereal unit of total (grains + stover + straw)

RESULTS AND DISCUSSION

1–Effect of intercropping of Forage crops

1-1 Growth characters

The data in Table (6) indicate that there are significant differences among the three tested forage crops for their growth characters (plant height, number of shoots/m^2, total chlorophyll, number of leaves and leaf area/shoot and total dry weight/shoot) when intercropped with different population density of maize at the three cuts during both seasons.

The data of plant height showed that sudan grass had taller plants compared to millet and teosinte in a descending order either when it was grown alone or intercropped with maize at three cuts in both growing seasons, Similar findings noted by Hassan *et al.* (2017) who found that sudan grass had the tallest plants followed by millet and teosinte crops when they were intercropped with some legume forage crops or sole croppings. In addition, it can be noticed that intercropping maize plants at any population density with the tested forage crops led to an increase in plant height of each forage crops as compared with its sole cropping in the three cuts in both seasons. Moreover, there are positive relationship between plant height of forage crops and population density of maize intercropped with forage crops, i.e. the greater population density of maize (100%) produced the longer plants of forage crops in the three cuts in both seasons. The superiority of plant height of forage crops associated with dense sowing of maize plants may be explained by high inter specific

Table (6): Growth characters of some summer grass forage crops as affected by their intercropping with different plant densities of maize at three cuts during 2019 and 2020 seasons.

Intercropping patterns	Plant height (cm)				Number of shoots /m^2				Total chlorophyll (SPAD value)			
	1st cut	2nd cut	3rd cut	Mean	1st cut	2nd cut	3rd cut	Mean	1st cut	2nd cut	3rd cut	Mean
2019 Season												
100%Millet + 50% maize	181.34 e	170.91 f	124.10 hi	158.78 bc	200.03 b	181.13 bc	160.28 cd	180.48 abc	44.91 b-e	51.66 cd	54.59 b	50.39 cd
100%Millet + 75% maize	192.78 d	174.21 f	137.30 gh	168.10 abc	190.00 cd	174.50 cd	155.68 e	173.39 bcde	43.87 cde	49.65 def	53.51 b	49.01 de
100%Millet + 100% maize	196.41 d	184.75 e	145.85 fg	175.67 abc	182.50 def	169.25 de	148.00 fg	166.58 de	41.90 e	46.96 gh	50.56 c	46.47 efg
Millet sole cropping	177.38 e	156.78 g	117.38 i	150.51 c	215.00 a	188.00 a	169.03 b	190.67 a	47.18 bc	54.98 ab	55.19 b	52.45 bc
100% Sudan grass + 50% maize	227.90 b	197.36 d	175.65 bc	200.30 abc	190.50 cd	165.00 e	157.55 de	171.01 cde	44.30 cde	48.83 efg	49.56 cd	47.56 def
100% Sudan grass + 75% maize	234.95 b	203.77 cd	187.45 ab	208.72 ab	185.50 de	156.25 f	146.00 g	162.58 ef	43.46 de	46.67 gh	47.71 de	45.95 fg
100% Sudan grass + 100% maize	244.93 a	216.59 a	198.05 a	219.86 a	175.50 fg	146.25 g	137.25 h	153.00 f	41.86 e	45.06 h	46.32 e	44.42 g
Sudan grass sole cropping	214.40 c	186.64 e	170.50 cd	190.51 abc	195.00 bc	170.00 de	162.00 c	175.66 bcd	46.43bcd	50.94 de	50.47 c	49.28 de
100% Teosinte + 50% maize	115.00 g	205.90 bc	149.85 efg	156.92 bc	185.50 de	176.33 cd	168.10 b	176.64 bcd	47.93 b	53.65 bc	58.57 a	53.38 b
100% Teosinte + 75% maize	120.13 g	212.65 ab	156.15 def	162.98 abc	179.25 efg	170.50 de	160.25 cd	170.00 cde	43.99 cde	50.01 def	55.75 b	49.92 cd
100% Teosinte + 100% maize	129.54 f	216.40 a	166.26 cde	170.73 abc	172.25 g	166.25 e	150.34 f	162.94 ef	42.36 e	48.10 fg	53.49 b	47.98 def
Teosinte sole cropping	107.50 h	201.75 cd	136.35 gh	148.53 c	190.00 cd	183.76 ab	177.45 a	183.73 ab	54.15 a	56.47 a	58.88 a	56.50 a
2020 Season												
100%Millet + 50% maize	195.86 e	176.90 g	147.21 f	173.32 bcd	210.75 b	185.00 bc	164.00 d	186.58 ab	48.36 bc	54.85 ab	55.54 cd	52.92 bcd
100%Millet + 75% maize	207.90 d	185.70 f	158.80 de	184.13 abcd	196.03 c	179.36 d	158.34 e	177.91 bcd	46.62 cd	52.90 bc	53.75 def	51.09 de
100%Millet + 100% maize	210.05 d	193.90 e	169.85 c	191.27 abcd	187.50 de	170.08 f	153.23 g	170.27 de	45.16 de	50.76 cd	51.71 fg	49.21 e
Millet sole cropping	185.79 e	161.80 h	139.42 g	162.34 cd	219.38 a	190.28 a	172.00 b	193.88 a	50.28 b	55.98 a	56.74 bc	54.33 bc
100% Sudan grass + 50% maize	229.60 bc	208.23 d	191.30 b	209.71 abc	197.50 c	175.00 e	159.33 e	177.27 bcd	46.79 cd	49.83 d	50.95 g	49.19 e
100% Sudan grass + 75% maize	237.20 b	218.57 b	201.50 a	219.09 ab	191.25 cd	159.25 g	150.75 h	167.08 de	44.48 de	47.42 e	48.47 h	46.79 f
100% Sudan grass + 100% maize	249.60 a	229.10 a	207.16 a	228.62 a	182.50 ef	152.30 h	142.00 i	158.93 e	42.92 e	45.56 e	46.91 h	45.13 f
Sudan grass sole cropping	218.30 cd	198.14 e	187.00 b	201.15 abcd	205.00 b	182.45 cd	166.50 c	184.65 abc	49.08 bc	52.69 bc	52.63 efg	51.47 d
100% Teosinte + 50% maize	130.41 fg	210.25 cd	154.50 e	165.05 cd	186.25 de	180.50 d	170.50 b	179.08 bcd	50.00 b	55.06 ab	58.56 ab	54.54 b
100% Teosinte + 75% maize	131.34 fg	215.51 bc	164.75 cd	170.53 bcd	181.00 ef	174.68 e	163.00 d	172.89 cd	47.39bcd	53.01 bc	56.52 bc	52.31 cd
100% Teosinte + 100% maize	141.08 f	220.00 b	184.75 b	181.94 abcd	177.25 f	168.50 f	156.00 f	167.25 de	46.60 cd	51.08 cd	54.89 cde	50.86 de
Teosinte sole cropping	122.05 g	205.55 d	146.00 f	157.87 d	195.00 c	187.25 ab	180.50 a	187.58 ab	54.95a	57.36 a	59.98 a	57.43 a

Table (6): Cont.

Intercropping patterns	Number of leaves /shoot				Leaf area/shoot (cm^2)				Total dry weight/shoot (g)			
	1st cut	2nd cut	3rd cut	Mean	1st cut	2nd cut	3rd cut	Mean	1st cut	2nd cut	3rd cut	Mean
2019 Season												
100%Millet + 50% maize	7.42 a	6.61 cde	5.67 de	6.56 abc	1490.6 b	1177.7 efg	945.7 cd	1204.6 b	5.90 c	5.19 d	3.32 e	4.80 abc
100%Millet + 75% maize	7.27 a	6.57 cde	5.59 def	6.48 abc	1395.4 bc	1060.9 gh	788.6 de	1081.6 b	5.11 d	4.27 e	2.71 f	4.03 abc
100%Millet + 100% maize	7.21a	5.50 f	5.21 efg	5.97 abc	1251.5 cd	879.7 h	688.8 e	940.0 b	4.40 e	3.62 f	2.28 g	3.43 bc
Millet sole cropping	7.82 a	7.15 cd	6.45 cd	7.14 abc	1739.0 a	1364.7 e	1140.1 c	1414.6 b	7.09 a	6.19 ab	4.16 b	5.81 a
100% Sudan grass + 50% maize	6.07 b	5.61 ef	4.53 g	5.41 bc	1462.2 b	1127.1 fg	840.8 de	1143.3 b	5.70 c	4.89 d	2.94 f	4.51 abc
100% Sudan grass + 75% maize	5.99 b	5.36 f	4.44 g	5.26 c	1380.4 bcd	1001.1 gh	771.9 de	1051.1 b	5.00 d	4.25 e	2.62 fg	3.96 abc
100% Sudan grass + 100% maize	5.78 b	5.31 f	4.33 g	5.14 c	1207.8 cd	871.7 h	672.0 e	917.2 b	4.02 e	3.37 f	2.26 g	3.22 bc
Sudan grass sole cropping	6.35 b	6.35 def	4.66 fg	5.79 abc	1577.9 ab	1306.9 ef	938.0 cd	1274.2 b	6.48 b	5.92 bc	3.78 cd	5.39 ab
100% Teosinte + 50% maize	5.61 bc	8.52 ab	8.41 a	7.51 ab	1410.4 bc	2817.1 b	2460.8 a	2229.4 a	2.40 f	5.68 c	3.92bc	4.00 abc
100% Teosinte + 75% maize	4.92 cd	7.62 bc	7.40 b	6.65 abc	1182.7 d	2291.7 c	1762.6 b	1745.7 ab	1.96 g	4.97 d	3.52 de	3.48 bc
100% Teosinte + 100% maize	4.30 d	7.08 cd	6.97 bc	6.12 abc	966.2 e	1838.5 d	1557.2 b	1454.0 b	1.53 h	4.14 e	2.91 f	2.86 c
Teosinte sole cropping	5.90 b	8.94 a	8.59 a	7.81 a	1539.5 b	3052.5 a	2577.8 a	2389.9 a	2.75 f	6.48 a	4.72 a	4.65 abc
2020 Season												
100%Millet + 50% maize	7.43 ab	7.19 bcd	6.40 cde	7.01 abc	1730.6 ab	1428.6 de	1085.4 ef	1414.9 cd	6.50 b	5.62 cd	3.80 de	5.30 abc
100%Millet + 75% maize	7.29 ab	7.13 bcd	6.34 def	6.92 abc	1461.9 cde	1327.5 def	987.6 fgh	1259.0 cd	5.64c	4.83 ef	3.11 gh	4.53 abc
100%Millet + 100% maize	7.22 abc	5.81 de	5.65 efg	6.23 abc	1403.8 de	1015.3 f	885.1 gh	1101.4 d	4.73 e	4.30 fg	2.65 ij	3.89 bc
Millet sole cropping	7.88 a	7.62 abc	6.91 cd	7.47 abc	1839.5 a	1559.6 d	1248.9 e	1549.3 bcd	7.32 a	6.75a	4.37 b	6.14 a
100% Sudan grass + 50% maize	6.17 cde	6.11 de	5.42 fg	5.90 bc	1526.5 b-e	1290.6 def	1057.4 fg	1291.5 cd	5.75 c	5.33 de	3.30 fg	4.79 abc
100% Sudan grass + 75% maize	6.10 de	5.91 de	5.36 g	5.79 bc	1410.4 de	1145.1 ef	957.1 fgh	1170.9 d	5.28 d	4.49 fg	2.88 hij	4.22 abc
100% Sudan grass + 100% maize	6.04 de	5.49 e	5.22 g	5.58 c	1342.5 e	990.4 f	862.0 h	1065.0 d	4.47e	4.02 g	2.60 j	3.69 bc
Sudan grass sole cropping	6.50 bcd	6.29 cde	5.45 fg	6.08 abc	1697.3 ab	1372.8 def	1115.9 ef	1395.3 cd	6.56 b	6.34 ab	3.97cd	5.62ab
100% Teosinte + 50% maize	5.88 de	8.77 a	8.52 a	7.72 ab	1589.6 bcd	3058.5 ab	2501.4 b	2383.1 ab	2.55 f	6.03 bc	4.23 bc	4.27 abc
100% Teosinte + 75% maize	5.33 ef	8.34 ab	7.88 ab	7.18 abc	1377.8 de	2784.6 b	2044.0 c	2068.8 abc	2.22 g	5.63 cd	3.57 ef	3.81 bc
100% Teosinte + 100% maize	4.59 f	8.32 ab	7.28 bc	6.73 abc	1058.6 f	2376.7 c	1672.0 d	1702.4 bcd	1.76 h	4.50 fg	3.03 ghi	3.09 c
Teosinte sole cropping	6.20 cde	8.99 a	8.74 a	7.98 a	1667.1 abc	3326.8 a	2736.1 a	2576.7 a	2.84 f	6.84 a	4.86 a	4.84 abc

competition between plants on light which caused an elongation in the internode length. In this concern, many researchers found that the intercropping increased the plant height of millet when intercropped with cowpea (Mohamed *et al.*, 2020) and sorghum when intercropped with cowpea (Chaudhary *et al.*, 2020) as well as fodder maize when intercropped with soybean (Salama and Abdel-Moneim, 2021). Moreover, Omoregie *et al.* (2020) noticed that plant height of millet was increased by increasing the competition among plants especially at the highest plant density of millet.

Number of shoots/m^2 of millet forage crop surpassed those recorded by teosinte crop and sudan grass crop at their sole croppings in a descending order. Moreover, the data showed that the intercropping maize at different plant density with the three forage crops caused a significant reduction in the values of number of shoots/m^2 for each forage crop compared to the sole cropping. This reduction was more pronounced by intercropping the highest plant density of maize (100%) more than the medium (75%) and lowest (50%) plant densities. The severe interspecific competition among the plants of forage crops intercropped with the greatest maize density in the light, water and nutrients may caused a depression in the number of shoots/m^2 for the forage crops which appeared herein. Similar results were obtained by Hassan *et al.* (2017) who found that pearl millet gave the highest values of number of tillers/plant compared to sudan grass and teosinte either when they were grown alone or intercropped with legume crops. In addition Iqbal *et al.* (2017) stated that intercropping sorghum with cowpea decreased number of plants/m^2 of sorghum compared to its sole cropping.

Teosinte forage crop had the highest values of total chlorophyll followed by millet and sudan grass in the first and second seasons, respectively. In addition, it can be noticed that intercropping maize plants at any population density, especially at 100% with the tested forage crops led to a reduction in the total chlorophyll of each forage crops as compared with its sole cropping in the three cuts in both seasons. From these results, it can be suggested that intercropping of high population density of maize with forage crops caused a great shading of the plants and consequently decreased the light intercepted by leaves and this in turn caused a reduction in their chlorophyll content. In this concern, Baraka *et al.* (2017) found also that intercropping millet with cowpea decreased the values of chlorophyll content for millet plant as compared with its sole cropping.

Teosinte forage crop produced also the highest values of number of leaves/shoot and leaf area/shoot when it was grown as sole cropping followed by millet and sudan grass in a descending order in both seasons. The superiority of leaf area /shoot of teosinte plant may be attributed to the increase in its chlorophyll content as well as the number of leaves/shoot as previously discussed. On the other hand, such two traits were decreased when the three forage crops were intercropped with maize at any plant density, especially at high density (100% of maize) as compared with their sole croppings. The present results are in accordance with those obtained by Mahdy and El-Said (2015) who found that intercropping sesame with sorghum fodder decreased number of leaves/stem of sorghum fodder compared to its sole cropping. Moreover, Islam *et al.* (2018) found that leaf area/plant of millet was decreased when it was grown with cowpea together. Also, Lankeppanavar *et al.* (2016) mentioned that intercropping forage sweet sorghum with cowpea or horse gram decreased each of number of leaves and leaf area/plant of forage sweet sorghum compared to sole cropping.

The highest values of total dry weight/shoot were attained by millet crop when it was grown alone or intercropped with maize at different densities compared to the other forage crops in both seasons. In comparison among the intercropping systems, the data also showed that the highest mean values of total dry weight/shoot were recorded when maize at 50% was intercropped with millet followed by sudan grass and teosinte. However, the lowest values of such trait were obtained for the three forage crops when they were intercropped with 100% of maize population density at the three cuts and their means in both seasons. The depression in the values of total dry weight / shoot (leaves + stem) for the three forage crops when they were intercropped with maize (especially at its high density) is mainly due to the severe inter and intra specific competition among maize and forage crops which caused a reduction in the total chlorophyll as well as number of leaves and leaf area/shoot, and consequently reduced the photosynthetic efficiency of forage crops, and this in turn affects the accumulation of dry matter/plant for each tested forage crops. Similar findings were reported by Qadir *et al.* (2021) who found that dry weight/plant of millet was decreased when it was intercropped with some legume forage crops in the same row. Bhakar *et al.* (2021) found also that intercropping fodder sorghum with cluster bean caused a decrease in the total shoot dry weight of sorghum compared to its sole cropping.

1-2 Forage production:

Data presented in Table (7) revealed that significant variation could be detected among the three tested forage crops in fresh and dry forage yields/fed when intercropped with different population density of maize at all cuts during both seasons. As a mean of the three cuts, millet crop sole cropping produced the highest significant values of fresh forage yield (49.759 and 51.132 ton / fed) and dry forage yield (8.627 and 9.209 ton/fed) in the 1^{st} and 2^{nd} seasons, respectively followed by sudan grass and teosinte in a descending order. The superiority of millet in dry forage production may due to the increase in total dry weight /shoot as well as number of shoots/m^2 more than the other forage crops in the three cuts as previously discussed in Table (6). Moreover, it can be noticed that intercropping maize at any density with the three forage crops decreased the fresh and dry forage yields/fed compared to their solid plantings in the three cuts in both seasons. In comparison among the tested intercropping patterns, it can be observed that intercropping low population density of maize (50%) outyielded the other population densities (75 and 100%) in fresh and dry forage yields/fed for the three forage crops. The superiority of forage production at thin population density of maize may be due to the soil volume is well ramified by plant roots, and consequently, the water and nutrients are highly utilized by plants. Therefore, the high utilization of light energy, the big amount of water used and great amount of nutrients absorbed per unit area in thin sowing might amount much for the superiority of growth characters of forage crops and consequently increased the fresh and dry forage production/fed. These results are in harmony with those obtained by Hassan *et al.* (2017) who found that pearl millet gave the highest values of fresh and dry yields/fed followed by sudan grass and teosinte when they were grown either alone or intercropped with some legume crops. Also, many investigators found that fresh and dry forage yields/unit area of some grass forage crops were decreased when they were intercropped with some crops such as maize (Samarappuli and Berti, 2018), cowpea (Shahwan *et al.*, 2013, Pal *et al*., 2014, Iqbal *et al.*, 2017, Ginwal *et al.* 2019 and Qadir *et al.*, 2021) and soybean (Salama and Abdel-Moneim, 2021 and Soe Htet *et al.*, 2021).

1-3 Chemical composition

The data tabulated in Table (8) indicated that the values of chemical analysis studied (crude protein, ash and crude fiber percentage) in the shoots of the three forage crops were significantly differed as affected by their intercropping with various population density of maize in both seasons. The maximum protein and ash percentages were obtained by teosinte crop, while the highest value of fiber % were obtained by sudan grass either when they grown alone or intercropped with maize under any plant density at the three cuts in both seasons. The superiority of teosinte forage crops in its protein content obtained herein may be due to its superiority in chlorophyll content as previously discussed in Table (6). Moreover, the sole cropping of the three tested forage crops had the highest values of protein and ash %, but the lowest values of crude fiber % compared to their intercropping with maize at different population densities. Also, it could be noticed that protein and ash % in shoot of the three tested forage crops was gradually decreased with increasing the population density of maize from 50% to 100% intercropped with forage crops, while the values of crude fiber % took the opposite trend

Table (7): Fresh and dry forage yields/fed of some summer grass forage crops as affected by their intercropping with different plant densities of maize at three cuts during 2019 and 2020 seasons.

Intercropping patterns	Fresh forage yield (ton/fed)				Dry forage yield (ton/fed)			
	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	Total
2019 Season								
100%Millet + 50% maize	21.095 ab	15.072 cd	8.276 c	44.443 b	3.310 ab	2.503 bc	1.799 bc	7.612 b
100%Millet + 75% maize	19.817 bc	13.987 de	7.050 de	40.854 c	3.028 bc	2.282 cd	1.436 e	6.746 c
100%Millet + 100% maize	17.697 d	11.549 f	6.675 ef	35.921 d	2.694 de	1.826 f	1.329 ef	5.849 d
Millet sole cropping	22.118 a	18.145 b	9.496 b	49.759 a	3.509 a	3.022 a	2.096 a	8.627 a
100% Sudan grass + 50% maize	18.165 cd	12.908 e	8.025 c	39.098 c	2.791 cd	2.100 de	1.639 cd	6.530 c
100% Sudan grass + 75% maize	16.432 d	11.389 f	6.956 de	34.777 d	2.449 e	1.813 f	1.408 e	5.670 d
100% Sudan grass + 100% maize	14.150 e	9.614 g	6.206 f	29.970 e	2.099 f	1.488 g	1.232 f	4.819e
Sudan grass sole cropping	21.026 ab	15.454 c	8.584 c	45.064 b	3.237 ab	2.529 bc	1.827 b	7.593 b
100% Teosinte + 50% maize	7.412 fg	17.291 b	9.477 b	34.180 d	1.003 h	2.732 b	1.852 b	5.587 d
100% Teosinte + 75% maize	6.626 gh	15.148 cd	8.415 c	30.189 e	0.767 hi	2.305 cd	1.627 d	4.699 e
100% Teosinte + 100% maize	5.518 h	14.175 cd	7.392 d	27.085 f	0.619 i	1.990 ef	1.421 e	4.030 f
Teosinte sole cropping	8.809 f	19.488 a	10.963 a	39.260 c	1.323 g	3.179 a	2.153 a	6.655 c
2020 Season								
100%Millet + 50% maize	21.839 b	16.133 c	8.358 cd	46.330 c	3.612 bc	2.760 bc	1.827 de	8.199 c
100%Millet + 75% maize	20.401 c	14.861 d	7.485 ef	42.747 d	3.349 d	2.525 cd	1.528 fg	7.402 d
100%Millet + 100% maize	17.851 e	12.044 e	7.178 f	37.073 f	2.869 e	1.965 f	1.459 g	6.293 f
Millet sole cropping	23.414 a	18.214 b	9.504 b	51.132 a	3.939 a	3.167 a	2.103 ab	9.209 a
100% Sudan grass + 50% maize	20.885 c	13.935 d	8.169 cde	42.989 d	3.450 cd	2.349 de	1.690 ef	7.489 d
100% Sudan grass + 75% maize	18.809 d	11.753 e	7.362 f	37.924 f	2.961 e	1.957 f	1.497 g	6.415 f
100% Sudan grass + 100% maize	16.973 f	9.634 f	6.369 g	32.976 gh	2.617 f	1.543 g	1.269 h	5.429 h
Sudan grass sole cropping	22.066 b	17.258 bc	9.372 b	48.696 b	3.703 b	2.954 ab	2.000 bc	8.657 b
100% Teosinte + 50% maize	7.283 h	17.710 b	9.547 b	34.540 g	1.100 h	2.807 bc	1.900 cd	5.807 g
100% Teosinte + 75% maize	6.177 i	16.951 bc	8.637 c	31.765 h	0.800 i	2.611 cd	1.674 ef	5.085 h
100% Teosinte + 100% maize	5.783 i	14.645 d	7.660 def	28.088 i	0.772 i	2.069 ef	1.477 g	4.318 i
Teosinte sole cropping	9.717 g	19.643 a	11.111 a	40.471 e	1.490 g	3.228 a	2.226 a	6.944 e

Table (8): Chemical composition in shoot (leaves + stem) of some summer grass forage crops as affected by their intercropping with different plant densities of maize at three cuts during 2019 and 2020 seasons.

Intercropping patterns	Crude protein %				Ash%				Crude fiber %			
	1st cut	2nd cut	3rd cut	Mean	1st cut	2nd cut	3rd cut	Mean	1st cut	2nd cut	3rd cut	Mean
2019 Season												
100%Millet + 50% maize	11.28 d	11.10 b	10.21 d	10.86 d	12.78 cd	12.42 b	11.35 bc	12.18 cd	24.89 cd	26.95 ef	30.37 e	27.40 e
100%Millet + 75% maize	10.13 ef	10.06 c	9.78 e	9.99 e	12.05 de	11.48 c	11.13 cd	11.55 e	25.90 bc	27.65 de	30.71 de	28.09 d
100%Millet + 100% maize	9.33 fg	8.76 de	8.34 g	8.81 fg	11.71 e	10.65 d	10.53 de	10.96 fg	26.54 ab	28.22 cd	31.85 c	28.87 c
Millet sole cropping	12.10 cd	11.23 b	10.87 c	11.40 c	13.60 b	13.21 a	11.95 ab	12.92 ab	24.30 de	26.47 fg	29.65 ef	26.81 f
100% Sudan grass + 50% maize	9.96 efg	9.53 cd	9.40 f	9.63 e	11.58 e	11.48 c	10.93 cd	11.33 efg	27.03 ab	29.01 b	32.14 bc	29.39 b
100% Sudan grass + 75% maize	9.47 efg	9.24 cde	8.35 g	9.02 f	11.43 e	10.82 d	10.18 ef	10.81 g	27.31 a	29.02 b	33.11 ab	29.81 b
100% Sudan grass+100% maize	9.16 g	8.35 e	8.00 g	8.50 g	10.18 f	9.95 e	9.83 f	9.99 h	27.81 a	30.07 a	33.62 a	30.50 a
Sudan grass sole cropping	10.28 e	9.98 c	9.86 de	10.04 e	11.85 e	11.63 c	11.04 cd	11.51 ef	26.56 ab	28.55 bc	31.70 cd	28.94 c
100% Teosinte + 50% maize	13.24 ab	12.18 ab	11.65 b	12.36 b	13.75 b	13.00 ab	12.11 a	12.95 ab	23.29 e	25.33 h	28.84 fg	25.82 g
100% Teosinte + 75% maize	12.75 bc	11.73 b	11.30 b	11.93 b	13.25 bc	12.69 ab	11.93 ab	12.62 bc	24.08 de	25.76 gh	28.94 fg	26.26 g
100% Teosinte + 100% maize	12.07 cd	11.39 b	10.17 d	11.21cd	12.68 cd	11.73 c	11.04 cd	11.82 de	24.38 de	26.75 f	30.42 e	27.18 ef
Teosinte sole cropping	13.72 a	12.85 a	12.26 a	12.94 a	14.68 a	13.29 a	12.18 a	13.38 a	21.99 f	24.57 i	28.36 g	24.97 h
2020 Season												
100%Mille + 50% maize	12.28 d	11.33 cd	11.08 cde	11.56 d	14.08 b	13.59 a	11.38 d	13.02 bc	25.42 d	27.53 c	30.78 de	27.91 f
100%Millet + 75% maize	10.78 e	10.45 de	10.38 def	10.54 e	13.00 cd	12.71 b	11.18 d	12.30 cd	26.59 c	28.63 b	31.08 d	28.77 a
100%Millet + 100% maize	9.89 ef	9.28 fg	9.00 gh	9.39 g	12.37 e	12.01 b	10.93 de	11.77 de	27.61 b	29.27 b	31.96 c	29.61 cd
Millet sole cropping	12.71 bcd	11.63 bc	11.43 bcd	11.92 cd	14.93 a	14.14 a	12.59 ab	13.89 a	24.60 e	27.03 c	30.03 ef	27.22 gh
100% Sudan grass + 50% maize	10.46 e	9.78 ef	9.65 fg	9.96 f	11.66 f	11.16 c	11.06 bc	11.29 ef	27.08 bc	29.53 ab	32.64 bc	29.75 c
100% Sudan grass + 75% maize	9.63 ef	9.47 efg	9.17 gh	9.42 g	11.45 f	10.67 cd	10.43 e	10.85 fg	27.87 b	29.72 ab	33.28 b	30.29 b
100% Sudan grass+100% maize	9.27 f	8.65 g	8.33 h	8.75 h	10.55 g	10.29 d	9.91 f	10.25 g	28.90 a	30.65 a	34.34 a	31.30 a
Sudan grass sole cropping	10.78 e	10.40 de	10.01 efg	10.40 ef	12.73 de	12.17 b	12.00 c	12.30 cd	26.67 c	28.87 b	32.09 c	29.21 de
100% Teosinte + 50% maize	13.79 ab	12.53 ab	12.26 ab	12.86 ab	14.33 b	13.81 a	12.16 bc	13.43 ab	23.49 fg	25.82 de	29.18 fg	26.16 i
100% Teosinte + 75% maize	13.60 abc	11.89 bc	11.80 abc	12.43 bc	13.49 c	13.46 a	11.94 c	12.96 bc	24.26 ef	26.55 cd	29.44 fg	26.75 h
100% Teosinte + 100% maize	12.61 cd	11.65 bc	10.45 def	11.57 d	12.93 cde	12.38 b	11.11 d	12.14 d	24.47 e	26.87 cd	30.75 de	27.36 g
Teosinte sole cropping	13.98 a	13.03 a	12.80 a	13.27 a	15.19 a	14.23 a	12.84 a	14.09 a	23.32 g	25.23 e	28.88 g	25.81 i

as it was increased with increasing plant density of maize. The reduction in protein and ash % obtained under high density of maize may be due to the high inter specific competition between forage crops and maize plants in light, water and nutrients which led to a reduction in chlorophyll content and consequently protein% as well as ash%. In this concern, Hassan *et al.* (2022) reported that teosinte forage crop surpassed millet and sudan grass crops in the values of CP% in a descending order. Moreover, other researchers found that intercropping grass forage crops with other crops decreased their protein and ash% (Mahdy and El-Said, 2015 and Samarappuli and Berti 2018), but increased their fiber% (Saad, 2015) compared to the sole cropping of them.

1-4 Nutritive values

Table (9) included that the values of DP% and TDN % differed significantly among the three tested forage crops when they were intercropped with maize and grown alone in the three cuts in both seasons. In comparison among the forage crops, it can be found that teosinte crop produced the maximum values of DP% and TDN % followed by millet and sudan grass in a descending order. These results hold fairly true when such crops grown alone or intercropped with maize in the three cuts and both seasons. The superiority of teosinte crop in DP% might be due to its increase in crude protein % as shown previously in Table (8). In addition, it clear that intercropping maize at different densities caused a reduction in DP% and TDN% in the shoot of forage crops as compared with their sole croppings. This reduction in DP% and TDN% was evident especially when the forage crops were intercropped with high maize density (100%). From these results, it can be suggested that the reduction in TDN% obtained herein by the intercropping of high density of maize may be due to either decrease in protein % and/or increase in fiber % in the shoots of forage crops as previously recorded in Table (8). Other investigators found that the values of TDN% were decreased by intercropping millet with soybean (Jahanzad *et al.*, 2015) and by intercropping sorghum x sudangrass hybrid with some legume crops (Song *et al.*, 2021). Also, Prajapati *et al.* (2019) found that CP% in the plants of teosinte, sorghum and maize was correlated positively with TDN%, but negatively with fiber% when they were intercropped with some legume crops.

2- Effect of intercropping on maize

2-1 Grain yield and its attributes

The data in Table (10) demonstrated that the values of grain yield and its components of maize studied herein were significantly differed when it was intercropped at different plant densities of maize (50, 75 and 100% of recommended density) with three summer grasses forage crops (millet, sudan grass and teosinte) at their 100% of recommended density during 2019 and 2020 seasons.

Data of grain maize yield/plant and its components (number of ears/plant, number of grains/ear, 100-grain weight and ear weight) noted that intercropping maize with the various forage crops significantly decreased such traits compared to maize sole cropping. In this respect, other researchers came with the same result and found that intercropping maize with other crops caused a reduction in each of no. of cobs/plant (Ijoyah *et al.*,2015), no .of grains/ear (Dusa and Roman, 2010; Abd El- Zaher and Ismail, 2014 and Suhi *et al.*, 2022), 100-grain weight (El-Ghobashy *et al.*, 2018), ear weight (Abou El-Enin *et al.*, 2023) and grain yield/plant (Mahdy, 2018 b) compared to maize sole cropping. Moreover, it can be observed generally that intercropping sudan grass with maize produced the highest reduction in grain maize yield and its attributes compared to the other tested forage crops. Also, increasing maize plant densities from 50 to 100% of recommended density caused a reduction in grain yield and its attributes of maize. The depression in grain yield/plant and its attributes was more pronounced when it was intercropped with sudan grass and millet crops especially in the presence of higher plant population of maize plants (100%). The present results are in accordance with those obtained by Shams *et al.* (2012), Charani *et al.,* (2017), Ibrahim *et al.* (2019), Sidi *et al.* (2019) and Lendzemo *et al.* (2021) who reported that intercropping maize at high plant density with other crops reduced grain yield/maize plant and its components compared to when it was intercropped at low plant density.

Table (9): Nutritive values in shoot (leaves + stem) of some summer grass forage crops as affected by their intercropping with different plant densities of maize at three cuts during 2019 and 2020 seasons.

Intercropping patterns	Digestible protein (DP %)				Total digestible nutrients (TDN %)			
	1st cut	2nd cut	3rd cut	Mean	1st cut	2nd cut	3rd cut	Mean
2019 Season								
100%Millet + 50% maize	7.28 d	7.10 b	6.25 d	6.88 d	60.40 d	60.07 c	58.90 d	59.79 d
100%Millet + 75% maize	6.17 ef	6.10 c	5.84 e	6.04 e	59.14 ef	58.94 d	58.44 e	58.84 e
100%Millet + 100% maize	5.40 fg	4.85 de	4.45 g	4.90 fg	58.25 gh	57.54 ef	56.86 g	57.55 fg
Millet sole cropping	8.06 cd	7.22 b	6.88 c	7.39 c	61.29 c	60.23 bc	59.64 c	60.39 c
100% Sudan grass + 50% maize	6.01 efg	5.59 cd	5.47 f	5.69 e	58.87 efg	58.29 de	57.94 f	58.37 e
100% Sudan grass + 75% maize	5.53 efg	5.32 cde	4.46 g	5.10 f	58.34 fgh	57.99 def	56.78 g	57.70 f
100% Sudan grass+100% maize	5.24 g	4.46 e	4.13 g	4.61 g	57.99 h	56.99 f	56.38 h	57.12 g
Sudan grass sole cropping	6.32 e	6.03 c	5.91 de	6.09 e	59.25 e	58.79 d	58.44 e	58.83 e
100% Teosinte + 50% maize	9.16 ab	8.14 ab	7.63 b	8.31 b	62.55 ab	61.30 ab	60.51 b	61.45 b
100% Teosinte + 75% maize	8.68 bc	7.71 b	7.29 b	7.89 b	61.98 bc	60.81 bc	60.13 b	60.97 b
100% Teosinte + 100% maize	8.03 cd	7.38 b	6.21 d	7.21 cd	61.25 c	60.38 bc	58.85 d	60.16 cd
Teosinte sole cropping	9.62 a	8.78 a	8.21 a	8.87 a	63.14 a	62.06 a	61.17 a	62.12 a
2020 Season								
100%Mille + 50% maize	8.24 d	7.32 cd	7.08 cde	7.55 c	61.41 c	60.26 cd	59.77 cde	60.48 c
100%Millet + 75% maize	6.80 e	6.47 de	6.41 def	6.56 d	59.76 d	59.27 de	59. 02 def	59.35 d
100%Millet + 100% maize	5.94 ef	5.36 fg	5.09 gh	5.46 f	58.76 def	58.02 fg	57.54 gh	58.11 f
Millet sole cropping	8.64 bcd	7.61 bc	7.41 bcd	7.89 c	61.90 bc	60.61 bc	60.19 bcd	60.90 c
100% Sudan grass + 50% maize	6.48 e	5.83 ef	5.71 fg	6.01 e	59.39 de	58.51 ef	58.16 fg	58.69 e
100% Sudan grass + 75% maize	5.69 ef	5.53 efg	5.25 gh	5.49 f	58.47 ef	58.18 efg	57.62 gh	58.09 f
100% Sudan grass+100% maize	5.34 f	4.75 g	4.44 h	4.84 g	58.03 f	57.26 g	56.66 h	57.32 g
Sudan grass sole cropping	6.80 e	6.43 de	6.05 efg	6.43 de	59.76 d	59.20 de	58.57 efg	59.18 de
100% Teosinte + 50% maize	9.68 eb	8.48 ab	8.22 ab	8.79 ab	63.11 a	61.64 ab	61.12 ab	61.96 ab
100% Teosinte + 75% maize	9.50 abc	7.86 bc	7.77 abc	8.38 b	62.85 ab	60.92 bc	60.62 abc	61.46 b
100% Teosinte + 100% maize	8.55 cd	7.63 bc	6.48 def	7.55 c	61.81 bc	60.64 bc	59.13 def	60.53 c
Teosinte sole cropping	9.87 a	8.95 a	8.74 a	9.19 a	63.32 a	62.20 a	61.70 a	62.41 a

Table (10): Yield and its components of maize as affected by its intercropping at different plant densities with some summer grass forage crops during 2019 and 2020 seasons.

Intercropping patterns	No. of ears /plant	No. of grains /ear	100-grain weight (g)	Ear weight (g)	Grain yield /plant (g)	Grain yield /fed (ton)	Stover yield /fed (ton)
2019 Season							
100% Millet + 50% Maize	1.07 bc	597.11 bc	34.36 ab	232.60 bc	207.48 bc	2.376 f	3.983 f
100% Millet + 75% Maize	1.03 de	569.50 cd	34.13 abc	226.73 c	191.96 d	3.229 de	4.740 de
100% Millet + 100% Maize	1.01 e	549.31 d	32.73 de	210.14 d	172.27 e	3.792 bc	5.253 bc
100% Sudan grass + 50% Maize	1.04 de	573.80 cd	33.00 cde	226.05 c	192.06 d	1.891 g	3.511 g
100% Sudan grass + 75% Maize	1.00 e	521.63 e	32.57 de	202.19 d	166.11 e	2.644 f	3.933 fg
100% Sudan grass + 100% Maize	1.00 e	469.80 f	31.80 e	181.29 e	147.32 f	2.993 e	4.313 ef
100% Teosinte + 50% Maize	1.09 ab	611.18 b	34.63 ab	238.88 ab	213.65 ab	2.460 f	4.086 f
100% Teosinte + 75% Maize	1.05 cd	579.16 cd	34.29 abc	232.83 bc	202.16 c	3.517 cd	5.093 cd
100% Teosinte + 100% Maize	1.02 de	564.72 d	33.38 de	223.75 c	187.32 d	4.043 b	5.582 bc
Maize sole cropping	1.12 a	641.66 a	35.04 a	244.74 a	221.46 a	4.626 a	6.222 a
2020 Season							
100% Millet + 50% Maize	1.07 b	604.61 b	35.06 ab	245.04 b	217.06 b	2.499 f	3.971 fg
100% Millet + 75% Maize	1.05 bc	570.54 cd	34.76 abc	228.40 cd	199.15 c	3.305 c	4.747 d
100% Millet + 100% Maize	1.01 d	554.61 de	33.89 c	218.56 e	184.06 d	3.984 b	5.482 b
100% Sudan grass + 50% Maize	1.05 bc	574.70 cd	34.85 abc	230.23 c	200.38 c	2.060 g	3.788 g
100% Sudan grass + 75% Maize	1.03 cd	541.16 e	34.48 bc	222.35 e	190.30 d	2.921 de	4.247 e
100% Sudan grass + 100% Maize	1.00 d	498.52 f	32.50 d	196.37 f	160.96 e	3.222 cd	4.594 d
100% Teosinte + 50% Maize	1.09 b	631.83 a	35.32 ab	247.69 ab	225.88 a	2.600 ef	4.094 ef
100% Teosinte + 75% Maize	1.06 bc	586.00 bc	34.84 abc	232.49 c	205.74 c	3.579 c	5.116 c
100% Teosinte + 100% Maize	1.03 cd	567.21 cd	34.38 bc	222.80 de	190.28 d	4.144 b	5.630 b
Maize sole cropping	1.14 a	648.98 a	35.78 a	253.01 a	232.92 a	4.729 a	6.327 a

Data of grain and stover yields/fed showed that maize sole cropping recorded the highest values of such traits compared to others intercropping patterns in both growing seasons. This superiority may be due to that maize sole cropping had increases in number of ears/plant and ear characters over all intercropping patterns as previously discussed. Moreover, intercropping sudan grass with maize under various densities caused the highest reduction in grain and stover yields/fed, while the lowest reduction was occurred when maize was intercropped with teosinte. This minimum reduction may be due to the decrease in the plant height of teosinte compared to other tested forage crops (Table 6), consequently that may lead to lower interspecific competition between them. This means that teosinte is a good crop in the intercropping patterns where it is not strong competitor for maize such other forage crops (sudan grass and millet). Regarding maize plant densities effect, the greater plant density of maize (100%) produced the highest grain and stover yields/fed in comparison with 75 and 50% of recommended density in both seasons. In this respect, many researchers reported that a reduction in maize grain yield/ha was obtained by intercropping maize with other crops such as millet (Shaalan and El-salamouni, 2016 and Selim, 2018), fodder maize (Shaalan *et al.*, 2015 and Amanullah and Nivethitha, 2020), as well as a depression in stover yield/ha of maize was recorded by intercropping maize with fodder maize (Amanullah and Nivethitha, 2020) and cowpea (Chhetri and Sinha, 2020). Also, other researchers found that grain yield of maize /unit area was increased by increasing plant density of maize up to 100% when it was intercropped with groundnut (Ibrahim *et al.*, 2019). Moreover, Walia and Kumar (2021) found that increasing plant density of maize up to 75% intercropped with marigold increased stover yield/ha of maize compared to medium (50%) or low (25%) densities.

2-2 Chemical composition in grains

Chemical composition values (protein, oil and total carbohydrates %) in maize grains at maturity as shown in Table (11) were significantly affected by intercropping patterns of summer forage grasses crops and maize at the two seasons. The data showed that the sole cropping of maize recorded the highest values of protein and carbohydrates percentages compared to the others intercropping patterns. However, intercropping sudan grass with maize produced the lowest values of such traits followed by millet and teosinte. In addition, it is clear that increasing population densities of maize from 50 to 100% intercropped with the three tested forage crops caused a gradual decrease in protein and carbohydrates % of maize grains. This result may be due to that the raising of plant population of two intercropping crops per the unit area caused a crowding and competition among the plants on the absorption of soil nitrogen, especially when sudan grass was intercropped with maize under higher population. Similar trends were reported by Patel *et al.* (2017) who found that maize sole cropping recorded the highest values of protein and total carbohydrate % in maize grains more than its intercropping with cowpea. Also, Ibrahim *et al.* (2019) observed that intercropping maize with groundnut under high density 100% of maize led to a decrease in protein percentage in grains of maize as compared to its intercropping with groundnut at low density (33%).

Data of oil% in maize grains indicated that intercropping maize at different plant population with the three tested forage crops caused an increase in oil% compared to maize sole cropping. Moreover, the highest significant values of oil% were obtained by intercropping sudan grass with maize followed by millet and teosinte in a descending order. This means that there are negative relation between oil and protein accumulation in maize grains has been observed herein when the intercropping maize with forage crops was done. Similar results were obtained by Chaudhary *et al*. (2012) who found the same conclusion. Moreover, the data obtained herein showed that raising plant densities of maize from 50 to 100% intercropped with any forage crop led to an increase in oil% in maize grains. In this concern, Kaufman (2013) found that increasing plant density of maize caused an increase in the values of oil% in its grain.

Table (11): Chemical composition in grains of maize as affected by its intercropping at different plant densities with some summer grass forage crops during 2019 and 2020 seasons.

Intercropping patterns	Protein %		Carbohydrates %		Oil %	
	2019	2020	2019	2020	2019	2020
100% Millet + 50% Maize	10.72 bc	11.01 bc	72.62 a	72.84 ab	4.74 d	4.46 d
100% Millet + 75% Maize	10.11 de	10.41 de	69.79 b	69.92 cd	5.12 c	4.76 c
100% Millet + 100% Maize	9.87 ef	10.17 ef	68.82 c	68.97 cd	5.29 bc	4.99 b
100% Sudan grass + 50% Maize	10.04 def	10.11 ef	69.78 b	70.11 cd	5.19 c	5.02 b
100% Sudan grass + 75% Maize	9.88 ef	10.03 ef	68.71 c	69.18 cd	5.43 b	5.31 a
100% Sudan grass + 100% Maize	9.60 f	9.80 f	68.45 c	68.88 d	5.63 a	5.39 a
100% Teosinte + 50% Maize	11.03 ab	11.31 ab	72.88 a	72.94 a	4.29 f	4.19 e
100% Teosinte + 75% Maize	10.41 cd	11.01 bc	70.29 b	71.31 abc	4.47 e	4.36 d
100% Teosinte + 100% Maize	10.11 de	10.72 cd	69.76 b	70.67 bcd	4.81 d	4.72 c
Maize sole cropping	11.31 a	11.60 a	73.08 a	73.37 a	4.27 f	4.17 e

3- Effect of intercropping on competitive relationships and yield advantage

3-1 Aggressivity (A)

The data in Table (12) revealed that the values of aggressivity (A) for maize were positive, while those for the three forage crops were negative when maize plants were intercropped at any plant density with the forage crops in both seasons. This means that maize was the dominant crop (higher competitive), while the three tested forage crops were dominated one (lower competitive). This result is to be expected owing to maize plants are taller and having more chlorophyll content, photosynthetic efficiency and dry matter accumulation than in the tested forage crops as previously discussed. Moreover, it can be noticed that increasing plant density of maize from 50% to 100% of the recommended density intercropped with the forage crops caused a gradual decrease in (A) values of maize. This reduction may be due to the increase in intraspecific competition within maize plants at the high density of maize (100%) and consequently decreased the competitive ability of maize compared to at the low plant density (50%).Moreover, in comparison among the tested intercropping patterns, it can be found that the highest (A) values for maize (+0.64 and+0.68) were obtained by intercropping teosinte with low maize plant density, while the lowest values (+0.01 and +0.05) were obtained when sudan grass crop was intercropped with 100% maize plant density in the 1st and 2nd seasons, respectively. In this respect, other investigators found that the aggressivity values of maize were positive when intercropped with cowpea as reported by Mahdy (2018 b) and its values was decreased with increasing plant density of maize as reported by Hassan *et al.*, (2016).

3-2 Relative crowding coefficient (RCC)

The data show that the values of relative crowding coefficient (RCC) exceeding the one for either maize or the three forage crops when they were intercropped together under different plant density of maize in both seasons. This means that intercropping maize with any tested forage crop produced more yield than expected of their sole croppings. Moreover, it can be noticed that maize crop had RCC values higher than those of the three tested forage crops, indicating that maize crop is the dominant and more competitive than the tested forage crops. It addition, the data show that increasing plant density of maize from 50% to 100% of its pure stand increased the values of total RCC for maize plus millet or maize plus teosinte crops, but decreased those for maize plus sudan grass in the two seasons. This means that intercropping high plant density of maize (100%) was more profitable when it was intercropped with millet or with teosinte than with sudan grass. In comparison among the tested intercropping patterns, it can be found that the highest total RCC values were obtained when maize at 100% was intercropped with teosinte (10.64, 11.65) and millet (9.58, 11.56) in the first and second seasons, respectively. In this concern, many investigators found that the values of RCC were increased than one when maize intercropped with peanut (EL-Koomy and Attalla, 2018), upland rice (Sheha *et al.*, 2021) and soybean (El-Ghobashi and Ismail, 2022). Moreover, Hassan *et al.* (2016) found that the values of total RCC was increased by increasing plant density of maize intercropped with cowpea.

3-3 Competitive ratio (CR)

As competitive ratio (CR) was worked out to know the exact degree of competition between one crop to another, the data showed that the CR values of maize were higher than those of the three tested forage crops when they were intercropped with any maize density in both seasons. This means that maize plants are more competitive than the tested forage plants at different intercropping patterns. Moreover, it can be noticed that the values of CR for maize were greater when it was intercropped with teosinte than that intercropped with millet and sudan grass in a descending order. This superiority may be due to the decrease in plant height and dry matter production of teosinte compared to the

Table (12): Competitive relationships and yield advantage as affected by intercropping different plant densities of maize with some summer grass forage crops during 2019 and 2020 seasons (on basis of dry forage yield and maize grain yield/fed).

Intercropping patterns	Aggressivity (A)		Relative crowding coefficient (RCC)			Competitive ratio (CR)		Land equivalent ratio (LER)		
	Forage	Maize	Forage	Maize	Total	Forage	Maize	Forage	Maize	Total
2019 Season										
100%Millet + 50% maize	-0.59	+0.59	1.88	4.23	7.93	0.43	2.33	0.88	0.51	1.40
100%Millet + 75% maize	-0.34	+0.34	2.02	4.10	8.29	0.63	1.58	0.78	0.70	1.48
100%Millet + 100% maize	-0.14	+0.14	2.11	4.55	9.58	0.83	1.21	0.68	0.82	1.50
100% Sudan grass + 50% maize	-0.39	+0.39	1.54	2.77	4.25	0.53	1.90	0.86	0.41	1.27
100% Sudan grass + 75% maize	-0.20	+0.20	1.66	2.37	3.93	0.74	1.36	0.75	0.57	1.32
100% Sudan grass + 100% maize	-0.01	+0.01	1.74	1.83	3.18	0.98	1.02	0.63	0.65	1.28
100% Teosinte + 50% maize	-0.64	+0.64	1.31	4.54	5.95	0.39	2.53	0.84	0.53	1.37
100% Teosinte + 75% maize	-0.48	+0.48	1.35	5.63	7.62	0.52	1.91	0.71	0.76	1.47
100% Teosinte + 100% maize	-0.27	+0.27	1.54	6.93	10.64	0.69	1.44	0.61	0.87	1.48
2020 Season										
100%Millet + 50% maize	-0.61	+0.61	2.03	4.48	9.09	0.42	2.37	0.89	0.53	1.42
100%Millet + 75% maize	-0.33	+0.33	2.31	4.12	9.51	0.65	1.54	0.80	0.70	1.50
100%Millet + 100% maize	-0.16	+0.16	2.16	5.35	11.56	0.81	1.23	0.68	0.84	1.53
100% Sudan grass + 50% maize	-0.44	+0.44	1.61	3.09	4.96	0.50	2.01	0.87	0.44	1.30
100% Sudan grass + 75% maize	-0.27	+0.27	1.61	2.87	4.62	0.68	1.48	0.74	0.62	1.36
100% Sudan grass + 100% maize	-0.05	+0.05	1.68	2.14	3.60	0.92	1.09	0.63	0.68	1.31
100% Teosinte + 50% maize	-0.68	+0.68	1.28	4.89	6.24	0.39	2.56	0.86	0.55	1.41
100% Teosinte + 75% maize	-0.46	+0.46	1.54	5.52	8.52	0.55	1.83	0.73	0.76	1.49
100% Teosinte + 100% maize	-0.25	+0.25	1.64	7.09	11.65	0.71	1.41	0.62	0.88	1.50

other forage crops intercropped with maize. However, it is clear that the CR values of maize were decreased while those of forage crops were increased with increasing plant density of maize from 50% to 100% of pure stand density intercropped with the three forage crops in the two seasons. This means that competitive ability of maize was decreased at its high plant density. From the abovementioned results, it can be concluded that the highest CR values for maize (2.53- 2.56) were obtained when teosinte was intercropped with maize at 50% plant density in the 1st and 2nd seasons, respectively. Reversely, the highest CR values for forage crops (0.98-0.92) were obtained by sudan grass when was intercropped with maize at 100% plant density in the same respective seasons. Previous studies demonstrated that the values of CR for maize were always more competitive than other crops such as rajmash (Kour *et al.*, 2016) and soybean (Wei *et al.*, 2022). Also, Ijoyah *et al.* (2012) found that intercropping maize at high plant density 50000 maize plants/ha with okra recorded the lowest competitive ratio (0.65) compared to the low and medium plant density (33000 and 40000 maize plants/ha).

3-4 Land equivalent ratio (LER)

The data indicate that intercropping maize at different densities with the three tested forage crops decreased the values of LER for each crop less than one compared to their sole croppings in both seasons. However, the values of total LER (combined of two crops per unit area) were increased over one for all tested intercropping patterns compared to their sole croppings. This indicate that there was a considerable yield advantage and increasing in land usage as a result of intercropping maize with the tested forage crops more than their sole croppings. The yield advantage occurred herein may be due to the each of the two component intercrops differ in their growth habit, and were able to complement each other as well as more efficient in the utilization of the available resources (light, nutrients and water) when they were grown in association than when grown alone. In comparison among the tested intercropping patterns, it can be found that the highest values of total LER were obtained when maize at highest density (100%) was intercropped with millet (1.50-1.53) or with teosinte (1.48-1.50) in the first and second seasons, respectively. This indicate that the land use efficiency was increased by about (50%-53%) or (48%- 50%) when maize was intercropped with millet or teosinte, respectively more than their sole croppings in the same unit area. From these results it can be concluded that for achieving greater yield advantage per unit area from intercropping maize with the tested forage crops, maize plant density must be increased up to 100% of pure stand especially in combination with millet followed by teosinte. Similar results were obtained by previous studies who found that the values of LER was increased more than one by intercropping maize + guar (Mahdy 2018 a), maize + cowpea (Elsaid *et al*., 2019), maize + soybean (Abd Rabboh *et al.,* 2020 and Wei *et al.,* 2022), teosinte + cowpea (Salem *et al.,* 2019) and millet + cowpea (Mohamed *et al.,* 2020) as compared to their sole croppings. Moreover, other investigators found that the values of LER were increased by increasing plant density of maize intercropped with soybean (Bechem *et al.*, 2018) and with okra (Ijoyah *et al.*, 2012).

3-5 Cereal units (CU)

The total biological yields of maize (grains + stover) as well as the total dry forage yield of the tested forage crops (straw) per feddan were changed to values namely cereal units (CU) for simplify the comparison between the different tested intercropping patterns to evaluate and determine the best one of them.

The values of cereal units for each of the three forage crops and maize as well as their combined per feddan when were intercropped together at different patterns compared to their sole croppings are presented in Table (13). The data indicate that the values of CU for maize crop are more mostly than those for any forage crop when they were grown together (as intercropping patterns) or grown alone (as sole cropping). Therefore, it can be noticed generally that the values of total CU of the mixture were contributed by the maize crop than the tested forage crops. This result probably because of maize crop having more biological yield (grain + straw) than that obtained by forage crops as previously detected in Tables (7 and 10). The data show also that the CU of maize at different plant density plus any tested forage crop were more than that of forage crops monoculture. In comparison among the tested intercropping patterns, the highest values of total CU were obtained when maize at 100% were intercropped with millet at 100% (54.91-57.59) and with teosinte at 100% (54.84-56.37) in the first and second seasons, respectively. This means that growing one feddan of maize at 100% plant density intercropped with millet or teosinte at the same plant density produced the highest land use efficiency for cereal units compared to one feddan grown by those crops as monoculture, indicating that those intercropping patterns are best combination in this respect. These results were coincided with those of LER values as previously detected in Table (12). In this concern, Ouda *et al.* (2007) found that intercropping soybean with maize increased the values of total cereal units as compared to their sole croppings.

Table (13): Cereal units as affected by intercropping different plant densities of maize with some summer grass forage crops during 2019 and 2020 seasons (on basis of biological yield of maize and dry forage yield of forage crops/fed).

Intercropping patterns	2019 Season					2020 Season				
	Maize			Forage	Total	Maize			Forage	Total
	Grain	Stover	Total	Straw		Grain	Stover	Total	Straw	
100%Millet + 50% maize	23.76	5.97	29.73	11.42	41.15	24.99	5.96	30.95	12.30	43.25
100%Millet + 75% maize	32.29	7.11	39.40	10.12	49.52	33.05	7.12	40.17	11.10	51.27
100%Millet + 100% maize	37.92	8.22	46.14	8.77	54.91	39.84	8.31	48.15	9.44	57.59
100% Sudan grass + 50% maize	18.91	5.27	24.18	9.80	33.98	20.60	5.68	26.28	11.23	37.51
100% Sudan grass + 75% maize	26.44	5.90	32.34	8.50	40.84	29.21	6.37	35.58	9.62	45.20
100% Sudan grass+ 100% maize	29.93	6.47	36.40	7.23	43.63	32.22	6.89	39.11	8.14	47.25
100% Teosinte + 50% maize	24.60	6.13	30.73	8.38	39.11	26.00	6.14	32.14	8.71	40.85
100% Teosinte + 75% maize	35.17	7.64	42.81	7.05	49.86	35.79	7.67	43.46	7.63	51.09
100% Teosinte + 100% maize	40.43	8.37	48.80	6.04	54.84	41.44	8.45	49.89	6.48	56.37
Maize sole cropping	46.26	8.50	54.76	-	54.76	47.29	8.66	55.95	-	55.95
Millet sole cropping	-	-	-	12.94	12.94	-	-	-	13.81	13.81
Sudan grass sole cropping	-	-	-	11.39	11.39	-	-	-	12.98	12.98
Teosinte sole cropping	-	-	-	9.98	9.98	-	-	-	10.42	10.42

Conclusion

From the abovementioned results, the highest total fresh forage yield (45.387 ton/fed) and total dry forage yield (7.905 ton/fed) were obtained by intercropping 100% seeding rate of millet + 50% of its pure 25 cm to give population density of maize (12000 plants/fed). Moreover, the highest grain yield/fed of maize (4.093 ton/fed) were obtained by intercropping 100% seeding rate of teosinte +100% population density of maize (24000 plants/fed). Finally, it can be concluded that intercropping forage crops with maize lead to maximizing land equivalent ratio (LER) for forage production and maize grain yield/fed especially when maize at high plant density (100%) was intercropped with millet (LER= 1.52) and teosinte (LER= 1.49), indicating that the land use efficiency was increased by about 52% and 49%, respectively more than their monocultures under the conditions of this experiment in Menoufia governorate.

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تعظيم كفاءة استغلال الأرض بتحميل محاصيل العلف الأخضر الصيفية مع الذرة الشامية

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الملخص العربى

أجريت هذه الدراسة بالمزرعة البحثية بكلية الزراعة – جامعة المنوفية بشبين الكوم – مصر لدراسة تأثير تحميل ثلاثة محاصيل علف أخضر صيفية (الدخن ، حشيشة السودان ، الذرة الريانة) مع ثلاث كثافات نباتية من الذرة الشامية وذلك على صفات النمو ، والمحصول ومكوناته ، والتركيب الكيماوي لكلاً من محاصيل العلف ومحصول الذرة الشامية بالإضافة إلى تقدير كفاءة إستغلال الأرض والعلاقات التنافسية بين المحصول الرئيسى والمحاصيل المحملة. حيث تم تحميل محاصيل العلف الثلاثة بنسبة ١٠٠% من معدل التقاوى الموصى به لكل منهما مع ثلاث كثافات من الذرة وهى ٥٠ ، ٧٥ ، ١٠٠% من الكثافة المثلى للذرة الشامية (٢٤ ألف نبات للفدان) بالإضافة الى الزراعة المنفردة لهم وذلك خلال موسمي الزراعة ٢٠١٩ ، ٢٠٢٠م. وتم استخدام تصميم القطاعات كاملة العشوائية في أربع مكررات لتنفيذ التجربة. وكانت أهم النتائج المتحصل عليها كالتالى:

١- أدى تحميل محاصيل العلف الأخضر الثلاثة مع الذرة الشامية الى نقص فى معظم صفات النمو (عدد الفروع /م^{2} الكلوروفيل الكلى ، عدد الاوراق/الفرع ، مساحة الاوراق/الفرع ، الوزن الكلى الجاف للفرع) وصفات المحصول (العلف الاخضر والجاف للفدان) وصفات التحليل الكيماوى (نسبة البروتين الخام والرماد) والقيمة الغذائية لمحاصيل العلف (البروتين القابل للهضم والعناصر الغذائية الكلية القابلة للهضم)، بينما أدى هذا التحميل إلى زيادة فى ارتفاع النبات ، نسبة الالياف وذلك مقارنة بالزراعة المنفردة لهم. وقد تفوقت حشيشة السودان فى صفات ارتفاع النبات بينما تفوق الدخن فى صفات عدد الفروع /م^{2} الوزن الكلى الجاف للفرع ومحصول العلف الاخضر والجاف للفدان فى حين تفوقت الذرة الريانة فى صفات الكلوروفيل وعدد الاوراق ومساحة الاوراق /الفرع ونسبة البروتين الخام والرماد والبروتين القابل للهضم والعناصر الغذائية الكلية القابلة للهضم.هذا وقد أدت زيادة الكثافة النباتية للذرة الشامية من ٥٠% إلى ١٠٠% المحملة مع محاصيل العلف إلى زيادة فى ارتفاع النبات لمحاصيل العلف ونقص لمعظم صفات النمو وصفات العلف الاخضر والجاف للفدان والقيمة الغذائية لمحاصيل العلف.

٢- أدى تحميل الذرة الشامية مع محاصيل العلف إلى نقص صفات محصول الذرة الشامية ومكوناته (عدد الكيزان للنبات ، عدد الحبوب للكوز ، وزن ١٠٠ حبة ، ووزن الكوز ، ومحصول الحبوب للنبات ومحصول الحبوب والقش للفدان) وصفات التحليل الكيماوى (نسبة البروتين والكربوهيدرات) بينما أدى التحميل الى زيادة نسبة الزيت فى الحبوب. هذا وقد حقق نظام تحميل الذرة الشامية مع الذرة الريانة أفضل النتائج لصفات الذرة الشامية يليه الدخن وحشيشة السودان على الترتيب. وقد أدت زيادة الكثافة النباتية للذرة الشامية من ٥٠% الى ١٠٠% الى زيادة فى محصول الحبوب والقش للفدان للذرة الشامية ونسبة الزيت بالحبوب فى حين انخفض محصول النبات الفردى ومكوناته وكذلك نسبة البروتين والكربوهيدرات فى حبوب الذرة الشامية.

٣- أظهرت نتائج العدوانية أن قيم الذرة الشامية كانت موجبة بينما قيم محاصيل العلف الثلاثة كانت سالبة وذلك عند تحميل الذرة الشامية بكثافاته المختلفة مع محاصيل العلف، كما أدى أيضاً زيادة الكثافة النباتية للذرة الشامية من ٥٠% إلى ١٠٠% المحملة مع محاصيل العلف إلى نقص فى قيمة العدوانية للذرة الشامية. هذا وقد كانت قيمة نسبة التنافس للذرة الشامية أكثر من محاصيل العلف عند تحميل محاصيل العلف مع الذرة الشامية. وأدت زيادة الكثافة النباتية للذرة الشامية إلى نقص فى نسبة التنافس للذرة الشامية وزيادة نسبة التنافس لمحاصيل العلف. كما زادت قيم معامل الحشد النسبى وكذلك كفاءة استغلال الارض عن قيمة ١ مقارنة بالزراعة المنفردة، مما يشير الى أن تحميل محصول الذرة الشامية مع محاصيل العلف الثلاثة قد رفع من كفاءة استغلال الأرض عن الزراعات المنفردة لهذه المحاصيل. هذا وتبين أن افضل

نظام للحصول على أعلى وحدات للحبوب للفدان قد تحقق عند تحميل الذرة الشامية بنسبة ١٠٠% مع الدخن أو الذرة الريانة.

٤- من النتائج المتحصل عليها يمكن التوصية بتحميل محاصيل العلف الأخضر الثلاثة المختبرة مع الذرة الشامية لتعظيم كفاءة استغلال الارض من إنتاج العلف لمحاصيل العلف وإنتاج الحبوب للذرة الشامية مقارنة بالزراعات المنفردة لهم حيث أدى تحميل ١٠٠% دخن + ٥٠% ذرة شامية إلي الحصول على اعلى إنتاجية لمحصول العلف الأخضر والجاف و يقدر بحوالى ٤٥,٣٨٧ ، ٧,٩٠٥ طن /فدان على التوالى، بينما أدى تحميل ١٠٠% ذرة ريانة +١٠٠% ذرة شامية الى الحصول على أعلى محصول حبوب لفدان الذرة الشامية و يقدر بحوالى٤,٠٩٣ طن للفدان.هذا وقد تم الحصول على أعلى كفاءة استغلال للأرض و تقدر بحوالى ١,٤٩ ، ١,٥٢ وذلك عند تحميل ١٠٠% من الكثافة النباتية المثلى من الذرة الشامية مع ١٠٠% من معدل التقاوى لمحصولى الذرة الريانة والدخن على التوالى مما يشير إلى إمكانية تعظيم الكفاءة الإنتاجية للأرض بمقدار ٤٩% ، ٥٢% زيادة فى إنتاجية هذه المحاصيل عن زراعتها كزراعة منفردة وذلك تحت ظروف التجربة بمحافظة المنوفية.