FINAL REPORT

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Nutrient Optimization for Sustainable Goat Production Systems in the Southeastern USA

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I- Summary

A year-round grazing is feasible in Alabama and Southern USA through utilization of cool- and warm-season forages. This can be achieved by allowing for as much grazing as possible throughout the year. Producers should select a combination of forages with different growth cycles that will best support the objectives of their operation. A series of experiments were conducted at the Caprine Research and Education Unit in George Washigton Carver Agricultural Experiment Station in Tuskegee University (Table 1; Figures 1 and 2) to develop and demonstrate a profitable and sustainable year-round forage based production system with sunn hemp, forage soybean or Bermudagrass system in the summer-fall, and annual ryegrass (**RG**) or RG + legume (Australian pea (**AP**), berseem clover (**BC**), and hairy vetch (**HV**)) pastures in the winter for goat production for the Southeastern U.S. during the last 3 years. The results indicated that animals on sunn hemp (as a summer forage) or RG + BC combination (as a winter forage) grew 18-44% faster ($P<0.05$) and reached expected slaughter weight in less time when compared to RG or Bermudagrass pasture systems, respectively. The sunn hemp in the summer and fall and the RG+ BC for winter and spring grazing systems were the most productive with regards to biomass production. Goats grazing RG+BC and RG+ HV+AP in March, April and May 2011 had higher ($P<0.05$) body weights and carcass weights than other forage combinations. This is probably due to higher nutritive values of forage diets throughout the year (Table 1). The soils contained significantly higher percent of OM, N, Ca, Mg, Fe, Al and S in the RG + BC clover systems compared to other treatments. Raising goats on sunn hemp was the least expensive system in terms of inputs required and seems profitable. The RG + BC or RG + HV system were also comparatively better than the traditional pasture system. The Bermudagrass pasture system was found to be the least sustainable because of the need for higher amounts of supplemental feeds and anthelmintics. We feel that using proper legume forages for the winter grazing followed by summer forages can provide for profitable year-round foraging system. However, combination of forages used for grazing should be selected to optimize animal performance, enhance soil property and reduce environmental impacts from animals while reducing dependency on petrochemical fertilizers. We believe that the combination of sunn hemp, BC and HV will increase protein outputs as well as restore N in soil, thus reducing dependency on petroleum-based fertilizers. Goats grazed on grass-based diets had higher saturated fatty acids (SFA) and polyunsaturated fatty acids (PUFA) in intramuscular fats ($P < 0.01$), but were lower in mescenteric kidney fat (MKF) and subcutaneous fat ($P < 0.05$-0.01) compared to legume forage-based diets (Tables 4, 5, and 6). Goats grazed on grasses-based diet, omega-3 and -6 fatty acids were higher in intramuscular fat content ($P < 0.05$-0.08), but were lower in subcutaneous fat ($P < 0.05$-0.01) compared to legume forage-based diets. Mono unsaturated fatty acids (MFA) were not affected by diets. These results indicated that goats receiving legume forage-based diets produced carcasses with more PUFA and higher omega-3 and -6 fatty acids in sub-cutaneous fat from Kiko-crossbred male goats. Soil quality in RW+ BC was significantly higher for the OM (%), Nitrate-N, base Ca, Ca, Mg, Fe, Al and S than for the

other treatments. Soil pH was higher for the RW+AP than for the other combinations. Soil mineral contents in RW+AP+HV+BC were higher for the P, Zn, and Mn contents. There was no significant difference between forage combination treatments for Mg (base), K and Cu contents. Soil mineral content in RW was the low level compared to other forage combinations, except Mn content. These results indicated that RW+AP or RW + AP + HV + BC legume forage combinations could be more beneficial to growing goats and provide sufficient nutrients for goats to maintain optimum weight gain in grazing animals. For the soil quality, RW + BC combination could be beneficial to soil improvement, but forage biomass production, animal performance and soil mineral contents were lower for RW pastures as compared to others.

1. Suggested grazing and rotational management:

Pasture | **Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.**

A Graze W/R+BC → ← Graze sunn hemp or soybean pasture → W/R+BC overseeded →

B Graze overseeded Wheat and rye (W/R) → Graze or clip hay from overseeded W/R → Graze and clip hay from summer forages (Sunn hemp/soybean) → W/R+BC overseeded →

C Holding pasture for hay feeding → Graze and clip hay → Graze frosted forages →

- W/R = wheat and rye grasses; BC= Berseem clover

2. Grazing Summary

Jan. – May Rotate between A, B

May – Oct. Rotate among A, B, C

Oct. – Nov. Rotate between B, C
Nov. – Dec. Graze C or hay supplementation

II. Objectives/Performance Targets:

1. To determine pasture quality changes using multi-culture grasses, and grasses in combination with legumes;
2. To determine animal health, performance and carcass quality of goats when browse is incorporated in the feeding system and when grazing multi-culture grasses, and grasses in combination with legumes;
3. To determine soil quality changes using multi-culture grasses, and grasses in combination with legumes;
4. To identify and assess economic characteristics and optimum economic return of different goat production (grazing/browsing) systems;
5. To evaluate adaptability (on an experiment station with goats) and demonstrate applicability (on three small farms) of an integrated year round forage system using commercial goats, pure bred goats, and goats co-foraging with cattle.

III. Accomplishments/Milestones

Objective 1. Determine pasture quality changes using multi-culture grasses, and grasses in combination with legumes

For this objective, 6 forage combinations (grasses/legumes), for winter gazing were planted in duplicates on 12 pasture paddocks of 0.5 acres each during 2011 and 2012, and has been successfully completed. Six different forage combinations were shown in Table 1. However, grazing Exp. for summer forages have not been conducted because of severe drought. Therefore, we changed our forage species with drought resistance summer forage in year 2013.

New forage legume Sunn hemp (*Crotalaria juncea* L) grows well during drought and on marginal soils with a pH between 5.0 and 7.5. Sunn hemp is an excellent choice for a summer cover crop for Southern USA because it returns nitrogen to the soil, suppresses weeds and nematodes, improves soil tilt and water holding capacity, and reduces erosion in fields otherwise left without plant cover. Sunn hemp forms a symbiotic relationship with soil bacteria that remove nitrogen (N) gas from the atmosphere and transforms N to plant-available forms.

Data Collection

Forage mass (kg DM/ha), botanical composition and forage chemical composition were measured from February to May for winter forages and May to August for summer forages in 2011 and 2012 (Figure 1). On each occasion four random quadrates (0.25 m^2) per paddock were cut using a hand-clipper for biomass. The forage samples were then oven-dried at 90 ^oC for 18 h, and weighed. For laboratory analysis, four quadrates of herbage on offer were cut to ground level from each paddock. Samples were combined for each paddock, mixed, and divided, with the first part used for botanical composition assessments and the second part for chemical analysis.

Table 1. The average biomass production (kg DM/ha?) and average daily gain (ADG) in multi-forage system grazing in goats.

Item	N[1]	Forage biomass	ADG (g/d)	Carcass weight (kg)
1. Winter forage system				
Rye grass (RG)	12	946	200	12.2
RG + Berseem clover (BC)	12	1049	245	11.6
RG+Australian pea (AP)	12	1179	195	11.8
RG+Hairy vetch (HV)	12	1091	195	10.2
RG+ AP + HV	12	1058	213	12.6
RG + AP+ HV + BC	12	1127	217	10.5
2. Summer forage system				
Sunn hemp	16	3700	169	-
Forage soybean	12	3144	102	-
Bermuda grass	12	1689	93	-

N = number of animals. Three replications per treatment.

Year-round multi-cultural forage system

1. Winter-spring forage system



(1) RG + Berseem Clover (BC) (2) RG+ Australian pea (AP) (3) RW + AP+ Hairy vetch (HV)



(4) RG+AP+HV+BC (5) RG + HV (6) RG

(2) Summer-fall grazing system



(7) Sunn hemp (8) Pasture soybean (9) Bermudagrass

Figure 1. Year-round multi-cultural forage system, Tuskegee, AL. Annual rye grass (RG) + Berseem clover (BC), (2) RG + Australian pea (AP), (3) RG + Hairy vetch (HV) + AP, (4) RG + HV + AP + BC, (5) RG + HV, and (6) annual rye grass (RG), (7) Sunn hemp, (8) Pasture soybean, and (9) Bermudagrass.

Statistical analysis

All data were analyzed as repeated measure with production system included in the model as a fixed effect using the Proc GLM procedure of SAS (SAS Inst. Inc., Carry, NC). Differences among means, for all analysis, were determined by least square means procedure with the protected F-test ($P < 0.05$).

Results

Forage biomass changes

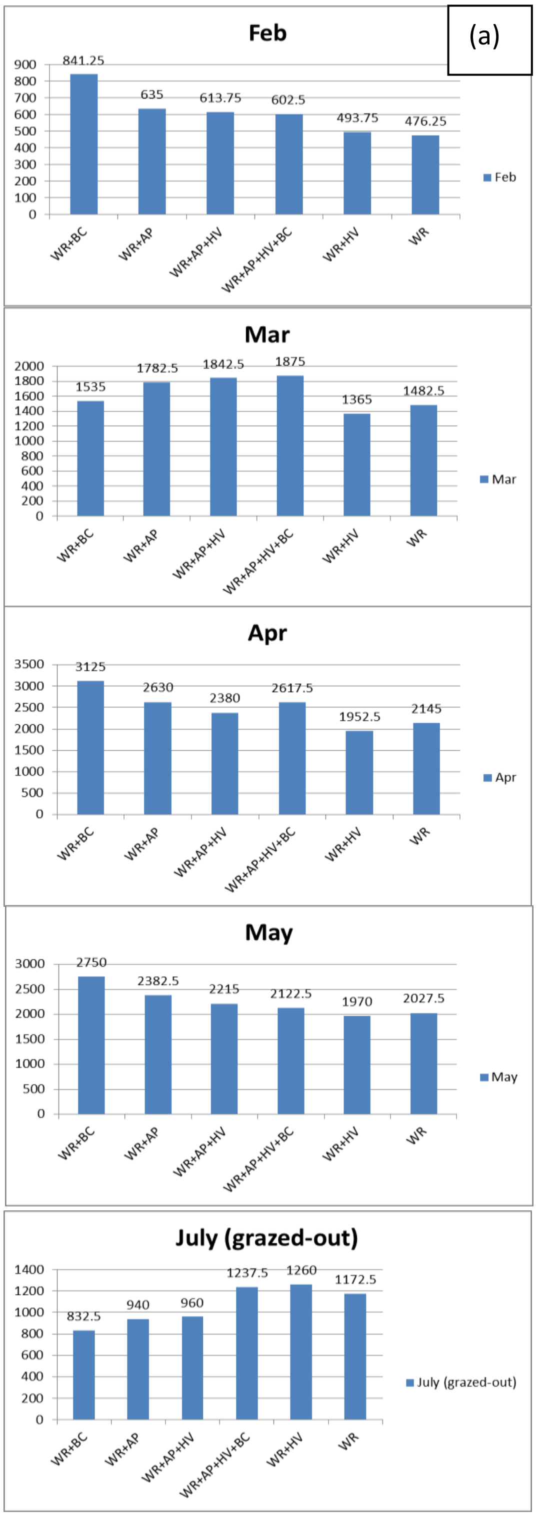
Winter forage biomass production

The benefit of using multiple species on the same pasture comes from the fact that different animals have different plant preferences. Forage dry matter production is presented in Figures 2 and 3. Multi-culture forage dry matter (DM) production (Figures 2a,b) in February, April and May 2011 was higher for RW+ BC than other forage combinations (Fig. 2 b). However, forage DM production in March was significantly different in the following order: RW + AP + HV + BC > RW + AP + HV > RW + AP > RW + BC > RW+ HV and RW combinations ($P < 0.01$; Figure 2a). In July, we measured voluntary forage re-growth after grazing period was over and paddocks were cleared for hay production. As indicated in Figure 2, RW, RW+HV and RW+AP+BC+HV combinations produced highest DM production than others. Average forage DM production was lower ($P < 0.01$) for WR or WR + HV than other combination groups for winter grazing; however, RW + HV sustained forage production with high re-growth after harvest biomass in July. It should be noted that this biomass was made of different summer weeds also that are very desirable for goats.

However, multi-culture forage dry matter (DM) production (Figures 3) in February and March 2012 was higher for RW+AP and RW + AP + HV + BC than other forage combinations. In addition,, forage DM production in RW was significantly lower than other combinations.

Summer forage biomass production

Multi-culture forage dry matter (DM) production (Figures 4a, b) in May to July 2013 was higher (P<0.05) for sunn hemp (3500-4000 kg DM/ha) than other forages (forage soybean; 3200 kg DM/ha) and Bermuda grass; 1500 kg DM/ha). In addition, forage DM production in Bermuda grass was significantly lower (P<0.01) than other forages.



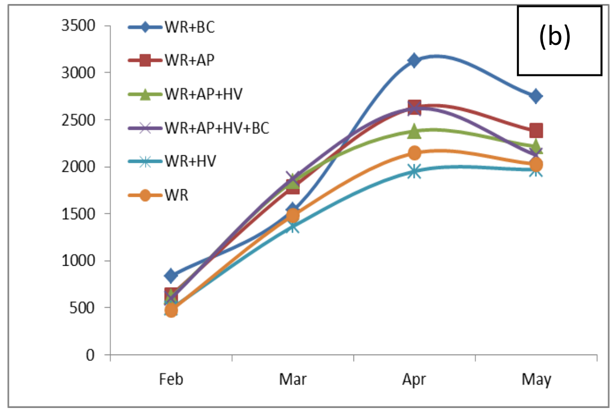


Figure 2. Winter forage biomass production (DM/kg) with multi-grasses with legumes combinations in each month (a) and average (b), 2011, and voluntary summer forage production.

RW= Rye and wheat; AP = Australian pea; HV = hairy vetch; BC = Berseem clover

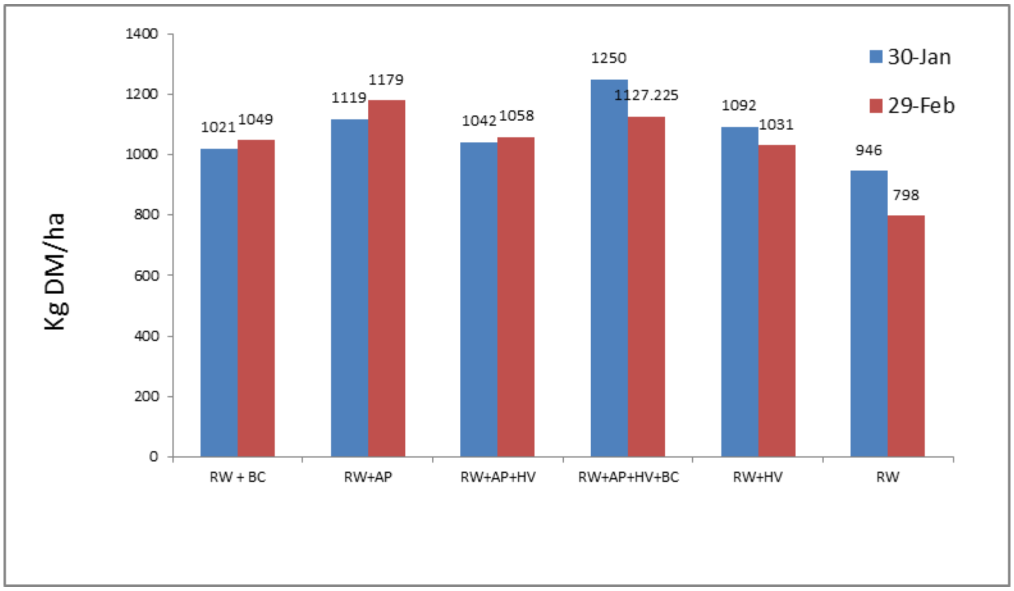


Figure 3. Winter forage biomass production (DM/kg/ha) with multi-grasses with legumes combinations, 2012. RW= Rye and wheat; AP = Australian pea; HV = hairy vetch; BC = Berseem clover

Forage chemical composition

Winter forage chemical composition of multi-cultural forage system is presented in Tables 2 and Figure 4a,b. There was a forage sampling time x multi-forage combination interaction ($P < 0.01$) for CP and NDF (Figure 5). Forage CP content was higher in March than February and April, but DM and NDF content continuously increased with time. The data indicated that plant maturity and forage growth are important factors affecting forage quality and forage DM production. Interestingly, RW + HV combinations continued to have greater CP content until April and then decreased gradually with time. However, fiber content (NDF) was constant until April and then increased. It is important to point-out that HV is locally available legume forage and has better survival rate in hot temperature (April to May) than the other introduced legume forages (e.g. BC or AP; Figure 4). The soluble protein, P, K, Na, Cl, Fe, Cu, Zn contents remained similar with varying species of legume forage combination (Table 2), but CP, ADF, NDF, crude fat, ash, Ca, Mg, S, Mn, and lycine were varied. For summer forages, sunn hemp contained higher CP (23.9%) content than forage soy bean (16.3%) and Bermuda grass (7.3%) forages (Table 3).

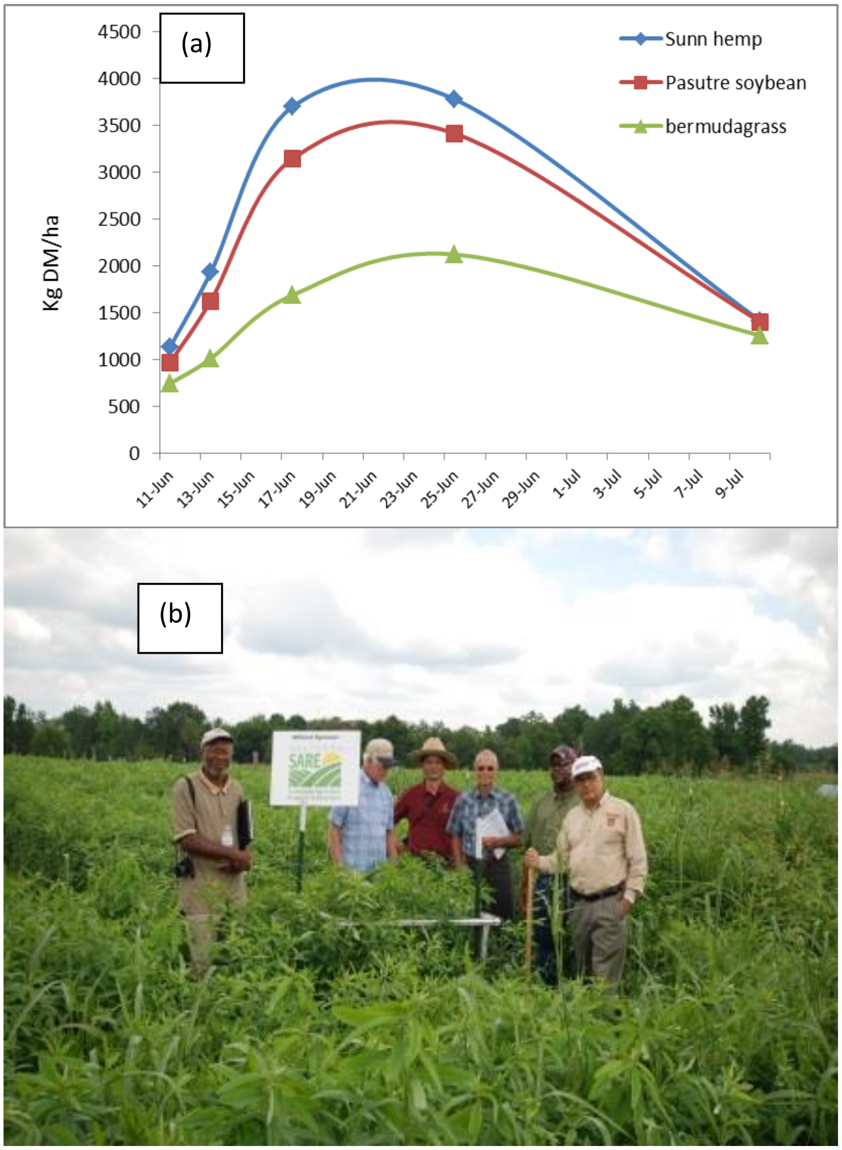


Figure 4. SARE summer forage biomass production (a; DM/kg/ha) and sunn hemp forage picture with minority farmers, Tuskegee University, June 2013.

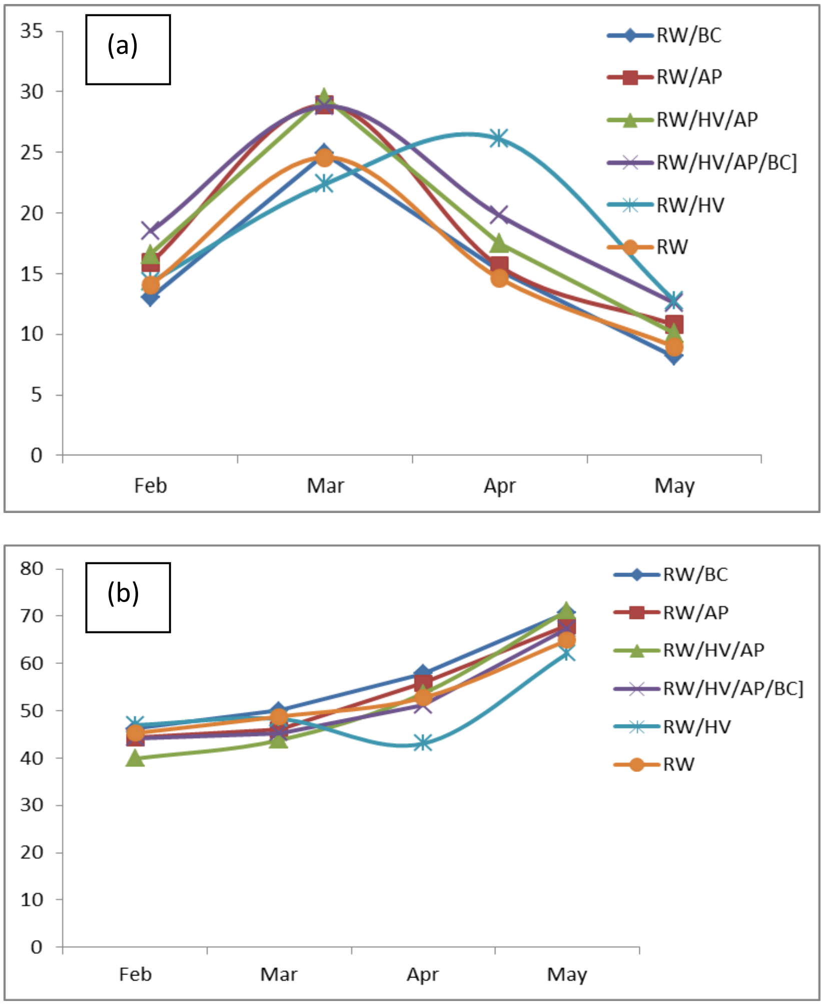


Figure 5. Monthly forage crude protein (CP; A) and fiber (neutral detergent fiber; B) compositions in multi-forage system. RW = Rye and wheat; AP = Australian pea; HV = hairy vetch; BC = Berseem clover.

Table 2. Forage chemical composition (% DM) in multi forages system in winter 2011.

Item	WR+BC	WR+AP	WR+HV+AP	WR+AP+HV+BC	WR+HV	WR	SEM	P-value
CP	15.3^{c}	17.8^{b}	18.4^{a}	19.9^{a}	18.9^{b}	15.5^{c}	0.74	0.02
Soluble protein	35.1	36.1	36.0	35.4	35.0	34.3	0.65	0.29
ADF	33.9^{a}	32.8^{a}	32.0^{ab}	32.8^{a}	31.8^{b}	32.1^{ab}	0.59	0.02
NDF	56.2^{a}	53.5^{ab}	52.1^{b}	52.1^{b}	50.1^{b}	52.9^{ab}	1.14	0.01
Crude fat	3.3^{b}	3.4^{ab}	3.5^{ab}	3.5^{ab}	3.6^{a}	3.4^{ab}	0.09	0.01
TDN	60.8^{b}	61.5^{ab}	61.9^{ab}	61.2^{ab}	62.1^{a}	62.6^{a}	0.50	0.01
Ash	7.0^{b}	7.5^{ab}	7.2^{ab}	7.5^{ab}	7.7^{a}	7.1^{b}	0.18	0.03
Ca	0.57^{b}	0.59^{b}	0.60^{ab}	0.66^{a}	0.63^{ab}	0.51^{b}	0.02	0.01
P	0.42	0.43	0.41	0.47	0.46	0.40	0.02	0.12
Mg	0.33^{a}	0.34^{a}	0.33^{a}	0.33^{a}	0.30^{ab}	0.26^{b}	0.01	0.001
K	1.94	2.02	1.83	2.04	2.13	2.10	0.07	0.45
S	0.21^{b}	0.22^{ab}	0.22^{ab}	0.23^{a}	0.23^{a}	0.21^{b}	0.05	0.01
Na	0.02	0.02	0.02	0.01	0.02	0.02	0.002	0.84
Cl	0.72	0.78	0.75	0.75	0.74	0.74	0.04	0.30
Fe, ppm	86.8	99.6	88.1	100.0	96.1	87.0	5.21	0.08
Cu, ppm	3.5	3.3	3.5	3.7	3.6	3.5	0.20	0.39
Mn, ppm	139.1^{bc}	130.1^{bc}	128.3^{c}	157.4^{b}	156.8^{b}	174.8^{a}	10.71	0.02
Zn, ppm	21.3	20.0	20.2	23.3	23.1	20.8	1.23	0.43
Lysine	0.21^{b}	0.24^{ab}	0.25^{ab}	0.27^{a}	0.26^{a}	0.21^{b}	0.02	0.001

CP = crude protein; ADF = acid detergent fiber; NDF = Neutral detergent fiber; IVDMD = *in vitro* dry matter digestibility; WR=wheat and rye; AP = Australian pea; HV = hairy vetch;

BC = Berseem clover

Table 3. Nutritive value of three summer forages. Tuskegee University (6/17/2013)

Item	Bermudagrass	Sunn hemp	Pasture soybean
Dry matter	92.6	91.9	92.4
Acid detergent fiber	43.0	36.5	35.0
Neutral detergent fiber	71.0	56.1	53.4
Crude protein	**7.3**	**23.9**	**16.3**

Hay production

After winter grazing season was over in May, animals were removed and remaining biomass was harvested for hay production (Table 4). The benefit of hay making after grazing is to extend the sustainability of the system in terms of animal feeding and production. Our results indicated that dry matter biomass production as hay was higher for RW when compared to other combinations and resulted in 50 bales of hay produced vs. on average 31-39 bales of hay produced on other combination of forages.

Table 4. Hay produced at the end of grazing period on different forage combinations.

Items	RW/BC	RW/AP	RW/HP/AP	RW/HV/AP/BC	RW/HV	RW	SEM	P-value
Bales/paddock								
	36.5[b]	39.5[b]	31.5[b]	35.5[b]	37.5[b]	50.5[a]	3.09	0.02
Lbs/paddock								
	985.5[b]	1066.5[b]	850.5[b]	958.5[b]	1012.5[b]	1363.5[a]	83.58	0.01

RW= Rye and wheat; AP = Australian pea; HV = hairy vetch; BC = Berseem clover.

Objective 2) Determine animal performance, animal health and carcass quality of goats when grazing multi-culture grasses, and grasses in combination with legumes;

Figure 3. SARE 12 paddocks, Tuskegee University, winter grazing, 2011-2012

Animal Body Weight Gain, carcass quality of goats

This objective was fully investigated by 2011 and 2012. Goats were placed in each of the two 1½ acre plots (n = 5 and 2 replicates) and spent approximately 3 month in each plot (Figure 6). This objective is fully investigated by this project and it is one of the main contributions of this report. Forty-eight cross breed goats were placed on 12 paddocks, 4 goats each (the two ½ acre plots of each forage combination replicated twice) and spent approximately 45 days in each plot during 2 years. Finding goats for winter grazing is a challenge in AL and maybe southeast. We could not locate 48 uniform young stockers until first week of March in 2011. Therefore goats were placed very late on paddocks and only grazed for 45 days. However, goats were stocked and started experiment from February to May 2012. Goats were quarantined for 3 weeks and placed on the paddocks by March 29 and after grazing for 45 days they were removed from pastures by May 17. After grazing period, goats were transported to Mississippi State University Meat lab and were slaughtered according to the USDA guidelines and carcass characteristics and traits were determined. Animal body weight (BW) changes in multi-forage system in March, April, and May are presented in Figure 6 and animal performance and average daily gains are presented in Table 5 and Figure 7, while carcass characteristics and traits are presented in Table 6. Carcass fatty acids profiles are presented in Tables 7, 8, and 9. Multi-culture forage BW responses (Figure 6 and Table 5) in March, April and May 2011 and 2012 and shoulder weights were higher in three forage combination groups (RW+ HV + AP) than other forage combinations. Average daily gain was highest ($P < 0.01$; ADG =225 g) for goats grazing on RW+AP+HV and was lowest (ADG = 108 g) for goats on all four forage combinations (RW+AP+HV+BC) and RW alone (ADG = 128 g). According to our results animal BW changes were different ($P = 0.07$) in the following order: RW + AP + HV > RW + AP > RW + HV > RW and WR+HV+AP+BC combinations.

Multi-culture forage ADG responses (Figure 5) in March and April 2012 were higher in RW + berseem clover combination groups than other forage combinations. According to our results shown that that animal ADG changes was different (P=0.07) in the following order: Wheat and rye (WR) + BC > WR + AP + HV > WR + AP+ HV > WR+HV > WR and WR+AP combinations (Figure 5).

For summer forages, animal performance and average daily gain (ADG) are presented in Figure 8. Average daily gain was highest ($P < 0.01$; ADG =129.2 g) for goats grazing on sunn hemp and was lowest (ADG = 19.7 g) for goats on bermudagrass and middle ADG for soyben (ADG = 81.1 g/day).

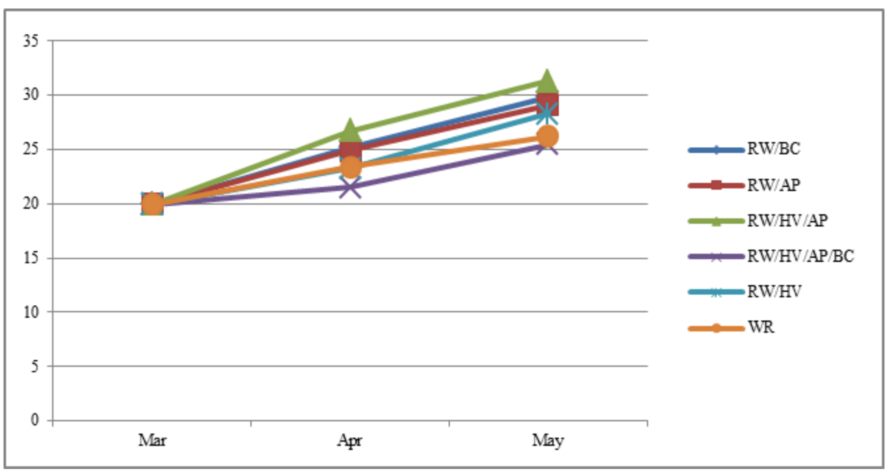


Figure 6. Monthly animal body weight (BW) changed in multi-forage system. WR=wheat and rye; AP = Australian pea; HV = hairy vetch; BC = Berseem clover. Animal BW has been covariate by initial BW (March 2011).

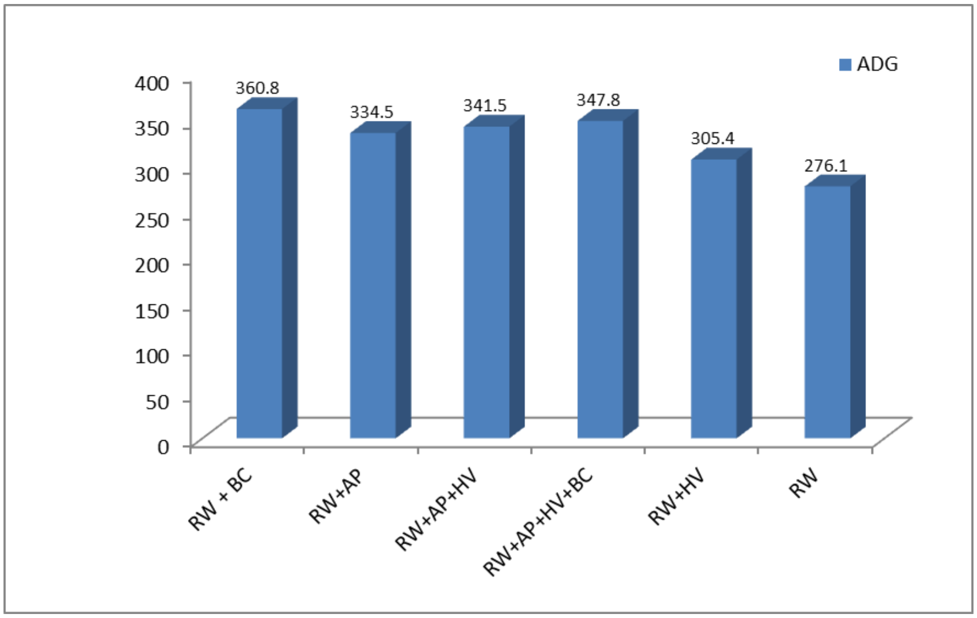


Figure 7. Monthly average daily gain (ADG) in multi-forage system. WR=wheat and rye; AP = Australian pea; HV = hairy vetch; BC = Berseem clover. Animal BW has been covariate by initial BW (March 2012).

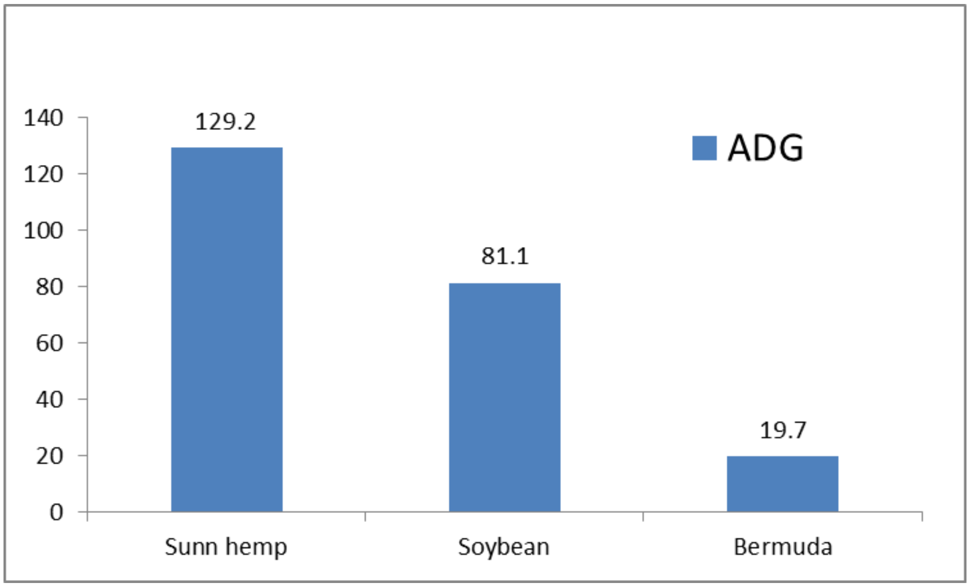


Figure 8. Average daily gain (ADG) in summer multi-forage system, 2013.

Table 5. Monthly animal body weight (BW) changed in multi-forage system.

Items	RW/BC	RW/AP	RW/HP/AP	RW/HV/AP/BC	RW/HV	RW	SEM	P-value
Mar[1]	19.6	19.6	19.6	19.6	19.6	19.6	-	-
Apr	25.2^{a}	24.9^{ab}	26.7^{a}	21.5^{b}	23.3^{ab}	23.4^{ab}	1.32	0.05
May	29.9^{ab}	29.1^{ab}	31.1^{a}	25.5^{b}	28.3^{ab}	26.2^{ab}	1.88	0.02
ADG (g/d)[2]	197.5^{ab}	182.3^{ab}	225.1^{a}	108.2^{b}	164.0^{ab}	121.9^{ab}	3.85	0.01

RW= Rye and wheat; AP = Australian pea; HV = hairy vetch; BC = Berseem clover.

[1]Animal BW has been covariate by initial BW (March 2011).

[2] ADG was calculated from March 29 to May 17, 2011 (49 days).

Table 6. Carcass traits (kg/head) of goats grazing in multi forages system in winter 2011.

Item	RW+BC	RW+AP	RW+HV+AP	RW+AP+HV+BC	RW+HV	RW	SEM	*P*-value
Carcass	12.2^{a}	11.6^{ab}	12.6^{a}	10.5^{b}	11.8^{ab}	10.2^{b}	0.73	0.02
Shoulder	2.6	2.3	2.6^{a}	2.2	2.1^{b}	2.0^{b}	0.27	0.05
Ribs	0.98	0.97	1.03	0.81	0.84	0.81	0.08	0.08
Loin	0.85	0.85	0.91	0.76	0.77	0.74	0.07	0.31
Sirloin	0.93^{a}	0.78	0.87	0.74	0.74	0.66^{b}	0.08	0.04
Leg	2.04	1.91	2.08^{a}	1.69	1.93	1.67^{b}	0.12	0.03
Hind shank	0.47	0.46	0.53	0.46	0.61	0.46	0.07	0.07
Trim	0.34	0.31	0.35	.27^{b}	0.37^{a}	0.31	0.04	0.04

Table 6 Continued. Carcass traits (kg/head) of goats grazing in multi forages system in winter 2011.

Bones	0.39	0.35	0.35	0.34	0.42	0.30	0.03	0.05
Kidney fat	0.09	0.09	0.10	0.07	0.12	0.07	0.034	0.24

Animal Health and Parasite Load

As an indication of animal health, fecal egg counts for animals were measured for months of February and March, 2012. Mean fecal egg count (FEC) of *Haemonchus* for growing goats was higher for RW+AP+HV+BC than for other combination (Figure 9 a,b), but Coccidia number was higher for the RW+BC than for the other combinations. These results indicated that legume forage combinations could not affect what???to growing goats during winter/spring period. This is probably mainly due to the carry over effect from previous farm.

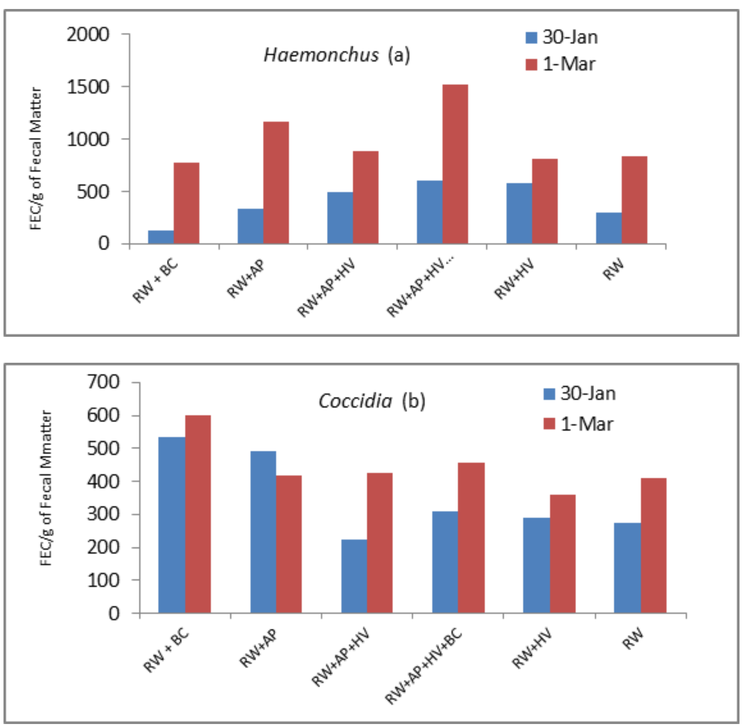


Figure 9. Fecal egg count (FEC) for *Haemonchus* (a) and *Coccidia* (b) in multi-forage system. RW = Rye and wheat; AP = Australian pea; HV = hairy vetch; BC = Berseem clover.

Fatty acids profile in carcass

Fatty acids are the major component of lipids and affect meat quality. The fatty acid composition of fats determines its degree of saturation, and therefore, significantly affects its quality. Twenty-four Kiko-cross meat goats (*Capra hircus*; 27.46 kg) were used to quantify fatty acid profile of goats consuming grasses or legume forages during 83 d experimental period. Experimental treatments included: the grasses-based diet (winter wheat/rye grass) vs. mixed legumes (hairy vetch + Australian peas+ big bersim clover) forage diets. Goats grazed on grasses-based diet, saturated fatty acids (SFA) and polyunsaturated fatty acids (PUFA) were higher in intramuscular fat content ($P < 0.01$), but were lower in mesenteric kidney fat (MKF) and subcutaneous fat ($P < 0.05$-0.01) compared to legume forage-based diets (Tables 4, 5, and 6). Goats grazed on grasses-based diet, omega-3 and -6 fatty acids were higher in intramuscular fat content ($P < 0.05$-0.08), but were lower in subcutaneous fat ($P < 0.05$-0.01) compared to legume forage-based diets. Mono unsaturated fatty acids (MFA) were not affected by diets. These results indicated that goats receiving legume forage-based diets produced carcasses with more PUFA and higher omega-3 and -6 fatty acids in sub-cutaneous fat from Kiko-crossbred male goats.

Table 7. Effects of legume forage on fatty acids composition (mg/g of tissue) of intramuscular fat from Kiko crossbred male goat kids

	Diets			
Item	Wheat & Rye	Legume forage	SEM	P-value
Number of animals	12	12		
C10	226.6	33.5	163.90	0.53
C11	140.2	155.5	65.67	0.87
C12	99.0	122.07	38.1	0.78
C13	187.4	284.7	114.76	0.32
C14	185.3	198.6	167.86	0.48
C14:1	78.0	84.9	49.95	0.94
C15	68.6	141.4	58.81	0.73
C15:1	234.0	76.8	68.86	0.24
C16:0	141.4	65.3	49.9	0.33
C16:1	36.3	20.4	18.18	0.57
C17:0	193.6	173.6	57.3	0.38
C17:1	79.8	109.9	44.60	0.66
C18:0	116.5	82.4	40.45	0.54
C18:1n9c	244.8	175.4	0.39	0.39
C18:1n9t	169.3	175.4	110.80	0.92
C18:2n6c	111.5	101.6	30.90	0.83
C18:2n6t	14.9	64.6	23.18	0.15
C18:3n3c	24.5	34.5	14.70	0.66

C18:3n6	193.4	56.8	79.68	0.28
C19	65.4	74.0	5.60	0.33
C20	84.4	28.4	18.8	0.07
C20:1	70.6	86.5	33.21	0.75
C20:3n3	27.9	19.5	11.24	0.61
C20:3n6	79.4	55.5	36.41	0.67
C20:4n6	32.7	27.4	20.071	0.86
C20:5n3	432.4	161.4	178.21	0.33
C21	44.5	55.8	17.63	0.07
C22	47.3	175.7	44.55	0.08
C22:2	257.4	240.2	98.70	0.91
C22:6n3	779.6	692.8	282.1	0.84
C23	73.5	23.5	24.22	0.19
C24	377.5	315.8	191.71	0.83
C24:1	878.6	418.9	322.4	0.36
SFA	527.6	374.7	29.01	0.01
MFA	564.5	547.2	36.9	0.71
PUFA	916.7	521.3	33.11	0.05
PUFA/SFA	1.74	1.39	0.35	0.18
Total omega-3	1204.4	908.2	180.77	0.08
Total omega-6	352.4	250.4	133.6	0.05

SFA= saturated fatty acid =(C14:0+C16:0+C18:0+C20:0).
MFA=Monounsaturated fatty acid = (C17:1+C18:1+C20:1).
PUFA- polyunsaturated fatty acid = (C18:2+C18:3+C20:2+C20:3+C20:4+C22:4).

Table 8. Effects of legume forage on fatty acids composition (mg/g of tissue) of mesenteric kidney fat (MKF) from Kiko crossbred male goat kids

	Diets			
Item	Wheat & Rye	Legume forage	SEM	P-value
Number of animals	12	12		
C10	150.7	73.6	51.11	0.30
C11	465.8	193.1	201.7	0.33
C12	333.6	258.3	191.9	0.78
C13	398.0	316.9	180.30	0.75
C14	500.1	322.7	188.64	0.60
C14:1	177.2	254.9	120.74	0.61
C15	206.7	164.1	79.9	0.76

C15:1	60.3	81.1	25.34	0.03
C16	880.1	894.5	267.3	0.96
C16:1	189.5	101.1	18.18	0.35
C17	77.3	388.8	98.3	0.04
C17:1	114.6	135.4	44.60	0.63
C18	1387.4	2129.7	600.20	0.32
C18:1n9c	1252.3	1524.3	424.80	0.61
C18:1n9t	231.5	221.6	71.9	0.92
18:2n6c	139.3	264.1	51.40	0.01
C18:2n6t	27.4	82.9	41.50	0.03
C18:3n3	99.2	34.4	30.9	0.20
C18:3n6	170.3	123.8	67.15	0.02
C19	74.0	78.2	3.50	0.66
C20	64.9	183.1	96.15	0.001
C20:1	171.1	39.2	85.1	0.69
C20:3n3	23.1	11.9	8.01	0.88
C20:3n6	49.7	32.8	29.2	0.037
C20:4n6	60.3	60.1	24.4	0.68
C20:5n3	80.6	161.4	178.21	0.33
C21	144.5	51.5	42.63	0.01
C22	47.3	175.7	44.55	0.08
C22:2	148.9	142.4	55.70	0.39
C22:6n3	530.5	425.7	116.76	0.71
C23	31.9	76.0	47.4	0.39
C24	32.7	238.2	92.51	0.001
C24:1	449.1	303.1	81.86	0.95
SFA	2832.5	3530.0	362.11	0.01
MFA	1769.5	1920.5	359.00	0.29
PUFA	649.9	771.4	25.03	0.05
Total omega-3	733.4	633.4	110.23	0.11
Total omega-6	419.6	480.8	115.4	0.24

SFA= saturated fatty acid =(C14:0+C16:0+C18:0+C20:0).
MFA=Monounsaturated fatty acid = (C17:1+C18:1+C20:1).
PUFA- polyunsaturated fatty acid = (C18:2+C18:3+C20:2+C20:3+C20:4+C22:4).

Table 9. Effects of legume forage on fatty acids composition (mg/g of tissue) of sub-cutaneous fat from Kiko crossbred male goat kids

Item	Diets		SEM	P-value
	Wheat & Rye	Legume forage		
Number of animals	12	12		
C10	91.1	30.9	25.28	0.20
C11	46.9	66.5	21.1	0.67
C12	122.4	62.9	48.95	0.28
C13	59.4	275.8	124.8	0.36
C14	217.9	421.4	121.1	0.22
C14:1	156.0	374.1	227.52	0.47
C15	31.4	283.9	119.42	0.28
C15:1	818.2	503.1	489.51	0.89
C16	509.9	902.7	215.04	0.21
C16:1	334.7	344.4	129.31	0.72
C17	45.4	157.4	39.94	0.18
C17:1	591.5	623.8	534.55	0.76
C18	568.5	1080.4	383.22	0.16
C18:1n9c	1060.1	2622.6	342.7	0.05
C18:1n9t	2689.2	288.4	281.70	0.002
18:2n6c	233.4	235.9	92.8	0.93
C18:2n6t	180.2	67.7	82.8	0.12
C18:3n3	13.4	166.5	62.91	0.27
C18:3n6	75.1	123.3	95.04	0.51
C19	74.0	78.2	3.50	0.66
C20	4.9	232.2	44.61	0.05
C20:1	44.3	131.5	85.3	0.15
C20:3n3	3.6	130.9	34.71	0.05
C20:3n6	44.4	205.4	96.8	0.09
C20:4n6	7.8	61.7	29.7	0.06
C20:5n3	65.1	75.1	39.56	0.81
C21	75.4	84.5	23.5	0.84
C22	165.3	368.7	104.6	0.05
C22:2	73.1	143.4	31.54	0.05
C22:6n3	263.3	1292.4	116.76	0.05
C23	39.1	44.4	18.8	0.95
C24	139.9	58.1	43.32	0.24

C24:1	506.7	353.1	216.99	0.75
SFA	1301.2	2636.7	190.99	0.01
MFA	4385.1	3666.3	311.06	0.29
PUFA	623.1	1066.5	66.78	0.05
Total omega-3	345.4	1664.9	63.48	0.01
Total omega-6	540.9	694.0	79.42	0.05

SFA= saturated fatty acid =(C14:0+C16:0+C18:0+C20:0).
MFA=Monounsaturated fatty acid = (C17:1+C18:1+C20:1).
PUFA- polyunsaturated fatty acid = (C18:2+C18:3+C20:2+C20:3+C20:4+C22:4).

Objective 3) Determine soil quality changes using multi-culture grasses, and grasses in combination with legumes;

We know that soil changes as affected by sources of forages growing on the soil may be slow and need long term studies. Soil quality in RW+ BC was significantly higher for the OM (%), Nitrate-N, base Ca, Ca, Mg, Fe, Al and S than for the other treatments (Table 10). Soil pH was higher for the RW+AP than for the other combination. Soil mineral contents in RW+AP+HV+BC were higher for the P, Zn, and Mn contents. There was no significant differences between forage combination treatments in Mg (base), K and Cu contents. Soil mineral content in RW was the lowest level compared to other forage combinations, except Mn content.

Table 10. Soil nutrient composition in multi forages system in winter 2012.

Item	RW+BC	RW+AP	RW+HV+AP	RW+AP+HV+BC	RW+HV	RW	SEM	*P*-value
OM, %	1.45^{a}	1.01^{c}	1.29^{b}	1.26^{b}	1.0^{c}	1.23^{b}	0.19	0.03
Nitrate-N	9.0^{a}	0.0	0.0	3.0^{b}	3.0^{b}	3.25	3.10	0.01
Base-Ca	47.4^{a}	31.7^{b}	27.8^{b}	36.3^{ab}	21.3^{c}	26.6^{c}	10.70	0.04
Base-Mg	19.55	17.45	19.25	18.27	12.3	13.32	5.06	0.29
Base-K	2.4^{b}	3.2	3.6	3.3	4.6^{a}	3.5	2.07	0.05
Base total	69.7^{a}	52.4	50.6	57.9	38.8^{b}	43.6^{b}	14.7	0.10
Buffer pH	6.28	6.29^{a}	6.26	6.25	6.23	6.19^{b}	0.98	0.05
Ppm								

Ca	437.7^{a}	173.2^{b}	167.2^{b}	257.0^{b}	112.5^{c}	160.5^{b}	99.1	0.02
P	98.5^{a}	78.7^{b}	59.2^{b}	115.5^{a}	99.7^{a}	96.5^{ab}	18.43	0.007
Mg	106.2^{a}	57.2^{b}	67.7^{b}	78.5^{ab}	40.5^{c}	49.7^{b}	25.3	0.02
K	40.5	33.2	39.0	44.0	45.2	40.5	11.08	0.71
Fe	100.7^{a}	42.0^{c}	30.0^{c}	54.2^{b}	42.5^{c}	56.2^{b}	9.63	0.001
Zn	2.4^{ab}	1.1^{b}	0.95^{b}	3.27^{a}	2.0^{ab}	3.1^{a}	1.03	0.02
Cu	0.07^{ab}	0.07^{ab}	0.1^{ab}	0.15^{a}	0.02^{b}	0.02^{b}	0.06	0.12
Mn	46.9^{a}	37.1^{b}	38.8^{b}	57.8^{a}	45.2^{a}	55.6^{a}	8.29	0.01
Al	646^{a}	463^{b}	485^{b}	600^{ab}	516^{b}	535^{b}	52.2	0.008
S	8.75^{a}	2.75^{c}	4.50^{c}	6.25^{b}	2.50^{c}	4.00^{c}	1.41	0.0001

Objective 4) Identify and assess economic characteristics and optimum economic return of different goat production (grazing/browsing) systems.

Annual cool-season grain legumes grown in mixtures with winter wheat forage, may offer advantages over winter wheat sole crops for forage production. Our objective was to evaluate the effects of intercropping winter wheat forage along with legume planting on forage yields, nutritive value, animal performance and economic returns.

The increased seeding costs associated with the legume component of legume–winter wheat intercropping relative to sole winter wheat forage system can only be justified if intercrop yields are similar to or greater than sole winter wheat, and nutritive value is improved. Aasen et al. (2004) compared the economic suitability of sole barley cropping and pea–barley intercropping for forage production. Based on 1998 costs, they determined input costs to be $140/ha for barley sole crops and $190 to $202/ha for pea–barley intercrops. They concluded that small improvements in the nutritive value of the pea–barley mixture was not enough to off-set the increased costs of mixed cropping relative to sole cropping. However, their study did not attempt to determine a dollar value for the higher nutritive value forage, or costs for supplementing lower nutritive value feed, which might have altered their conclusions.

In our study, mean economic returns for summer were $583, $639, $788, and $809/ha and mean seed costs were $120, $102, 125, and $30/ha for Australian pea–wheat, hairy batch–wheat, berseem clover–wheat, and sole wheat and rye crop forage, respectively. How was economic return calculated? Total seed costs are based on $0.35 kg-1 for Australian pea seed, $0.37 kg–1 for berseem clover and hairy batch seed, $0.26/kg for certified wheat and rye seed. Total forage values are based on the alfalfa pellet pricing formula. Fertilizer (16-16-15) cost was $0.74/kg in year 2012. Economic returns for summer forage were $1050 and 890/ha and mean seed cost were 140 and $ 100 for sunn hemp and pasture soy bean, respectively. We feel using proper forages for winter grazing followed by summer forages can provide for year-round foraging system. However, combination of forages used for grazing should be selected to optimize animal performance, enhance the soil property and reduce methane or ammonia emission from feces while reducing dependency on petrochemical fertilizer. We are hoping that combining legume forages with grasses will increase protein output as well as restore N in soil, thus reducing dependency on petroleum-based fertilizer.

These major economic benefits were as follows:

- Cool season legume forages can be used for alternative forage crops for year-round forage systems and provide high nutritive value of feed for animal and soil-N for crop production and reduce fertilizer costs.
- Sunn hemp, is a tropical legume that can both produce a large amount of biomass, provide high nutritive value of forage, and fix large amounts of N, thus providing two benefits from one cover crop. In addition, sunn hemp used as cover crop/green manure could help reduce N fertilizer.
- Pasture soybean also can be used as cover crop/green manure, similar to sunn hemp, but less biomass production compared to sunn hemp.
- These results indicated that RW+AP or RW + AP + HV + BC legume forage combinations could be more beneficial to growing goats and provide sufficient nutrients for goats to maintain optimum weight gain in grazing animals. For the soil quality, RW + BC combination could be beneficial to soil improvement, but forage biomass production, animal performance and soil mineral contents were lower for RW pastures as compared to others.
- It appears that sunn hemp can fit well into sustainable goat production system in Alabama.

Objective 5) Evaluate adaptability on an experiment station with goats and demonstrate applicability to an integrated year round forage system using commercial goats.

One of the greatest successes of the outreach activity in our team has been the infusion of new year-round forage system and knowledge into commercial goat production system through helping progressive forage improvement and practical approaches model (Figure 11). For this objective four producers (Bennie Simmons (Dallas Co.), Russell Bean (Barbour Co.), Bill Edwards (Montgomery Co.), Rose Hill (Wilcox County, Al), and Sandra Simone (Talladega County, AL) had been identified and are currently working with our team. The year 2012 was particularly difficult year for goat producers because of widespread drought, which affected pasture production for Ms. Simone. However, the year 2013 we have the great success to introduce our new knowledge and cooperative work with producers that make improve pasture production and animal performance (Figure 11 and Pasture Work handout, Tuskegee University). Sunn hemp is a good source of protein (23.9% DM CP) compared to bermudagrass (7.3% DM CP) and pasture soybean (16.3% DM CP; Table 3 and Figure 8). Over the summer sunn hemp produced massive biomass and improve average daily gain as well as grow up to 40 inches tall (8-10 feet tall in September; Figures 8 and 10) and release 25% more nitrogen and organic matter back into the soil (Figure 11).

Much of the interest was focused on summer forages such as sunn hemp, forage soybean, and Bermuda grass forages. Producers were also requesting us to carry out further studies with sunn hemp that can produce seeds. The final goat production performance based on these forages will be disseminated to a larger audience and other stake holders through fact sheets, popular articles and to scientific community through referred journal articles. We feel using proper forages for winter grazing followed by summer forages can provide for year-round foraging system. However, combination of forages used for grazing should be selected to optimize animal performance, enhance the soil property and reduce methane or ammonia emission from feces while reducing dependency on petrochemical fertilizer. We are hoping that combining legume forages with grasses will increase protein output as well as restore N in soil, thus reducing dependency on petroleum-based fertilizers. We will continue working with these farmers to adopt summer and winter grazing systems.

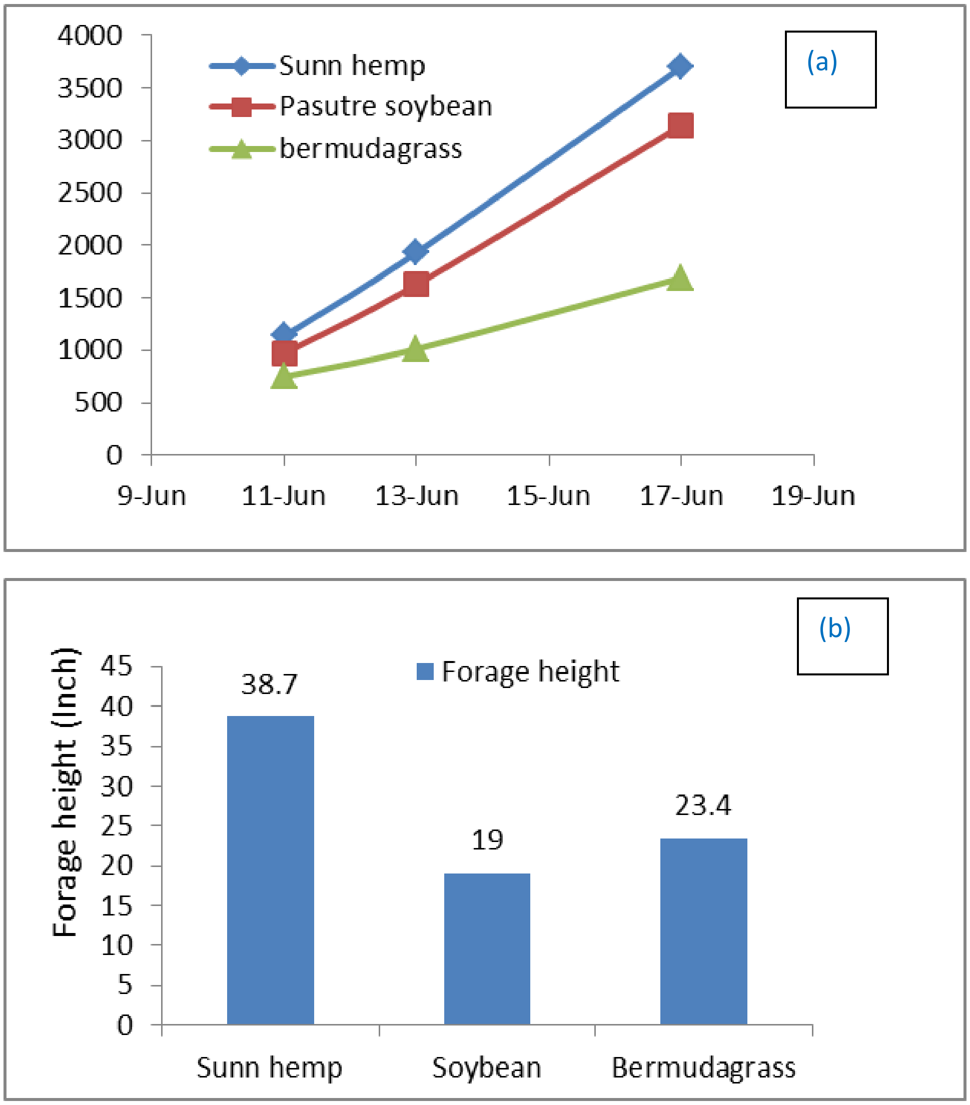


Figure 10. Forage biomass (kg DM/ha; a) production and forage height (inch; b) in sunn hemp, pasture soybean and bermudagrass from June 11 to June 17, 2013, Tuskegee, AL

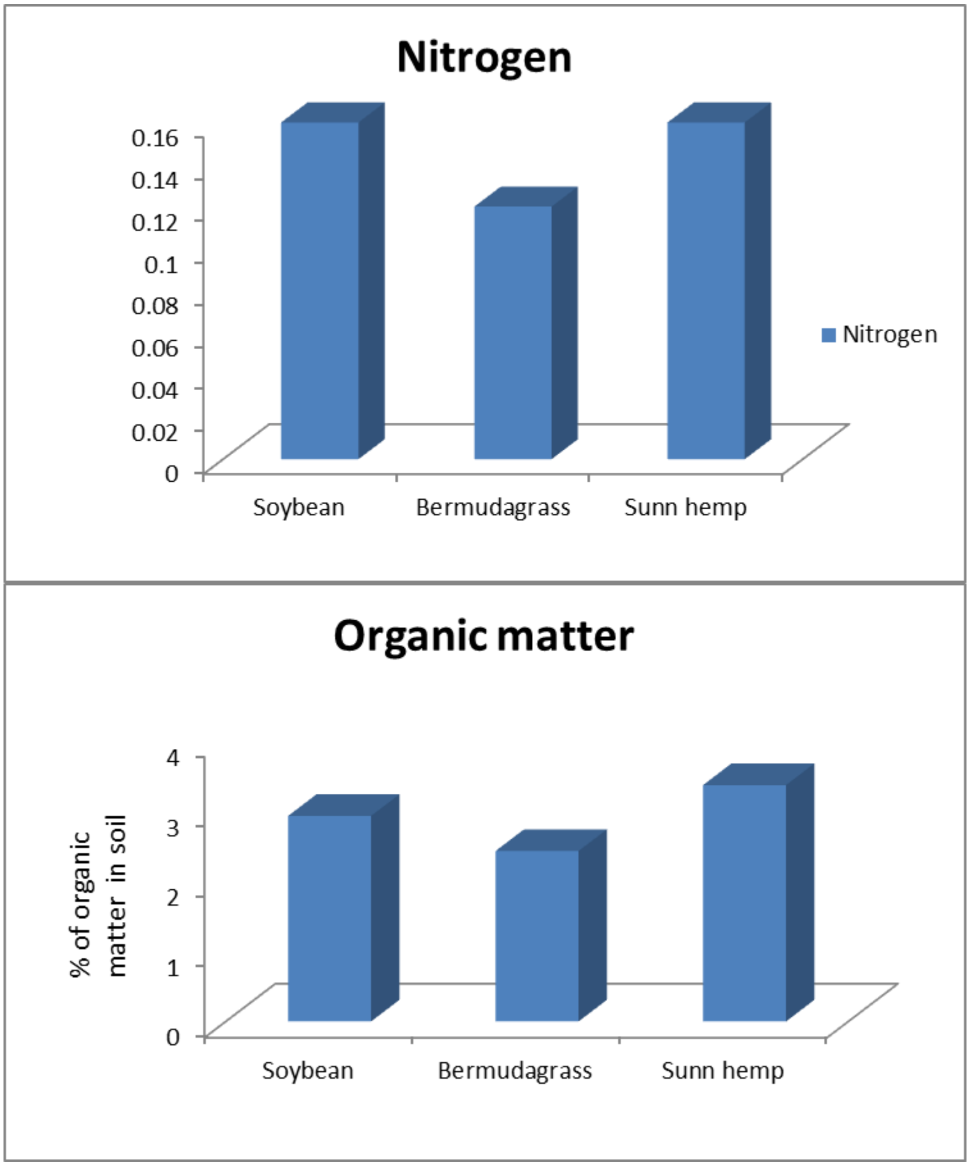


Figure 11. Soil nitrogen (N) and organic matter content in soybean, bermugarass and sunn hemp forages, 2013. Tuskegee University, Tuskegee, AL.

<u>Summary of Year-Round Grazing System Approach</u>

1. **Test year-round forage system using specialized summer forages, Tuskegee University**

Pasture Soy Bean

Sunn Hemp pasture, June 2012

Infusion of new knowledge through Forage Work

2. **Mitigate year-round forage system using a Forage Work/Conference meeting with local producers at Tuskegee University goat farm**

3. **Practical application to new model farms (demonstrate site)**

Bennie Simmons goat farm, August 2013 (Dallas Co.).

Figure 11. Year-round forage system approaches from research farm to producers.

Report prepared by Nii O. Tackie, PhD, Professor, DAES/GWCAES/CEP, Tuskegee University

Sandra Simone resides in Alpine, Talladega County, and is a goat and organic vegetable farmer. At the beginning of the year, we delivered 5 Kiko-Boer crosses (female does) for herd improvement as well as provided general technical advice.

I later visited the farm, and went over her record-keeping data for 2011 (calendar year) with her, and also explained and demonstrated how to use the marketing plan template/format. There was also a visit to assess her operational needs regarding goat production. Following this, I delivered to her minerals for her goats, and gave technical assistance on record-keeping.

Later, Tuskegee University and this farmer signed a memorandum of understanding (MOU) that Tuskegee University will provide assistance and the farmer will allow her farm to be designated a research and Extension farm (i.e., she will provide Tuskegee University with certain data). I, subsequently, delivered to her12 bags of minerals, 3 bags of lespedeza (a type of legume) seeds, 36 bags of fertilizer, 3 feeders, 2 shades, 40 fencing posts, 8 fencing wire rolls, and 1 chain saw to use for her goat operation in spring year 2012.

It is worthwhile to make several comments about these items: (1) the lespedeza was planted on a one-acre plot cordoned off for improved pasture. However, because of the drought it failed to germinate; (2) the feeders are being used for feeding minerals to the goats (see below for testimonial); the shades are on two different sites on the farm; (4) the fencing materials are yet to be used; and (5) the fertilizer has been partially used. **Note:** A testimonial from farmer is provided.

Testimonial:

Good morning Dr. Hill,

Summer harvest is over, the goats are in their respective pastures, and I get a chance to thank you! Tuskegee University has been so important in supporting my efforts to raise quality meat goats here at Huckleberry Hills Farm.

From the beginning in 2002 until this day, The College of Agricultural, Environmental and Nutrition Sciences, professors and staff, have provided me with invaluable support. They have provided me with information in much needed areas such as: herd management; pasture maintenance; nutrition; parasite control and health issues; educational opportunities; record keeping; research programs and more. This means so much to small farmers as myself. There are many challenges which provide opportunities for doubts and failure. Without the information and assistance such as I have received, the success rate of a small farmer is truly limited.

My sincere appreciation….I am thankful.

Testimonial Dated Friday, November 2, 2012

Extension and Outreach Program.

A one-day pasture walk program was organized with several producers in attendance. The names of the producers are Bennie Simmons (Dallas Co.), Russell Bean (Barbour Co.), and Bill Edwards (Montgomery Co.). The program began with a pasture walk followed by questions/answers session. Much of the interest was focused on sunn hemp and forage soybean. Producers were also requesting us to carry out further studies with sunn hemp that can produce seeds. The final goat production performance based on these forages will be disseminated to a larger audience and other stake holders through fact sheets, popular articles and to scientific community through referred journal articles.

Figure 2. Year-round forage systems. Forage walk with local producers; (a, b) forage soybean and (c) sunn hemp, Tuskegee University, June 2013.

IV. Impacts and Contributions/Outcomes

We feel using proper forages for winter grazing followed by summer forages can provide for year-round foraging system. However, combination of forages used for grazing should be selected to optimize animal performance, enhance the soil property and reduce methane or ammonia emission from feces while reducing dependency on petrochemical fertilizer. We are hoping that combining legume forages with grasses will increase protein output as well as restore 25-30% more N and organic matter in soil, thus reducing dependency on petroleum-based fertilizer. Publications from SARE project are shown below:

1. Nutrient optimization for sustainable goat production systems in southern USA. S. Solaiman, and B. R. Min. 2012. 11th International Goats Conference, Canary Isles, Spain, September 24-27.
2. Sustainable Year-Round Forage System for Goat Production in Southern USA. 2014. B.R. Min, S. Solaiman, N. Gurung, W. McElhenny. J. Animal Science. Submitted.
3. Effects of multi-culture grasses combined with legume forages on biomass production, animal performance, carcass characteristics, and soil fertility of Kiko crossbred male goats. 2014. B.R. Min, S. Solaiman, and N. Gurung. J. Animal Science. In preparation.

4. Forage work for producers. 2013. B. R. Min, N. Gurung, and A. Elliott. Potential for Using New Sunn Hemp (*Crotalaria junces* L.) and Pasture Soy Bean (*Glycine max*) as Forages for Meat Goats in Alabama. June 21, 2013.

V. Added Component

We are concerned about human health as well. Proper ratios of omega-3 and -6 fatty acids are important in human diet. We have collected different fat tissues, depot, mesenteric, and subcutaneous from pastured goats, to determine fatty acid profile of carcasses as affected by feeding RW vs. RW + legume combinations. Our data indicated that goats receiving legume forage-based diets produced carcasses with more unsaturated fatty acids and higher omega-3 and -6 fatty acids in sub-cutaneous fat from Kiko-crossbred male goats.

Summary

- **P**asture feeding is safe and relatively low cost.
- **C**ool season legume forages can be used for alternative forage crops for year-round forage systems and provide high nutritive value of feed for animal and soil-N for crop production and reduce fertilizer costs.
- **S**ummer forages such as Sunn hemp and pasture soybean that can both produces a large amount of biomass, provide high nutritive value of forage, and fix 25-30% more soil nitrogen and organic matter, thus providing two benefits from one cover crop and help reduce N fertilizer. It appears that legumes forages in cool and warm season forages can fit well into sustainable goat production system in Alabama.

Appendix 1.

Forage-work (Hand-out)

Potential for Using Sunn Hemp and Soy Bean as Forages for Meat Goats in Alabama

This project has made goat production more sustainable, healthier, and low-cost strategies for mitigating year-round forage production from grazing animal, thus improve overall meat production and protecting animal and soil nutrients, producer profits, and stable, safe food supply.

B. R. Min, N. Gurung, and A. Elliott

Collaborators/producers

Rose Hill
Gregory Scott
Russell Bean
Bennie Simmons

June 26, 2013

Supported by Southern SARE and

G.W. Carver Agricultural Experiment Station, Caprine Research and Education Unit, Tuskegee University, Tuskegee, AL 36088

Objectives

1. ***Quantify effects of modifying sward composition of pastures with multi-species mixtures of improved grasses and legumes on animal performance and production system economics in grazing trials***- Three years experiments have been conducted at the TU Goat research and Education Unit from year 2010-2013.

2. ***Quantify effects of improved forage varieties (Sunn hemp, pasture soybean, Sericea lespedeza, and others) adapted to the central Alabama on grazing animal performance and production system in grazing trials***- current research

Sunn Hemp (*Crotalaria juncea* L.)

Sunn hemp is originally from India (Figure 1). It has been grown as a green manure, livestock feed for forage, hay and for non-wood fiber. It is also excellent forage for deer and goats. Sunn hemp is a good source of protein (23.9% DM CP) compared to bermudagrass (7.3% DM CP) and pastuere soybean (16.3% DM CP; Table 1). Over the summer sunn hemp may grow up to ten to twelve feet tall and release 150-200 pounds of Nitrogen back into the soil.

Why goats grazing on sunn hemp?

First of all, the sunn hemp contained up to 24 percent protein (leaves are over 30%). In addition, Sunn hemp produced massive biomass production (more than 3500 kg DM/ha) within 60 days after planted (Figure 2). This may increase improve animal performance and health. The plant grows straight up with leaves coming off the main stem. It is very important to let the Sunn hemp achieve at least 39 inch (Figure 2 b), preferably 40 inch, in height before allowing the goats to graze. This typically will be around 50 days after planting. If the stems are mowed below 12 inches the sunn hemp may die instead of producing fast regrowth.

Figure 1.Sunn hemp planted on April 24, 2013 at the Caprine Research and Education Unit, Tuskegee, AL (54 days old).

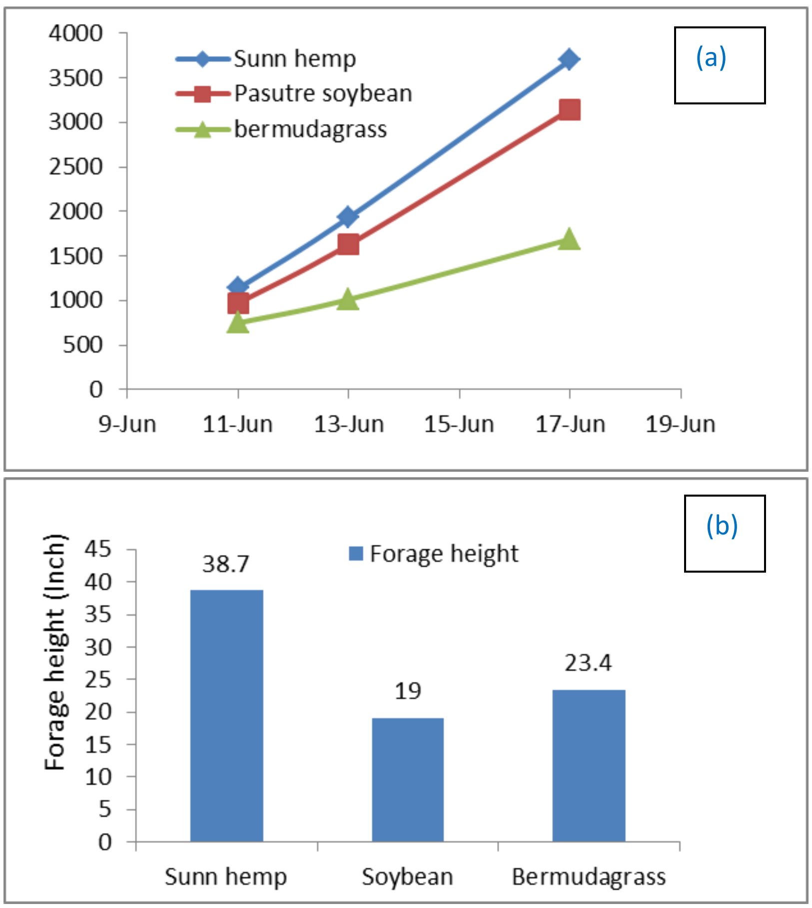


Figure 2. Forage biomass (kg DM/ha; a) production and forage height (inch; b) in sunn hemp, pasture soybean and bermudagrass from June 11 to June 17, 2013, Tuskegee, AL

Cultural practice: The recommended seeding rate is 50 pounds per acre. Seed costs are now around $2.50 per pound ($125/50 Lbs.) so growers might experiment with lower rates, even 25 pound per acre. Seed can be broadcast and covered about ½ to 1 inch deep or drilled in.

Sunn hemp will grow on poor soil with a pH of from 5 to 7.5. It will grow on sandy or clay soils, just not too hard packed clay. The soil does need to be fairly well drained. It will need zero Nitrogen, but will grow better if ample Phosphorus and Potash are in or added to the soil.

Sunn hemp is fairly drought tolerant, but will grow better if it receives ample moisture. Sunn hemp may be planted any time after there is no danger of frost in the spring and will die again at first frost in the fall.

The plant grows very fast and in about 60 days will be 6 feet tall or taller. If allowed to get too tall and old the stems will become tough and fibrous and will not decompose rapidly. If the plants are too tough they will also cause problems the following year when you are trying to prepare your soil and plant.

Table 1. Nutritive value of three forages. Tuskegee University (6/17/2013)

Item	Bermudagrass	Sunn hemp	Pasture soybean
Dry matter	92.6	91.9	92.4
Acid detergent fiber	43.0	36.5	35.0
Neutral detergent fiber	71.0	56.1	53.4
Crude protein	7.3	23.9	16.3

Pasture Soybean (*Glycine max*)

Soybean is presently grown almost exclusively as a protein and oil-seed crop in the USA, but it was previously a popular summer annual forage legume. Soybean may still be considered a viable alternative forage when alfalfa or clover are in short supply due to drought conditions.

Recent research at Tuskegee University, Tuskegee has demonstrated that it is possible to produce greater than 3 ton/ha of soybean forage (Figures 1, 2, and 3) containing 16% CP, 35% ADF, and 53.4% NDF (Table 1). This makes soybean a very attractive alternative when high quality forage is in short supply.

Grazing - Grazing is the most efficient means of harvesting the forage. Strip grazing soybeans will result in less waste due to trampling, fouling with manure etc. Grazing is the best option, especially if the beans made very little growth, but the field must be fenced, and water needs to be provided to the animals. Under proper management, soybean can be grazed three times during the growing season from June through September. Soybean can be first grazed when 24-inches tall and has excellent nutritive value.

The recommended seeding rate is 60-100 pounds per acre. Seed costs are now around $1.56 per pound ($78/50 Lbs).

Figure 3. Forage soybean, planted on April 24, 2013, Tuskegee University, AL. (54 days old).

Bermuda grass

Bermudagrass (*Cynodondactylon*), a warm-season grass native to southeast Africa, is widely grown in the southeastern United States (Figure 4). Of the warm-season perennial grasses available, bermudagrass is one of the most suitable grasses in a management-intensive grazing system. It has the potential to provide a large quantity of forage throughout the summer in southeastern USA if managed correctly. However, bermudagrass contained low protein content compared to legume forages (Table 1).

However, Bermudagrasses require fertilization (about 80 Lbs. N/ac) or high soil nutrients to produce high yields. They are very responsive to nitrogen. The initial application of fertilizer each year should be applied when the grass starts growing, which is usually in April. For grazing apply 80 pounds of nitrogen per acre and soil test recommended amounts of P & K. An additional 80 pounds of N can be applied mid-season if needed. Therefore, legume forages are needed. Legume forages are an excellent source of high quality forage, and are generally very digestible and contain high levels of crude protein (CP). Many legumes also provide substantial forage yields. Perhaps most importantly, legumes and the rhizobium bacteria that colonize nodules on their roots provide an important source of biologically-fixed nitrogen (N).

Figure 4. Bermuda grass pasture, Tuskegee University, AL.

Take-Home Messages:

- **Legumes have been used for long time to provide N for crop production and reduce fertilizer costs. Sunn hemp, is a tropical legume that can both produce a large amount of biomass and fix large amounts of N, thus providing two benefits from one cover crop. In addition, Sunn hemp used as cover crop/green manure could help reduce N fertilizer.**
- **Pasture soybean also can be used as cover crop/green manure, similar to sunn hemp, but less biomass production compared to sunn hemp.**
- **It appears that sunn hemp can fit well into sustainable goat production system in Alabama.**

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