Egyptian J. Nutrition and Feeds (2021), 24(3): 399-410

NUTRITIONAL AND ECONOMICAL EVALUATION OF CORN SILAGE CULTIVATED AT TWENTY AND THIRTY THOUSAND PLANTS PER FEDDAN

Sayed, S.K.[1] and Shereen M. El-Nahrawy[2]

[1]Animal Production Research Institute (APRI), Agricultural Research Center, Dokki, Giza, Egypt.

[2]Field Crops Research Institute (FCRI), Agricultural Research Center, Giza, Egypt.

(Received 4/11/2021, accepted 1/12/2021)

SUMMARY

This is study was conducted to evaluate the Corn hybrid single cross 10 (S.C. 10) was cultivated at two planting density rates of low density was 20 thousand plants per feddan (20TPF) or high density was 30 thousand plants per feddan (30TPF) as a silage through two digestibility trials were conducted using Rhmani rams to determine nutrients digestibility and nutritive values. The yield of corn crop and plant parts (ears, stems and leaves) were estimated for each sub-plots and calculated per feddan. Whole corn plants were harvested after 92 days of planting at the dough stage of maturity, chopped to 1-1.5 cm of length and ensiled in plastic bags for 35 days.. Representative samples of corn silage were analyzed for composition, fiber fractions and silage quality. Results revealed that high corn plant density showed significantly higher yield of fresh corn crop and TDN ($P<0.05$) and dry crop and CP and DCP ($P<0.01$), however, fresh and dry plant weight were lower significantly ($P<0.01$) compared to low plant density. The percentage of ears was significantly higher ($P<0.01$), however percentages of stems and leaves were significantly lower ($P<0.05$) for low plant density compared with high plant density. Low corn plant density revealed significantly higher contents of DM, OM ($P<0.05$), NFE and NFC ($P<0.01$) and lower contents of CP, ash ($P<0.05$), CF, NDF, ADF, ADL, hemicellulose and cellulose ($P<0.001$) with compared to high corn plant density. The concentrations of total volatile fatty acids (TVFA's, $P<0.05$), lactic, propionic, isobutyric, isovaleric and valeric acids were higher, however, pH value and the concentrations of TVFA's, NH_3-N ($P<0.05$), acetic and butyric acids were lower in low plant density compared to high plant density silage. The DMI and digestibility coefficients of DM, OM, NFE and NFC and TDN value were significantly higher ($P<0.05$), however, the digestibility coefficients of CP, CF, EE, NDF, ADF, ADL, hemicellulose and cellulose and DCP value were significantly lower ($P<0.05$) for high plant density compared to low plant density corn silage. Ruminal pH value, the concentration of NH_3-N ($P<0.05$) were lower, however, the concentrations of TVFA's ($P<0.05$), propionic, isobutyric, isovaleric and valeric acids were higher with high corn plant density compared to low density corn silage. While, acetic and butyric acids concentrations were nearly similar. There were no significant differences in rent of land, cultivation cost and total cost between low and high plant density. Whereas, high corn plant density recorded higher output of silage yield and output improvement ($P<0.01$), net revenue and net revenue improvement ($P<0.001$) compared to low corn plant density.

Keywords: *Corn plant density, yield, composition, quality, intake, digestibility, nutritive values, rumen fermentation and economic evaluation.*

INTRODUCTION

Maize (*Zea mays L.*) is the most important silage plants in the world because of its high yield, high energy forage produced with lower labor and machinery requirements than other forage crops (Roth *et al.*, 1995). Corn silage is a major energy and fiber source in diets for dairy cattle. Corn grain producers plant corn at relatively low densities (i.e., less than 75,000 seeds/ha), whereas dairy producers frequently plant corn at relatively high densities (i.e., more than 95,000 seeds/ha). Planting with appropriate plant density is one of the most important factors in corn production (Norwood, 2001). Recently, there has been concerned among corn silage producers in raising plant density to increase dry matter (DM) yield of silage crops. Forage from corn has high value for food, high yield capability, short-growth period, and is suitable as forage and feed for poultry and livestock and it is gaining an essential position in the cropping system (Saif *et al*., 2003). Cox and Cherney (2001) indicated effect of plant density on production and quality of forage corn. They assessed corn DM yield at two plant densities, 32,000 and 47,000 plants per acer. They found that, increasing plant density increased DM yield, but the difference in DM yield between the two plant densities was only 3.7%. Also they found that increased plant density had a negative effect on CP concentrations. Averaged across years, CP concentration averaged 3 g kg^{-1} less at 116,000 vs. 80,000 plants ha^{-1}. On the contrary, Marsalis *et al*. (2009) demonstrated that none of the quality parameters of corn (e.g., CP, NDF, ADF) was affected by reducing the seeding rate from 74,200 to 55,600 plants ha^{-1}. Plant population density main effects were significant for many of the quality traits. Concentrations of ADF increased linearly as the plant population density increased (Stanton *et al.,* 2007). Basically, there was no advantage or disadvantage by increasing plant density with respect to feed value.

Typical recommended plant densities for corn silage range from 30,000 to 35,000 plants/ac. With these plant densities, a reasonable DM yield is about 8 to 10 tons/ac (Marsalis *et al.*, 2008). Dry matter yields were maintained at over 10.5 tons/ac and wet yields exceeded 25.0 tons/ac, even at 22,500 plants/ac (Marsalis *et al*., 2009). Cusicanqui and Lauer (1999) assess the effect of plant density and corn hybrid on forage yield and nutritive value. Corn plant densities ranged from 18,000 to 42,300 plants/ac. They found a maximum DM yield at around 35,000 plants/ac and declining DM yield at greater plant densities.

For instance, Cusicanqui and Lauer (1999) observed maximum whole plant DM yields when corn was planted at 97,300 to 102,200 plants/ha. Considering total biomass yield as the only priority, planting corn for silage at high densities may be an attractive approach for dairy farmers to recover forage inventories. (Subedi *et al*., 2006; Boomsma *et al.*, 2009). Cusicanqui and Lauer (1999) reported that increasing corn planting density results in whole plant corn silages with greater concentrations of fiber and, likely, less energy containing corn silages. The negative relationship between planting density and forage quality makes difficult to recommend high planting density based on biomass yield (Cusicanqui and Lauer, 1999).

Corn plant density did not affect the quality of whole plant corn destined for silage when precipitation was abundant. Therefore, greater yields of silage can be obtained by increasing corn plant density. Crop rotation and management should be considered when planning forage management strategies to obtain great quantities of good quality forage for dairy farming systems (Ferreira *et al*., 2014).

The relationship between maize forage yield and plant density is not well established. Total dry matter increases from 6 to 40 % when plant density increases from about 55 000 to 88 000 plants ha^{-1} in some studies (Rutger and Crowder, 1967; Karlen *et al.*, 1985) and 79 000 to 165 000 plants ha-1 in some other studies (Sparks, 1988; Graybill *et al*., 1991; Cox and Otis, 1993; Turgut *et al*., 2005; Yandim, 2006; Yilmaz *et al.*, 2007). Contents of ADF and NDF a good indicator of forage quality were reported that their relations with plant densities were controversial. The NDF was affected by plant densities (Iptas and Acar, 2006). Leaf percentage values were affected by plant densities (Saruhan and Sireli, 2005) or not affected (Dogan *et al*., 1997; Iptas and Acar, 2003; Cuomo *et al*., 1998; Iptas and Acar, 2006). Stem percentages increased as plant densities increased (Oktem and Oktem, 2005).

Dry matter yield of forage maize responded positively to high plant densities with maximum dry matter yields occurring at 180 000 plants ha-1. Ear percentages decreased, stem percentage and ADF increased, leaf percentage, crude protein content and NDF did not change as plant densities increased suggest that forage maize producers must carefully balance the potential benefits of higher dry matter yields and forage quality. 180 000 plants ha^{-1} may be practiced (Çarpici *et al.,* 2010). Curran and Posch (2000) reported that good forage crops must have high digestible energy, low fiber and the desired amount of dry matter at harvest for storage. El-Metwally *et al*. (2011) pointed out that optimum plant density for high grain yield/of corn hybrid S.C. 10 was 20,000 plants per feddan. El-Hosary, *et al.* (2019) stated that the best plant population density was 20000 plants/fed to maximized grain yield and 28,000 plants/fed to maximized forage crop yield.

Forage corn is an important source of high yielding and consistent feed and is the most important feed crop for animal husbandry in many areas of world. Therefore, it is important to understand how forage corn performance is influenced by agronomic practices, such as plant density on digestibility, rumen fermentation during use it as silage.

MATERIALS AND METHODS

Corn cultivation management:

Corn hybrid single cross 10 (S.C. 10) was cultivated at two planting density rates of low density was 20 thousand plants per feddan (20TPF) or high density was 30 thousand plants per feddan (30TPF) with a split-plot design with randomized complete blocks arrangement in two plant density. Main plots were devoted to the two plant density. Sub-plots were assigned to three replicates. Each sub-plot consisted of four ridges, 4 m length and 0.6 m width for each ridge. Organic fertilizer was added to the soil before plowing at 20-30 cubic meters, 150 kg super phosphate and 50 kg potassium sulphate per feddan. Maize plants were later thinned to one plant per hill. Handing hoeings were done before the first and second irrigations and pesticides were sprayed as necessary. The fertilization by adding 120 nitrogen units per feddan, equivalent to 6 bags of urea, or 8 bags of nitrate per feddan, and therefore to obtain the highest production and divide the compost in the first two steps after the haze and before the prehistoric and the second before the next larvae of the soil and add compost below and below plants. The first irrigation was applied after 21 days from sowing, while the following irrigations were applied at two or three week intervals and stopping irrigation before harvesting about two weeks.

Yield determination and making silage:

The yield of corn crop and plant parts (ears, stems and leaves) were estimated for each sub-plots and calculated per feddan. Whole corn plants were harvested after 92 days of planting at the dough stage of maturity and chopping using Holland Chopper machine to 1-1.5 cm of length. Five hundred kg of each density was ensiled in double plastic bags with 80 kg weight for each, pressed by hand to exclude the air from the bags and ensiled for 35 days.

Silage quality determination:

Color and odor of each tested silage were examined and samples were taken for chemical analysis, where silage pH was directly determined using Orian 680 digital pH meter, Concentrations of VFA fractions in silage were analyzed using gas chromatograph equipped with a double flame ionization detector according to Cottyn and Boucque (1968). TVFA's concentrations was determined according to Warner (1964), and ammonia nitrogen concentrations were determined according to Bergen *et al.* (1974).

Digestibility trial:

Two digestibility trials were conducted at Sakha Animal Production Research Station, Animal Production Research Institute, Agricultural Research Center, Giza, Egypt to determine the digestion coefficients and nutritive values of the experimental corn silages. Three Rahmany rams were used in each trial with average body weight of 50±0.58 kg and 3 years old were used. Rams were housed individually in digestion crates for fifteen days as preliminary period followed by seven days as collection period. Digestion crates permitted total collection of feces. Ninety percent of *ad libtum* intake of maize silage was offered for each ram in two meals at 8 a.m. and 4 p.m. during the days of collection period. The water was available all the day round in plastic buckets. Fecal samples were collected twice daily for 7 days during the collection period. Representative samples of silages and feces were analyzed according to the methods of AOAC (1990). Fiber constituents including neutral detergent fiber (NDF) was determined according to Van Soest and Marcus (1964). Acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest (1963).

Rumen samples and determination:

At the last day of the digestible trail, rumen liquor samples were taken at 3 hr. after the morning feeding by a rubber stomach tube. The samples were filtered through a double layer of cheese cloth. The rumen pH value was determined directly by HANNA pH meter (HI-8424 Sophisticated micro-processor, pH meter). Total volatile fatty acids (TVFA's) concentration was estimated by using steam distillation method (Warner, 1964). Ammonia-N (NH_3-N) concentration was determined using magnesium oxide (MgO) as described by AOAC (1990). Concentrations of VFA fractions in rumen liquor were analyzed using gas chromatograph equipped with a double flame ionization detector according to Cottyn and Boucque (1968).

Statistical analysis:

For statistical analysis, independent two samples T-test were performed using IBM SPSS Statistics (2014) for user's Guide. A statistical significance of was checked for p value, 0.05.

RESULTS AND DISCUSSION

Crop yield:

Yield of fresh and dry corn crops are presented in Table (1). The yield of fresh corn crop was higher significantly (P<0.05) for high plant density compared to low plant density being 29.01 vs. 22.98 ton/fed. Moreover, the yield of dry crop was higher significantly (P<0.01) for high plant density compared to low plant density (8.31 vs. 6.86 ton/fed.). Fresh and dry corn crops increased by 26.24 and 21.14% for high plant densities than for low plant densities, respectively, although fresh and dry plant weight were significantly higher (P < 0.01) for low plant densities compared to high plant densities (1.15 and 0.34 vs. 0.97 and 0.28 kg, respectively). The fresh and dry plant weight increased by 18.56 and 21.43% for low plant density compared to high plant density, respectively. Planting with appropriate plant density is one of the most important factors in corn production (Norwood, 2001). Greater yields of silage can be obtained by increasing corn plant density (Ferreira *et al*., 2014). Total DM yield increased as plant density n n bbbbb/@?okKkokincreased (Widdicombe and Thelen, 2002). Typical recommended plant densities for corn silage range from 30,000 to 35,000 plants/ac. With these plant densities, a reasonable DM yield is about 8 to 10 tons/ac (Marsalis *et al.*, 2008). Dry matter yields were maintained at over 10.5 tons/ac and wet yields exceeded 25.0 tons/ac, even at 22,500 plants/ac (Marsalis *et al*., 2009). El-Hosary, *et al.* (2019) stated that the best plant population density was 20000 plants/fed to maximized grain yield and 28,000 plants/fed to maximized forage crop yield.

Table (1): Yield of fresh and dry corn crop, relative plant parts and yield of digestible nutrients for low and high density corn plants.

Item	Low density	High density	MSE	p-value	Sig.
Yield (ton/fed.)					
Fresh crop	22.98	29.01	1.10	0.016	*
Dry crop	6.86	8.31	0.35	0.010	**
Plant weight (kg/plant)					
Fresh plant	1.15	0.97	0.04	0.004	**
Dry plant	0.34	0.28	0.02	0.007	**
Relative parts %					
Ears	42.36	35.64	1.68	0.004	**
Stems	39.69	44.71	1.29	0.011	*
Leaves	17.95	19.66	0.45	0.022	*
Yield of nutrients (ton/fed.)					
TDN	4.72	5.52	0.19	0.012	*
CP	0.55	0.68	0.03	0.006	**
DCP	0.35	0.46	0.02	0.005	**

** Significant at P≤0.05.* *** Significant at P≤0.01.*

Relative plant parts:

Relative plant parts in Table (1) revealed that the percentage of ears was significantly higher (P<0.001), however percentages of stems and leaves were significantly lower (P<0.05) for low plant density compared with high plant density. Ear percentage decreased, stem percentage increased and leaf percentage did not change as plant densities increased (Çarpici *et al.*, 2010). Leaf percentage values were affected by plant densities (Saruhan and Sireli, 2005). Stem percentages increased as plant densities increased (Oktem and Oktem, 2005). The percentages of stover, stalks and leaves increased significantly (P<0.05), while the percentages of ear and grain decreased significantly (P<0.05) with increasing plant density Gaafar (2009).

Yield of nutrients:

Data of nutrients yield presented in Table (1) showed that the yield of total digestible nutrients (TDN) was significantly higher (P<0.05), while crude protein (CP) and digestible crude protein (DCP) were significantly higher (P<0.01) for high plant density compared to the low plant density. Yield of TDN, CP and DCP of high plant density increased by 16.70, 23.64 and 31.43% than those of low plant density, respectively. High significant (P<0.01) positive correlations exist between dry crops yield and the yield of TDN, CP and DCP were 0.90, 95 and 0.91, respectively. Also, the correlations between the yield of TDN, CP and DCP and their contents were – 0.68, 0.97 and 0.87, respectively. Cusicanqui and Lauer (1999) assess the effect of plant density and corn hybrid on yield of nutritive value. Wang *et al.* (2005) observed better nutritive value yield of whole forage maize can be achieved through the increase of the plant density. Gaafar (2009) found that the yield of TDN and DCP per feddan increased significantly (P<0.05) with increasing plant density.

Chemical composition:

Results of chemical composition of corn silage are presented in Table (2). Low corn plant density revealed significantly higher contents of DM, OM (P<0.05) and NFE (P<0.01) and lower contents of CP, EE, ash (P<0.05) and CF (P<0.001) with compared to high corn plant density. Results of chemical composition are confirmed with the differences the percentages of relative plant parts in Table (1). High significant (P<0.01) positive correlation exist between both ear percentage and NFE content (r = 0.93), stem percentage and CF content (r = 0.092) and leave percentage and CP content (r = 0.90).These results agreed with those obtained by Pinter *et al.* (1994) who found that CP and fiber fractions increased, while starch and soluble carbohydrates decreased with increasing plant density. Wang *et al.* (2005) found that crude protein, ether extract, crude fiber and nitrogen free extract significantly increased with plant density. The contents of DM, OM and NFE of whole plant corn silage decreased significantly (P<0.05), while the contents of CP, CF, EE and ash increased significantly (P<0.05) with increasing plant density (Gaafar, 2009). Also, he noticed that DM, OM and NFE contents increased with increasing the percentages of ear and grain, while the contents of CP, CF, EE and ash increased with increasing the percentages of stover, stalks and leaves. Crude protein content did not change as corn plant densities increased (Marsalis *et al*., 2009; Çarpici *et al.*, 2010). Roth and Heinrichs (2001) stated the ranges of 7.2-10.0% for crude protein (CP) contents in maize silage. Mc Donald *et al*. (1998) reported the values of 23.3, 5.7 and 10.0% for crude fiber (CF), ether extract (EE) and ash, respectively.

Fiber fractions:

Data of fiber fractions in Table (2) assessed that high plant density and showed higher contents of NDF, ADF, ADL, hemicellulose and cellulose (P<0.01) and lower content of NFC (P<0.01) in compared low corn plant density. These results are confirmed with relative plant parts presented in Table (1), which fiber fraction increased with increasing the percentage of stems, however, NFC content increased with increasing the percentage of ears. High significant (P<0.01) positive correlation exist between stem percentage and NDF, ADF, ADL, hemicellulose and cellulose being 0.94, 0.95, 92, 90 and 0.96, respectively. Also, the high significant (P<0.01) positive correlation between ear percentage and NFC was 0.96. Contents of NDF and ADF a good indicator of forage quality were reported that their relations with plant densities were controversial (Iptas and Acar, 2006). Marsalis *et al*. (2009) demonstrated that none of the quality parameters of corn (e.g., NDF, ADF) was affected by plant density. Valdez *et al*. (1989) found that NDF and ADF concentrations increased by increasing corn plant density. Roth and Heinrichs (2001) stated the ranges of 23.6-33.2 and 41.0-54.1% for acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents, respectively in maize silage.

Table (2): Chemical composition and fiber fractions of low and high density corn silage.

Item	Low density	High density	MSE	p-value	Sig.
DM %	32.86	30.65	0.61	0.046	*
Composition of DM %					
OM	95.16	94.04	0.31	0.047	*
CP	7.95	8.21	0.07	0.026	*
CF	22.12	25.45	0.84	0.007	**
EE	2.89	2.95	0.03	0.027	*
NFE	62.20	57.43	1.22	0.009	**
Ash	4.84	5.96	0.48	0.018	*
Fiber fractions %					
NDF	43.78	47.87	0.97	0.005	**
ADF	25.73	28.31	0.61	0.004	**
ADL	5.13	5.43	0.07	0.006	**
Hemicellulose	18.05	19.56	0.36	0.008	**
Cellulose	20.60	22.88	0.53	0.004	**
NFC	40.44	34.81	1.29	0.003	**

** Significant at P≤0.05.* *** Significant at P≤0.01.*

Silage fermentation characteristics:

Fermentation characteristics of corn silage as affected by plant density are shown in Table (3). The concentration of total volatile fatty acids (TOA) was significantly higher (P<0.05), but pH value and the concentrations of TVFA's and NH3-N were significantly lower (P<0.05) for low plan density compared to high plant density silage. The concentrations of lactic, propionic, isobutyric, isovaleric and valeric acids were higher, however, acetic and butyric acids were lower in low plant density compared to high plant density silage. These results indicated that both low and high density corn silage have a considerable amount of soluble carbohydrates to promote silage fermentation. Total organic and lactic acids concentrations was highly positive correlated with both NFE and NFC being 0.97, 0.95 and 0.95, 0.92, respectively (P<0.01). The high significant positive correlation between TVFA's and acetic acids concentrations and the contents of CF, NDF, ADF, hemicellulose and cellulose were 0.96, 0.96; 0.97, 0.93; 0.97, 0.95; 0.96, 0.90 and 0.96, 0.96, respectively (P<0.05). The pH values obtained in this study is within the recommended range of 3.7 - 4.2 stated by Karsten *et al*. (2003). As corn plant density increases quality is affected adversely (Widdicombe and Thelen, 2002). Individual volatile fatty acids % of total volatile fatty acids were lactic acid 50 – 75%. Acetic acid 13.9 – 25.5%, propionic acid 0.14 – 10.40%, isobutyric acid 0.10 – 5.46%, butyric acid 1.82 – 17.64%, isovaleric acid 0.64 – 3.53% and valeric acid 0.36 – 2.56%. (Bendary *et al.*, 2001). Kung *et al*. (2018) suggested that typical concentration in corn silage was ammonia-N 5-7% of total-N. Wang *et al.* (2005) found that silage quality of whole forage maize varied with plant density. As increased plant densities have resulted in reduced maize forage quality (Cox and Cherney 2001). Gaafar (2009) reported that pH value and the concentrations of ammonia-N, isobutyric, butyric, isovaleric and valeric acids increased significantly (P<0.05), however the concentrations of lactic, acetic and propionic acids decreased significantly (P<0.05) with increasing plant density. The concentrations of individual volatile fatty acids in silages of low and high density revealed a good quality silage as reported by McDonald *et al.* (1995).

Table (3): Fermentation characteristics of low and high density corn silage.

Item	Low density	High density	MSE	p-value	Sig.
pH value	3.84	4.05	0.06	0.037	*
TOA % of DM	7.75	6.93	0.20	0.016	*
TVFA's % of DM	1.92	2.13	0.04	0.21	*
NH_3-N % of total-N	4.54	6.93	0.64	0.028	*
Individual organic acids % of DM					
Lactic acid	5.83	4.80			
Acetic acid	0.59	0.96			
Propionic acid	0.16	0.11			
Isobutyric acid	0.62	0.48			
Butyric acid	0,20	0.35			
Isovaleric acid	0.15	0.10			
Valeric acid	0.20	0.13			

** Significant at P≤0.05.*

Dry matter intake:

Dry matter intake by rams fed low and high density corn silage are shown in Table (4). *Ad libtum* DM intake expressed as g/kg $LBW^{0.75}$ was higher significantly (P<0.05) for low density silage compared to high density corn silage (63.25 vs. 59.50 g/kg $LBW^{0.75}$, respectively). The percentages of relative plant parts in Table (1) as well as the contents of CF, NFE, fiber fractions and NFC in Table (2) might be affect DMI by rams. Dry matter intake was positively correlated with NFE and NFC contents (r = 0.93 and 0.88, respectively, P<0.01) and negatively correlated with CF, NDF, ADF, hemicellulose and cellulose (r = - 0.84 (P<0.05), - 0.77, - 0.78, - 0.74 and – 0.80, respectively). These results agreed with those illustrated by Gaafar (2009) who found that the DM intake of different silages decreased significantly (P<0.05) with increasing plant density. It is well known that DM intake is closely related to the rumen digesta passage rate, and a rapid passage rate facilitates high DM intake (Campling, 1966 and Shaver *et al.*, 1986). In the study by Van der Linden *et al.* (1984) who supplemented corn stover with corn grain containing high NFC content, the ruminal solid passage rate increased with increasing levels of NFC. Intake of dry matter declined with increasing dietary neutral detergent fiber (West *et al.*, 1999).

Nutrients digestibility:

Nutrients digestibility coefficients of low and high density corn silages by rams are presented in Table (4). The digestibility coefficients of DM, OM, NFE and NFC were significantly higher (P<0.05), however, the digestibility coefficients of CP, CF, EE, NDF, ADF, ADL, hemicellulose and cellulose were significantly lower (P<0.05) for high plant density compared to low plant density corn silage. Nutrients digestibility are confirmed with nutrients contents of low and high plant density corn silage, which carbohydrates and fiber were the most nutrients affected by plan density (Table 2). There are high positive significant correlations between nutrients contents and digestibility, DM (r = 0.95), OM (r = 0.94), CP (r = 0.96), CF (r = 0.92), EE (r = 0.80), NFE (r = 0.94), NDF (r = 0.95), ADF (r = 0.96), hemicellulose (r = 0.92)m cellulose (r = 0.97) and NFC (r = 0.95). Despite being positively correlated, DMD and NDFD did not have the same relationships with other nutrients, DMD was positively correlated with starch concentration only and negatively correlated with NDF, ADF, CP, and ADL concentrations (Guyader *et al.*, 2018). Gaafar (2009) found that the digestibilities of DM, OM and NFE decreased significantly (P<0.05), while the digestibilities of CP, CF and EE increased significantly (P<0.05) with increasing plant density. The apparent total tract digestibility of DM and gross energy decreased when total dietary fiber increased (Zhang *et al*., 2013).

Table (4): Dry matter intake, nutrients digestibility and nutritive values of low and high density corn silage.

Item	Low density	High density	MSE	p-value	Sig.
DMI (g/kg $LBW^{0.75}$)	63.25	59.50	0.99	0.023	*
Digestibility coefficients %					
DM	66.84	64.72	0.57	0.030	*
OM	68.92	66.86	0.55	0.027	*
CP	64.85	66.98	0.56	0.018	*
CF	63.83	66.38	0.67	0.019	*
EE	72.80	76.49	0.98	0.028	*
NFE	72.03	67.72	1.13	0.020	*
NDF	63.49	67.08	0.93	0.014	*
ADF	58.49	61.85	0.87	0.013	*
Hemicellulose	65.12	68.80	0.95	0.014	*
Cellulose	60.74	64.06	0.86	0.015	*
NFC	73.53	69.31	1.08	0.011	*
Nutritive values %					
TDN	68.81	66.36	0.66	0.034	*
DCP	5.16	5.50	0.10	0.044	*

** Significant at P≤0.05.*

Nutritive values:

Nutritive values of low and high corn plant density expressed as TDN and DCP are shown in Table (4). The TDN value was higher significantly (P<0.05), but DCP significantly lower (P<0.05) in low density than those of high density. The TDN value increased with increasing NFE content and while DCP value increased with increasing CP content (Table 2) as well as with NFE and CP digestibilities (Table 4). The positive correlation between TDN value and both content and digestibility of NFE (r = 0.86 and 0.94, respectively) and NFC (r = 0.80 and 0.89, respectively). Also, DCP value was positively correlated with both CP content and digestibility (r = 0.94 and 0.90, respectively). Pinter *et al.* (1994) reported that TDN value decreased, but DCP value increased with increasing plant density of corn silage. Gaafar (2009) reported that the TDN value decreased significantly (P<0.05), while the DCP value increased significantly (P<0.05) with increasing plant density.

Rumen fermentation parameters:

Rumen liquor parameters in Table (5) showed that lower pH value, the concentrations of NH_3-N (P<0.05) and higher concentrations of TVFA's (P<0.05), propionic, isobutyric, isovaleric and valeric acids in rumen fluid of rams fed low corn plant density compared to high density corn silage. While, acetic and butyric acids concentrations were nearly similar with low and high plant density. Acetic acid concentration increased with increasing CF and fiber fractions contents, propionic acid concentration increased with increasing NFE and NFC contents and ammonia-N concentration increased with increasing CP content (Table 2). The correlation between TVFA's and propionic acids concentration and NFE and NFC contents were 0.97, 0.95 and 0.96, 0.94, respectively. Also, the correlations between acetic acid concentration and the contents of CF, NDF, ADF, hemicellulose and cellulose were 0.95, 0.95, 0.98, 0.98 and 0.97, respectively. The correlation between ammonia-N concentration and CP content was 0.88 and with ammonia-N concentration in silage was 0.89. As the silo becomes anaerobic, various anaerobic and facultative microorganisms increase in population and ferment primarily sugars and organic acids in the crop. The principal fermentative microbial groups include lactic acid bacteria (LAB), enterobacteria, clostridia, and yeasts (Pahlow *et al*., 2003). Van Soest (1994) stated that the optimum pH value for growth of cellulolytic microorganisms was 6.7 and the range for normal condition with about ±0.5 pH degree. Moreover, Hungate (1966) and Mehrez *et al.* (1983) reported that the acidity of cellulolytic bacteria during ruminal fermentation may be inhibited when pH value of rumen liquor is below 6. Russell and Dombrowski (1980) who reported that ruminal VFA production was closely related to ruminal pH, which can be considered an important regulator of microbial yield. Hungate (1966) demonstrated that rumen microorganisms utilize more NH_3-N when more energy sources are fermented. Values of ruminal volatile fatty acids fractions obtained in this study were nearly similar to the values obtained with feeding calves on corn silage alone as a sole feed (Mohsen *et al.*, 2001).

Table (5): Rumen fermentation parameters of rams fed low and high density corn silage.

Item	Low density	High density	MSE	p-value	Sig.
pH value	6.53	6.78	0.07	0.029	*
TVFA's (meq/100 ml)	16.55	14.73	0.46	0.022	*
NH_3-N (mg/100 ml)	15.11	16.60	0.21	0.024	*
Volatile fatty acids fractions (meq/100 ml)					
Acetic acid	7.18	7.20			
Propionic acid	5.14	3.87			
Isobutyric acid	0.68	0.50			
Butyric acid	2.37	2.42			
Isovaleric acid	0.53	0.36			
Valeric acid	0.65	0.38			

** Significant at P≤0.05.*

Economical evaluation:

Results of economical evaluation of low and high density corn plant silage are shown in Table (6). There were no significant differences in rent of land, cultivation cost and total cost between low and high plant density. Whereas, high corn plant density recorded higher output of silage yield and output improvement (P<0.01), net revenue and net revenue improvement (P<0.001) compared to low corn plant density. Output of silage yield and net revenue of high density corn silage increased by 26.16 and 41.56% compared to low density silage, respectively. These results are confirmed with the yield of fresh crop presented in Table (1), which was higher in high density than that of low density. The correlations between fresh crop yield and both output and net revenue were 0.99 and 0.96, respectively. Economic production of corn silage is dependent on silage DM yield and nutritive value (Guyader *et al*., 2018). Cox *et al.* (2006) reported that high plant density can provide an increased profit over low plant corn silage. Rotz *et al.* (1999) stated that economic benefit of corn silage processing was moderately sensitive to the length-of-cut setting of the harvester, milk price, and processing's effect on forage digestibility and available energy. Cox *et al.* (1998) found that maximum economic yields occurred at about 39,500 plants/acre.

Table (6): Economical evaluation of low and high density corn silage.

Item	Low density	High density	MSE	p-value	Sig.
Rent of land (LE/fed./season)	3000	3000	0.00	1.00	NS
Cultivation cost (LE/fed.)	3000	3100	43.23	0.275	NS
Total cost (LE/fed.)	6000	6100	45.12	0.328	NS
Output of silage yield (LE/fed.)*	15626	19727	964	0.004	**
Output improvement %	100.00	126.16	6.23	0.005	**
Net revenue (LE/fed.)	9626	13627	909	0.001	***
Net revenue improvement %	100.00	141.56	9.47	0.001	***

*[NS] Not significant. ** Significant at P≤0.01. *** Significant at P≤0.001.*

** Price of 1 ton corn silage = 680 LE according to price 2019.*

CONCLUSION

Cultivation corn crop for making silage should be planted at high plant density of 30 thousand plants per feddan to achieve the higher yield of silage crop as well as the yield of digestible nutrients.

REFERENCES

AOAC (1990). Association of Official Analytical Chemists. Official Methods of Analysis, 15th Ed., Washington, DC.

Bendary, M.M.; S.A. Mahmoud; E.M. Abd El-Raouf; M.K. Mohsen and H.M.A. Gaafar (2001). Economical and nutritional evaluation of ensiling corn crop. Egyption J. Nutrition and Feeds (Special Issue), 4: 89.

Bergen, W.G.; E.H. Cash and H.E. Henderson (1974). Changes in nitrogenous compounds of the whole corn plant during ensiling and subsequent effects on dry matter intake by sheep. J. Anim. Sci., 39: 629.

Boomsma, C.R.; J.B. Santini; M. Tollenaar and T.J. Vyn (2009). Maize morphophysiological responses to intense crowding and low nitrogen availability: An analysis and review. Agron. J., 101: 1426–1452.

Campling, R.C. (1966). The effect of concentrates on the rate of disappearance of digesta from the alimentary tract of cows given hay. J. Dairy Res., 33: 13-23.

Çarpıcı, E.; B. Çelik; N.G. Bayram and B. Asik (2010). The Effects of Salt Stress on Growth, Biochemical Parameter and Minaral Element Content of Maize (Zea mays L.) Cultivars. African Journal of Biotechnology, 9 (41): 6937-6942.

Cottyn, B.. and C.V. Boucque (1968). Rapid method for the gas-chromatographic determination of volatile fatty acids in rumen fluid. J. Agric. Food Chem., 16: 105–107.

Cox, W.J. and D.J. Otis (1993). Grain and Silage Responses of Commercial Corn Hybrids to Plant Densities. p. 132. In Agronomy Abstract, ASA, Madison, WI.

Cox, W.J. and D.R. Cherney (2001). Row spacing, plant density and nitrogen effects on corn silage. Agron. J., 93: 597.

Cox, W.J.; D.R. Cherney and J.J. Hanchar (1998). Row spacing, hybrid, and plant density effects on corn silage yield and quality. J. Prod. Agric., 11: 128.

Cox, W.J.; J.J. Hanchar and W.A. Knoblauch (2006). Growth, yield, quality, and economics of corn silage under different row spacing. Agronomy Journal, 98:163-167.

Cuomo, G.J.; D.D. Redfearn and D.C. Blouin (1998). Plant Density Effects on Tropical Corn Forage Mass, Morphology, and Nutritive Value. Agron. J., 90: 93–96.

Curran, B. and J. Posch (2000). Agronomic Management of Silage for Yield and Quality (Silage Cutting Height). Crop Insights. 10(2): 1-4.

Cusicanqui, J.A. and J.G. Lauer (1999). Plant Density and Hybrid Influence on Corn Forage Yield and Quality. Agronomy Journal. 91(6): 911-915.

Dogan, R.; I. Turgut and N. Yurur (1997). The Effect of Plant Density on the Silage Yield and Quality of Some Dent Corn Varieties (Zea mays indentata sturt.) Grown under Bursa Conditions. II. Field Crops Congress in Turkey, 22-25 September, 467-471, Samsun.

El-Hosary, A.A.; M.E. Sidi; G.Y. Hammam; E.M. El-Gedwy and A.A.A. El-Hosary (2019). Maize hybrids yield potential as affected by plant population density in Qalyubia, Egypt. Bioscience Research, 16(2): 1565-1576,

El-Metwally, E. A.; A. A. El-Deeb; S. A. Safina and B.G. Rabbani (2011). Behavior of some maize hybrids cultivated with different plant densities. J. Plant Production, Mansoura Univ., 2 (3): 479 – 490.

Ferreira, G.; M. Alfonso; S. Depino and E. Alessandri (2014). Effect of planting density on nutritional quality of green-chopped corn for silage. J. Dairy Sci., 97: 5918–5921.

Gaafar, H.M.A. (2009). Some factors affecting on nutritive value of whole plant corn silage. XVth International Silage Conference Proceedings, July 27-29, 2009 – Madison, Wisconsin, USA.

Graybill, J.S.; W.J. Cox and D.J. Otis (1991). Yield and Quality of Froge Maize as Influenced by Hybrid, Planting Date and Plant Density. Agron. J, 83:559-564.

Guyader, J.; V.S. Baron and K.A. Beauchemin (2018). Corn forage yield and quality for silage in short growing season areas of the Canadian prairies. Agronomy, 8: 164.

Hungate, R.E. (1966). The rumen and its microbes. Academic press. New York and London.

IBM SPSS Statistics (2014). Statistical package for the social sciences, Release 22, SPSS INC, Chicago, USA.

Iptas, S. and A.A. Acar (2003). Genotype and row spacing influence on corn silage yield and some agronomic characters. Proceeding of Turkey V. Field Corps, 13-17 October, pp: 458-462.

Iptas, S. and A.A. Acar (2006). Effects of hybrid and row spacing on maize forage yield and quality. Plant, Soil and Environment, 52: 515-522.

Karlen D.L.; C.R. Camp and J.P. Zublena (1985). Plant Density, Distribution, and Fertilizer Effects on Yield and Quality of Irrigated Corn Silage. Commun. Soil Sci. Plant Anal., 16: 5570.

Karsten, H.D.; O.W. Roth and L.D. Meuller (2003). Evaluation of corn hybrids at two stages of development for grazing heifers. Agronomy Journal, 95, 870-877.

Kung, L.; R.D. Shaver; R.J. Grant and R.J. Schmidt (2018). Silage review: Interpretation of chemical, microbial, and organoleptic components of silages. J. Dairy Sci., 101:4020–4033.

Marsalis, M.A.; R.E. Kirksey; L. Carrasco; F.E. Contreras-Govea; M.K. O'Neill; L.M. Lauriault and M. Place. (2008). New Mexico 2008, Corn and Sorghum Performance Tests. Las Cruces: New Mexico State University Agricultural Experiment Station.

Marsalis, M.A.; S. Angadi and F.E. Contreras-Govea (2009). Effect of seeding and nitrogen rates on limited irrigated corn and forage sorghum yield and nutritive value. In Abstracts: An- annual Meeting, Western Society of Crop Science, June 22–24, 2009, Ft. Collins, CO.

McDonald, P.; R.A. Edwards; J.F.D. GreenhaIgh and C.A. Morgan (1995). Animal nutrition. 5th Ed., Copyright licensing LTD., London.

Mehrez, A.Z.; M.M. El-Shinnawy; M.M. El-Ashry and H.M. El-Sad (1983). Assessment of the associative effect of roughage and concentrates. Diamond Jubilee of Amer. Soc. Anim. Sci. Pullman, Washington State Univ.

Mohsen, M.K.; S.A. Mahmoud; E.M. Abdel-Raouf; M.M. Bendary and H.M.A. Gaafar (2001). Performance of growing Friesian calves fed rations containing corn silage. 1- Nutrient digestibility, rumen activity, live body weight gain and economic evaluation. Egyptian J. Nutrition and Feeds (2001) 4 (Special Issue): 485-497.

Norwood, C.A. (2001). Dry land Corn in Western Kansas: Effects of Hybrid Maturity, Planting Date, and Plant Population. Agronomy Journal. 93(3): 540-547.

Oktem, A. and A.G. Oktem (2005). Effect of Different Intra Row Spaces to Forage Value of Three Silage Corn (Zea mays L. indentata) Genotypes. III. National Animal Nutrition Congress in Turkey, 7-10 September, 523-527, Adana.

Pahlow, G.; R.E. Muck; F. Driehuis; S.J.W.H. Oude Elferink and S.F. Spoelstra (2003). Microbiology of ensiling. Pages 31–93 in Silage Science and Technology. D. R. Buxton, R. E. Muck, and J. H Harrison, ed. American Society of Agronomy, Madison, WI.

Pinter, L.; Z. Alfoldi; Z. Burucs and E. Paldi (1994). Feed value of forage maize hybrids varying in tolerance to plant density. Agron. J., 86: 799.

Roth, G.; D. Undersander; M. Allen; S. Ford; J. Harrison and C. Hunt (1995). Corn Silage Production, Management, and Feeding. ASA, Madison, WI. NCR574.

Roth, G.W. and A.J. Heinrichs (2001). Maize silage production and management. Agronomy fact-18. Published by Information and Communication Technology in the College of Agricultural Sciences, Pennsylvania State University.

Rotz, C.A.; L.M. Johnson and J.H. Harrison (1999). Economic of corn silage processing on North American dairy farms. Applied Engineering in Agriculture, 15(5): 411-421.

Russell, J.B. and D.B. Dombrowski (1980). Effect of PH on the efficiency of growth by pure culture of ruminal bacteria in continuous culture. Apple. Environs. Microbial., 39: 604.

Rutger, J.N., and L.V. Crowder (1967). Effect of High Plant Density on Silage and Grain Yields of Six Corn Hybrids. Crop Sci. 7:182–184.

Saif, U.; M. Maqsood; M. Farooq; S. Hussain and A. Habib (2003). Effect of Planting Patterns and Different Irrigation Levels on Yield and Yield Component of Maize (Zea Mays L.). International Journal of Agriculture and Biology. 1: 64-66.

Saruhan, V. and H.D. Sireli (2005). An InvestÕgatÕon on the Effect of Plant Densities and Nitrogen Doses on Ear, Stem and Leaf Yields of Maize (Zea mays L.). J.Agric.Fac.Hr.U., 9 (2): 45-53.

Shaver, R.D.; A.J. Nytes; L.D. Satter and N.A. Jorgensen (1986). Influence of amount of feed intake and forage physical form on digestion and passage of prebloom alfalfa hay in dairy cows. J. Dairy Sci., 69:1545.

Sparks, T.H. (1988). An Examination of the Effect of Plant Population on Dry Matter Yield in UK Variety Trials of Forage Maize. Plant Var. Seeds, 1:147-151.

Stanton, D.; A. Grombacher; R. Pinnisch; H. Mason and D. Spaner (2007). Hybrid and Population Density Affect Yield and Quality of Silage Maize in Central Alberta. Canadian journal of plant science. 87(4): 867-871.

Subedi, K.D.; B.L. Ma and D.L. Smith (2006). Response of a leafy and non-leafy maize hybrid to population densities and fertilizer nitrogen levels. Crop Sci., 46: 1860–1869.

Turgut, I.; A. Duman; U. Bilgili and E. Acikogoz (2005). Alternate row spacing and plant density effects on forage and dry matter yield of maize (Zea mays L). Journal of Agronomy and Crop Science, 191:12132.

Valdez, F.R.; J.H. Harrison and S.C. Fransen (1989). Effect of feeding silage of early and late maturity corn planted at two population densities to lactating dairy cows. Journal of Dairy Science, 72: 2081-2086.

Van der Linden, Y.; N. Van Gylswyk and H.M. Schwartz (1984). Influence of supplementation of corn stover with corn grain on the fibrolytic bacteria in the rumen of sheep and their relation to the intake and digestion of fiber. J. Anim. Sci., 59: 772-783.

Van Soest, P.J. (1994). Nutritional ecology of the ruminant. 2nd Edition, Cornell University Press, Ithaca, 476.

Van Soest, P.J. and W.C. Marcus (1964). A Method for the Determination of Cell-Wall Constituents of Forages Using Detergent and the Relationship Between this Frction and Voluntary Intake and Digestibility. J. Dairy Sci., 47: 704.

Van Soest, P.J.(1963). The Use of Detergents in the Analysis of Fibrous Feeds. II. A Rapid Method for the Determination of Fiber and Lignin. J. Assoc. Offic. Agr. Chemists, 46: 829.

Wang, Z. J.; H. C. Hao; W. K. Jun; D. S. Ting and L. Peng (2005). Effects of plant density on forage nutritive value of whole plant corn. Scientia Agricultura Sinica, 38: 1126-1131.

Warner, A.C.I. (1964). Production of volatile fatty acids in the rumen, method of measurements. Nut. Abst. and Rev., 34: 339.

West, J.W.; G.M. Hill; J.M. Fernandez; P. Mandebvu and B.G. Mullinix (1999). Effects of dietary fiber on intake, milk yield, and digestion by lactation dairy cows during cool or hot, humid weather. J. Dairy Sci., 82: 2455-2465.

Widdicombe, W.D. and K.D. Thelen (2002). Row Width and Plant Density Effect on Corn Forage Hybrids. Agronomy Journal. 94: 326-330.

Yandim, E. (2006). Ikinci Ürün Misurda (Zea mays L.) Bitki Sikhgmn Verim ve BazÕ Tarnmsal Karakterler Uzerine Etkisi. Yuzuncu Yil Universitesi Fen Bilimleri Enstitusu Tarla Bitkileri Anabilim Dali (Yayinlanmamis), Van, 27 p

Yilmaz, S.; H. Gozubenli; O. Knuskan and I. Atis (2007). Genotype and Plant Density Effects on Corn (Zea mays L.) Forage Yield. Asian J. Plant Sci,, 6(3): 538-541.

Zhang, W.; D. Li; L. Liu; J. Zang; Q. Duan; W. Yang and L. Zhang (2013). The effects of dietary fiber level on nutrient digestibility in growing pigs. Journal of Animal Science and Biotechnology, 4: 17.

التقييم الغذائي والاقتصادي لسيلاج الذرة المزروع بمعدل عشرين وثلاثين ألف نبات للفدان

صلاح كمال سيد[1] و شيرين محمد النحراوى[2]

[1] معهد بحوث الإنتاج الحيواني- مركز البحوث الزراعية- الدقي- الجيزة - مصر.

[2] معهد بحوث المحاصيل الحقلية- مركز البحوث الزراعية- الجيزة- مصر.

تم زراعة هجين الذرة فردى 10 بمعدل 20 و 30 ألف نبات للفدان وتم تقدير انتاجية محصول الذرة وأجزاء النبات (الكيزان والسيقان والأوراق) للفدان. تم حصاد نباتات الذرة الكاملة بعد 92 يومًا من الزراعة في طور النضج العجينى، وتم فرم الذرة إلى بطول 1-1.5 سم وتم حفظه في أكياس بلاستيك لمدة 35 يومًا. تم إجراء تجربتين هضم على الكباش الرحمانى لتقدير معاملات هضم العناصر الغذائية والقيم الغذائية. تم تحليل عينات من سيلاج الذرة لتقدير التركيب الكيماوى ومكونات الألياف وجودة السيلاج. أظهرت النتائج أن معدل الكثافة النباتية المرتفع أظهرمعنويا عند مستوى 0,05 أعلى انتاجية لمحصول الذرة الطازجة والمحصول الجاف والمركبات الكلية المهضومة والبروتين الخام والبروتين الخام المهضوم، بينما قل وزن النبات الطازج والجاف معنويا عند مستوى 0,01 مقارنة بالكثافة النباتية المنخفضة. زيادة النسبة المئوية للكيزان، بينما قلت نسب السيقان والأوراق معنويا عند مستوى 0,05 للكثافة النباتية المنخفضة مقارنة بالكثافة النباتية العالية. أظهرت كثافة نبات الذرة المنخفضة ارتفاع محتويات كل من المادة الجافة والمادة العضوية والمستخلص الخالى من الأزوت والكربوهيدرات غير التركيبية وانخفاض محتويات كل من البروتين الخام والرماد والألياف الخام ومكوناتها بالمقارنة مع كثافة نبات الذرة العالية. ارتفاع تركيزات الأحماض العضوية الكلية، اللاكتيك، البروبيونيك، الأيزوبوتيريك، الأيزوفاليريك والفاليريك ، بينما انخفضت قيمة الأس الهيدروجيني وتركيزات الأحماض الدهنية الطيارة، أحماض الأسيتيك والبيوتريك ونيتروجين الأمونيا في الكثافة النباتية المنخفضة مقارنة بالسيلاج عالي الكثافة النباتية. ارتفاع كمية المادة الجافة المأكولة ومعاملات هضم هضم كل من المادة الجافة والمادة العضوية والمستخلص الخالى من الأزوت والكربوهيدرات غير التركيبية ومحتوى المركبات الكلية المهضومة، بينما انخفضت معاملات هضم كل من البروتين الخام والألياف الخام ومكوناتها والمستخلص الاثيرى ومحتوى البروتين الخام المهضوم معنويا عند مستوى 0,05 لكثافة النباتية العالية مقارنة مع الكثافة النباتية المنخفضة. انخفاض قيمة الأس الهيدروجيني في الكرش وتركيز نيتروجين الأمونيا، بينما ارتفعت تركيزات الأحماض الدهنية الطيارة والبروبيونيك والأيزوبوتيريك والأيزوفاليريك والفاليريك مع كثافة نبات الذرة العالية بالمقارنة مع سيلاج الذرة منخفض الكثافة. بينما كانت تركيزات أحماض الأسيتيك والبيوتريك متماثلة تقريبا. لا توجد فروق ذات دلالة معنوية في تكلفة إيجار الأرض وتكلفة الزراعة والتكلفة الإجمالية بين الكثافة النباتية المنخفضة والعالية. فى حين سجلت الكثافة العالية لمحصول الذرة ارتفاعًا في إنتاجية السيلاج والعائد الاجمالى والصافى للسيلاج مقارنة بكثافة نبات الذرة المنخفضة.

نستخلص من هذه الدراسة أنه يجب زراعة محصول الذرة بغرض لصنع السيلاج بكثافة نباتية عالية تصل إلى 30 ألف نبتة للفدان للحصول على محصول مرتفع من السيلاج والمركبات المهضومة وكذلك زيادة العائد النقدى للفدان.