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Effects of different organic materials on forage production from sorghum x sudangrass hybrid (*Sorghum bicolor x sorghum bicolor var. sudanense)*

Recep Irfan NAZLI[a*], İlker INAL[b], Alpaslan KUSVURAN[c], Veyis TANSI[a]
[a] Cukurova University Agriculture Faculty Field Crops Department, Adana Turkey
[b] Eastern Mediterranean Agricultural Institute, Adana, Turkey
[c] Cankiri Karatekin University Kizilirmak Vocational School, Cankiri, Turkey
Corresponding author:inazli@cu.edu.tr

Abstract

This study was conducted to investigate effects of three organic materials (poultry litter, cattle manure and leonardite) on forage production from sorghum x sudangrass hydrid under Cukurova conditions during the growing seasons of 2010 and 2011. Field trial was established at the experimental area of the Field Crops Department of Cukurova University (37°01'N, 35°18'E) according to randomized complete block design with three replications. The 8 different treatments used were; recommended inorganic fertilizer dose (INORG), poultry litter applied to meet crop P requirement and with supplemented inorganic nitrogen (PL-P+N), poultry litter applied to meet crop N requirement (PL-N), cattle manure applied to meet crop P requirement and supplemented with inorganic nitrogen (CM-P+N), cattle manure applied to meet crop N requirement (CM-N), 500 kg/ha leonardite plus 100% of recommended inorganic fertilizer dose (LEO-100), 500 kg/ha leonardite plus 75% of recommended inorganic fertilizer dose (LEO-75), 500 kg/ha leonardite plus 50% of recommended inorganic fertilizer dose (LEO-50). Green herbage and crude protein yields were studied in the study. According to results, green herbage yield (GHY) of sorghum x sudangrass hydrid ranged from 83126 to 58610 and 62740 to 36072 kg ha^{-1} in 2010 and 2011, respectively. The highest GHY values were provided by LEO-100 in both years whereas the lowest values were observed in PL-N and CM-N in 2010 and 2011, respectively. On the other hand, crude protein yield (CPY) of sorghum x sudangrass hydrid ranged from 1437 to 954 and 1193 to 626 kg ha^{-1} in 2010 and 2011, respectively. While the highest CPY (1437 kg ha^{-1}) was obtained from LEO-50 in 2010, LEO-100 gave the highest value (1193 kg ha^{-1}) in 2011. Combined use of leonardite and poultry litter with inorganic fertilizer produced similar GHY and CPY to INORG whereas N-based treatments significantly decreased both GHY and CPY of the crop.

Key words: Sorghum x sudangrass hybrid, organic material, poultry litter, cattle manure, leonardite

Farklı organik materyallerin sorgum x sudanotu melezinden (*Sorghum bicolor x sorghum bicolor var.sudanense*) yem üretimi üzerine etkileri

Özet

Bu araştırma Çukurova koşullarında 3 farklı organik materyalin (tavuk gübresi, sığır gübresi, leonardit) sorgum x sudanotu melezi bitkisinden yem üretimine etkilerini araştırmak amacıyla 2010 ve 2011 yıllarında yürütülmüştür. Tarla denemesi tesadüf blokları deneme desenine göre üç tekrarlamalı olarak Çukurova üniversitesi Tarla Bitkileri Araştırma ve Uygulama alanında kurulmuştur. Çalışmada, tavsiye edilen miktarda inorganik gübre dozu (INORG), Bitkinin fosfor ihtiyacını karşılamaya yönelik tavuk gübresi uygulaması + ilave inorganik azot (PL-P+N), Bitkinin azot ihtiyacını karşılamaya yönelik tavuk gübresi uygulaması (PL-N), Bitkinin fosfor ihtiyacını karşılamaya yönelik sığır gübresi uygulaması + ilave inorganik azot (CM-P+N), Bitkinin azot ihtiyacını karşılamaya yönelik sığır gübresi uygulaması (CM-N), 500 kg/ha leonardit + tavsiye edilen miktarda inorganik gübre dozunun %100'ü (LEO-100), 500 kg/ha leonardit + tavsiye edilen miktarda inorganik gübre dozunun %75'i (LEO-75), 500 kg/ha leonardit + tavsiye edilen miktarda inorganik gübre dozunun %50'si (LEO-50) olmak üzere 8 farklı uygulama kullanılmıştır. Çalışmada, uygulamaların bitkinin yeşil ot ve ham protein verimleri üzerine etkileri incelenmiştir. Elde edilen sonuçlara göre, sorgum x sudanotu melezinin yeşil ot verimi (GHY) 2010 yılında 58610-83126 kg ha^{-1}, 2011 yılında ise 36072-62740 kg ha^{-1} arasında değişmiştir. Her iki yılda da en yüksek yeşil ot verimi değerleri LEO-100 uygulamasından elde edilmiş olup, en düşük değerler ise 2010 yılında PL-N uygulamasından, 2011 yılında CM-N uygulamasından elde edilmiştir. Diğer taraftan, sorgum x sudanotu melezinin ham protein verimi (CPY) 2010 ve 2011 yıllarında sırasıyla 954-1437 ve 626-1193 kg ha^{-1} arasında değişmiştir. 2010 yılında en yüksek ham protein verimi (1437 kg ha^{-1}) LEO-50 uygulamasından elde edilirken, 2011 yılında LEO-100 uygulaması en yüksek ham protein verimini (1193 kg ha^{-1}) sağlamıştır. Leonardit ve tavuk gübresinin inorganik gübre ile birlikte kullanımı INORG uygulaması ile benzer yeşil ot ve ham protein verimleri sağlamışken, bitkinin azot ihtiyacına dayalı uygulamalar yeşil ot ve ham protein verimleri bitkinin hem yeşil ot hem de ham protein verimlerini azaltmıştır.

Anahtar kelimeler: Sorgum x sudanotu melezi, organik materyal, tavuk gübresi, sığır gübresi, leonardit

Introduction

Inorganic or chemical fertilizers are the most used plant nutrient sources around the world which provide macro and micronutrients at different quantities and they made great contribution on agricultural production in the last century due to their positive effects on crop yield. However, excessive application of them led to health problems, deterioration in soil structure and environmental pollution, especially of freshwater springs in the worldwide (Kang & Juo 1980; Ayoola & Adeniyan 2006; Khan et al. 2008; Sonmez et al. 2008; Yolcu et al. 2011).

Therefore, considerable interest has been generated regarding the use of organic materials on agricultural lands for restoring soil fertility and sustainability and for preventing potential environmental problems such as water quality degradation, air pollution through N gas emissions, odors, and dispersal of pathogenic organisms caused by the overuse of inorganic fertilizers (Edwards and Daniel, 1992; Chadwick et al., 2000; Barton and Schipper, 2001; Phongpan and Mosier, 2003; Sharpe et al., 2004). Moreover, organic materials provide the macro and microelements required by plants (fore-most N, but also P, K, Ca, Mg, Cu, Na, Fe, Mn, and Zn) in different quantities, and thereby can generate a positive residual effect that should be taken into account when planning the next crop (Edwards and Daniel, 1992; Eghball et al., 2004; Hirzel and Walter, 2008). Poultry litter, cattle manure, biosolids, crop residues, swine sludge, green manure and humic substances may be considered as the main organic materials currently used in agricultural production. Cattle manure and poultry litter are the likely most-utilized organic materials around the world due to steadily developing poultry and livestock industries which have been successfully used as sole or combination with inorganic fertilizers on cultivation of numerous cash crops, including maize, cotton, soybean, sorghum, pasture so far (Kingery et al. 1993; Moss et al. 2001; Adeli et al. 2005; Adeli et al. 2007; Ghosh 2007; Mosquera et al. 2008).

Leonardite is a very concentrated form of humic and fulvic acids which are usually used in agricultural production and are widely known as having agronomic potential (Ece et al. 2007). Humic substances (humic and fulvic acids), which are the major components of soil organic matter, are mostly used to eliminate the adverse effects of chemical fertilizers and decrease soil pH (Chen and Aviad, 1990; Akıncı et al.,2009; Katkat et al., 2009). Several studies showed that the application of leonardite along with adequate mineral fertilizer enhances soil organic matter and crop production (Akinremi et al. 2000; Ece et al. 2007; Demir et al. 2012; Sanli et al. 2013; Nazli et al., 2014).

Sorghum x sudangrass (*Sorghum bicolor x sorghum bicolor var. sudanense*), the hybrid of sorghum (*Sorghum bicolor* L.) and sudangrass (*Sorghum sudanense* L.) is a high yielding, rapid growing and drought tolerant forage crop providing a year round supply of nutritious forage for livestock consumption (Fribourg 1995). It is projected that sorghum x sudangrass hybrid will be preferred further as a summer forage crop in most regions of the world due to global warming increasing gradually (Chaudhuri et al. 1986; Uzun et al. 2009). However, there has been limited knowledge concerning organic material effects on sorghum x sudangrass hybrid cultivation in peer-reviewed literature. Therefore, further research is needed to clarify which fertilization regime should be chosen to achieve optimum forage yield.

The objective of this study was to determine the effects of three organic materials on forage production from sorghum x sudangrass hybrid.

Material and Method

The experiment was conducted at the experimental area of the Agricultural Faculty of Cukurova University during the 2010 and 2011 growing seasons in Adana (37° 01' N, 35° 18' E), Turkey. The region is under Mediterranean climate conditions, with high temperatures and low rainfall during the summer and low temperatures and high rainfall during the winter (Table 1).

Table 1. Weather data of the location in 2010, 2011 and long-term average (1970-2011) at Adana, Turkey.

	Mean Temperature (°C)			Total Precipitation (mm)			Mean Relative Humidity (%)		
	2010	2011	Long-term	2010	2011	Long-term	2010	2011	Long-term
January	11.3	10.1	9.6	113.9	76.5	101.6	77.6	64.0	65.2
February	12.3	10.9	10.5	67.6	92.4	83.3	71.0	62.3	64.9
March	15.6	13.5	13.6	14.8	107.0	60.2	68.9	64.6	66.2
April	18.6	16.6	17.6	89.3	78.3	57.7	68.7	66.3	67.5
May	22.4	21.4	21.8	56.6	105.6	42.5	74.4	64.1	66.8
June	26.1	25.6	25.7	0	0	18.5	71.2	66.2	67.3
July	28.5	28.6	28.2	0	0	8.6	76.9	67.2	70.6
August	30.8	29.5	28.5	0	0	6.2	74.8	62.8	70.6
September	28.3	27.3	26.1	0	0	14.6	73.6	60.4	65.3
October	22.2	20.8	21.6	30.8	4.1	44.5	70.0	47.9	61.4
November	18.2	12.4	15.3	94.5	34.5	78.4	63.5	53.8	64.1
December	12.7	10.0	10.9	194.5	156.4	121.2	73.9	66.4	67.2
Total	-	-	-	662.0	654.8	637.3	-	-	-
Average	20.6	18.9	19.1	-	-	-	72.0	62.2	66.4

Table 2. Nutrient and chemical composition of organic materials used in the study

Property	Poultry Litter	Cattle Manure	Leonardite
Organic Matter (%)	53,1	24,2	70,84
Salt (mmhos/cm)	7,36	5,55	1,41
pH	7,81	7,97	3,88
Moisture (%)	12,2	12,5	22,83
Total N (%)	2,05	1,55	0,97
Total P (%)	2,06	0,62	0,14
Total K (%)	0,86	0,62	0,1

Table 3. Initial chemical and physical properties of the soil

Property	Depth (15 cm)
Sand (%)	43,6
Clay (%)	31,6
Silt (%)	24,5
Organic matter (%)	1,59
pH	7,65
Salt (mmhos/cm)	0,28
Lime (%)	31,05
Available P (kg ha^{-1})	50
Available K (kg ha^{-1})	95,12

The trial area was cultivated two times in early autumn and late winter by rotary plow in both years and the soil was prepared with conventional tilling equipment to form an acceptable seedbed. No herbicide was applied before sowing; weed control was carried out by hand hoeing during study period.

Three kinds of organic materials were used in the present study, these are; poultry litter, cattle manure and leonardite. Nutrient and chemical composition of organic materials used in the experiment are presented in Table 2. Fertilizer treatments used in the trial were a recommended inorganic fertilizer dose (INORG), poultry litter applied to meet crop P requirement and with supplemented inorganic nitrogen (PL-P+N), poultry litter applied to meet crop N requirement (PL-N), cattle manure applied to meet crop P requirement and supplemented with inorganic nitrogen (CM-P+N), cattle manure applied to meet crop N requirement (CM-N), 500 kg/ha leonardite plus 100% of recommended inorganic fertilizer dose (LEO-100), 500 kg/ha leonardite plus 75% of recommended inorganic fertilizer dose (LEO-75), 500 kg/ha leonardite plus 50% of recommended inorganic fertilizer dose (LEO-50). The recommended inorganic fertilizer rate for the region is 100 kg/ha P, 100 kg/ha K, 200 kg/ha N.

The experiment was established according to complete randomized block design with 8 treatments and 3 replications. The size of each plot was 21 m^2 (4.2 × 5 m) and inter-row spacing and distances between the rows were 10 and 70 cm, respectively. Variance and correlation analyses were carried out using JMP 5.1 (SAS Institute Inc.) and a least significant differences (LSD) test was used to test the differences among means.

Leonardite (LEO) was considered as a soil amendment rather than an organic fertilizer in the present study because of its low N, P, and K contents, which were not taken into consideration for fertilization rates. Potassium (K) fertilizer was not applied since the soil was rich in K (Table 2). The soil at the site has a sandy clay loam texture and a low organic matter content of 1.59% (Table 3). Soil samples were taken to determine fertilizer needs for each plot at the beginning of each season. The amount of poultry litter (PL) and cattle manure (CM) applied to meet the P requirement was based on soil P, crop P requirement (100 kg ha), and litter or manure P content. On the plots where PL and CM were applied to meet N requirements, crop N requirement (200 kg ha^{-1}) and N content of the litter or manure were considered. Soil N content was not taken into account because only 1–2% of total N content of soil is in a readily available form to plants; therefore, it is not reliable data for fertilization recommendations (Liu et al. 2003; Liang et al. 2005; Bao et al. 2006). Organic materials were broadcasted to the plots 1 day before sowing by hand and incorporated immediately into the soil using a rototiller. Sorghum x sudangrass hybrid was sown in 14 May and 3 June, in 2010 and 2011, respectively. The late sowing was because of unexpected heavy rainfall in May 2011. The plants were harvested at 4 cuts in both years of the field trial at boot to early heading stage. All of the P and 1/2 of the N fertilizers were applied 1 day before sowing and the rest of the nitrogen was given in 3 parts after each cut in the form of ammonium-nitrate, (33% N) for the INORG, LEO-100, LEO-50 and LEO-75 treatments. In the PL-P and CM-P treatments, the P was applied 1 day before sowing in the form of poultry litter or cattle manure and the supplementary inorganic nitrogen was given in 3 parts after each cut in the form of ammonium-nitrate, (33% N). Supplemental inorganic nitrogen was never applied in the N-based treatments (PL-N and CM-N). The water supply required for the growing of sorghum x sudangrass hybrid was fulfilled by irrigation because of inadequate precipitation during the growing season (May–October).

In order to form a composite sample to determine crude protein content and dry matter percentage, 10 plants were collected randomly from each plot, chopped, oven dried at 70 °C for 48 h, and finally ground to pass through a 1-mm screen. Samples were scanned with a near-infrared scanning monochromator (NIRSystems, Silver Spring, MD, USA) and prediction equations were developed for nitrogen (N) content of all samples using near-infrared reflectance spectroscopy (NIRS). The NIRS was calibrated using a software program coded IC-0904FE. Four rows in the center of each plot were harvested by cutting at a height of 15 cm and were weight to determine green herbage yield (GHY). Crude protein yield (CPY) was calculated by multiplying dry matter yield and crude protein content.

Table 4. Results of traits determined by analysis of variance

Source of Variance	DF	GHY	CPY
Year (Y)	1	**	**
Treatment (T)	7	**	**
Y X T	7	ns	ns
CV (%)		10,13	13,95

**P<0.01, ns: not significant

Results

As shown in Table 4 treatments had significant effect on green herbage yield (GHY) of the sorgum x sudangrass hybrid . Over both years, GHY of the crop ranged from 36072 (CM-N, 2011) to 83126 kg ha^{-1} (LEO-100, 2010) (Table 5). Taking all data of the first and second years, significant differences were determined between growing seasons and mean GHY were found as 71330 and 49376 kg ha^{-1}, respectively. According to data derived from the study, while highest GHY values (83126 and 62740 kg ha^{-1} for 2010 and 2011, respectively) were provided by LEO-100 during growing period the lowest values were observed in PL-N (58610 kg ha^{-1}) and CM-N (36072 kg ha^{-1}) in 2010 and 2011, respectively. On the other hand, LEO-75, LEO-50 and PL-P+N treatments produced the similar GHY to INORG and LEO-100.

Significant differences were reported among the fertilization treatments for crude protein yield (CPY) of sorghum x sudangrass hybrid, ranging from 626 (CM-N in 2011) to 1437 (LEO-50 in 2010) (Table 4 and 5). Significant differences were observed between growing seasons, and average CPY results were 1217 and 875 kg ha^{-1}, for 2010 and 2011, respectively. The highest CPY values were obtained from LEO-50 (1437 kg ha^{-1}) and LEO-100 (1193 kg ha^{-1}) in the first and second years, respectively. On the other hand, the lowest CPY values were observed in PL-N (954 kg ha^{-1}) and CM-N (626 kg ha^{-1}) for 2010 and 2011, respectively. Poultry litter and cattle manure applications with additional inorganic nitrogen (PL-P+N and CM-P+N) and leonardite applications with lower nutrient supply (LEO-75 and LEO-50) produced the similar CPY to INORG.

Discussion

It is obvious from the study that GHY of the sorghum x sudangrass hybrid in the second year was significantly lower than that in the first year. Yield differences between growing seasons probably caused by late sowing. Negative effect of late sowing was also reported in several crops (sorghum x sudangrass hybrid, sweet sorghum, peanut and fababean) by previous researches (Fontaneli et al. 2001; Naab et al. 2005; Almodares & Darany 2006; Barker & Dennett 2013). According to results, combined use of organic materials with inorganic fertilizer had no adverse effect on GHY and CPY of sorghum x sudangrass hybrid. The leonardite treatments (LEO-100, LEO-75 and LEO-50) and poultry litter treatment based on P requirement of the crop with supplemented inorganic nitrogen (PL-P+N) produced the similar GHY and CPY to INORG. LEO-100 did not increase GHY despite it gave the highest values in both years and this results are conflict with the finding of Ece et al., (2007), Demir et al., (2012) and Nazli et al., (2014) in which combined use of leonardite with complete supply of recommended nutrient supply provided remarkable increase on yield of climbing bean, potato and silage maize. Other leaonaridte treatments (LEO-75 and LEO-50) gave the similar GHY to INORG in spite of lower nutrient supply. This might be due to favorable contributions of humic substance on soil fertility and nutrient availability. The humic substances are mostly used to remove or decrease the negative effects of chemical fertilizers from the soil and increase availability of nutrient elements by holding the them on mineral surfaces and converting them into forms available to plants, which eventually leads to a greater uptake of nutrients into the plant root and through the cell membrane (Linchan 1978; Pal & Sengupta 1985; Stevenson 1994; Lobartini et al. 1997; Ghabbour & Davies 2001; Tipping 2002; Kulikova et al. 2005; Akinci et al. 2009). Similar to our results, Ece et al., (2007) and Demir et al., (2012) also concluded that leonardite applications with lower nutrient supply produced comparable yield results to conventional fertilization in climbing bean and potato.

Despite lower nutrient supply in readily available form to plants, P-based application of poultry litter with supplemental inorganic nitrogen (PL-P+N) also produced similar GHY and CPY to INORG, perhaps due to the residual and soil amelioration effects of these materials as reported by different authors (Eghball et al., 2004; Adeli et al., 2007; Hirzel et al., 2007a). In addition, PL is a useful organic amendment that helps to recycle nutrients, improves soil quality, and leaves a positive residual effect on soil. The results of this study are in agreement with the finding of Sleugh et al., (2006) and Nazli et al., (2014) in which P-based application of poultry litter with supplemental inorganic nitrogen resulted in similar yield results in sorghum x sudangrass hybrid and silage maize.

Table 5. Effects of fertilization treatments on green herbage and crude protein yields of sorghum x sudangrass hybrid.

Treatments	GHY(kg ha^{-1})		CPY(kg ha^{-1})	
	2010	2011	2010	2011
PL-P+N	72008^{ab}	53096^{a-c}	1396^{a}	895^{bc}
CM-P+N	65863^{bc}	43215^{cd}	1089^{b-d}	762^{bc}
PL-N	58610^{c}	42739^{cd}	954^{d}	781^{bc}
CM-N	63141^{bc}	36072^{d}	996^{cd}	626^{c}
LEO-100	83126^{a}	62740^{a}	1375^{ab}	1193^{a}
LEO-75	71921^{ab}	50235^{a-d}	1206^{a-d}	790^{bc}
LEO-50	73640^{ab}	47501^{b-d}	1437^{a}	965^{ab}
INORG	82089^{a}	59406^{ab}	1281^{a-c}	988^{ab}
MEAN	71330^{a}	49376^{b}	1217^{a}	875^{b}
LSD (%5)	**	*	*	*

**: P<0.01, * P<0.05, means followed by the same letters are not significantly different at the 5% level of significance.

It is clearly seen in Table 5, N-based applications of PL and CM significantly decreased both GHY and CPY, presumably due to nitrogen deficiency caused by the lower nitrogen availability of PL and CM and the absence of supplemental inorganic nitrogen. The estimated N availability of PL was 55% in the first year and 36% in the second year, while the N availability of CM was 40% in the first year and 18% in the second year in previous studies (Eghball and Power, 1999; Hirzel et al., 2007b). Similar yield decrease caused by N-based applications of PL and CM was also determined in silage maize (Nazli et al., 2014). In addition, different authors (Kingery et al., 1994; Whittington, 2007; Codling,

2008) suggested that the application of organic materials based on the N requirements of crops must be avoided due to their negative effects on soil fertility and the environment due to the accumulation of soil phosphorus and metal ions.

Conclusion

Leonardite applications with lower nutrient supply (LEO-75 and LEO-50) and poultry litter application based on P requirement with supplemental inorganic nitrogen (PL-P+N) produced the similar GHY and CPY to conventional fertilization treatment (INORG), indicating that these treatments may be used in sorghum x sudangrass hybrid cultivation to decrease fertilization cost.

On the other hand, N-based napplications of PL and CM is not suitable fertilization regimes for cultivation of sorghum x sudangrass hybrid because these treatments (PL-N and CM-N) negatively affected forage production from the crop, probably due to their estimated lower nutrient availability.

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