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RESEARCH ARTICLE

DOUBLE CUTTING SORGHUM BICOLOR(L.) MOENCH AS A PROFITABLE FORAGE PRODUCTION SYSTEM IN NIGER

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Abstract

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Feed shortage has been identified to be one of the main constraints limiting animal production for milk and meat in Niger. Stover from cereal crops has been a significant source of feed during the long and dry season with producers showing preference for sorghum stover. Sorghum brown midrib (bmr) genes are well known for improving forage quality around the world; however, farmers in Niger do not have access to sorghum cultivars enriched with bmr genes. To address this limitation, a new forage sorghum breeding program has been initiated in 2016 in Niger to introgressbmr genes into elite Nigerien sorghum varieties. Agronomic studies were performed to determine the most efficient forage production system using split plot design for three **treatments:** TRT 1, TRT 2 and TRT 3. The data collected were subject ed to analysis of variance and Tukey HSD multiple range test was used to separate treatment means.NIRSanalysis revealed the good nutritional qualities of the TRT-1 and TRT-2and significant ($P<0.05$) differences were observed among treatments for CP, and ADL contents. The stover from the TRT-1 expressed high nutrients content levels. The double cutting technicopens new opportunities for alleviating feed shortage facing improved livestock productivity in Niger.

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Introduction:-

In Niger, as in most Sahelian countries, livestock farming plays an important role in the socio-cultural, economic and food security conditions of pastoralists and agro-pastoralists. (INS, 2022) reported that the national ruminant herd is approximately 48.5 million heads composed of cattle (31.5%), sheep (27.3%), goats (37.4%) and camels (3.8%). Over the past 10 years, the contribution of livestock to total gross domestic product (GDP) has varied from 11 to 14% (INS, 2022). Analyzes of the current agriculture-livestock systems in Niger, have identified crops and livestock productivity as one of the main agricultural problems and, therefore, one of the main obstacles to strengthening the resilience of agro-producers. The recurrence of fodder deficits which means that over the past two decade, two years out of three have been in deficit (Republique du Niger, Novembre 2022). Spore (2015) claimed that pastures and crop residues represent about 90% of feed for large ruminant animals in Niger. The qualitative and

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quantitative insufficiency of animal feed in addition to agro-industrial and agricultural by-products access difficulties limit intensification of animal production. To mitigate the feed shortage, in Niger, as well as in the other countries of West Africa, technology for treating cereals straw with urea and supplementation with multi-nutritional blocks have been popularized but poorly adopted by farmers (Abdou, 2010). On the other side,farmers use dual purpose varieties where the grain is used as food and the nutritionally low quality stover as feed for their livestock during dry season (Diakiteet al., 2017). Sorghum residues constitute an important source of forage for the important Niger livestock.Suad etal. (2015) highlighted that in view of the pressing demand for fodder coupled with the importance of the grain of sorghum for people in South Saharan Africa (SSA), it is imperative to reconsider the present mono-commodity breeding strategy of sorghum. In fact, sorghum is a crop with high potential for a wide variety of uses. In countries like SSA, sorghum is a good candidate for biomass production due to its low input demand, the strong farming experience of farmers, can thrive better under harsh conditions.

The use of sorghum as a forage crop is in fact growing in many regions of the world due to its high biomass productivity under drought prone environment (Sanchez etal., 2002). Multiple vegetative harvests (ratoon harvest) of sorghum are possible (Escalada and Plucknett.1975). In addition to its excellent growth potential, better nutritive value and quick regrowth, multicut, sorghum is capable of producing high-quality forage in India (Manishet al., 2018). Multicut fodder sorghum is more advantageous in many ways such as high yield in short period, saving in terms of seed and land preparation(Iyanaret al., 2015).Moreover, the genus Sorghum covers various species with high forage potential and quality.Among them, the brown midrib types are well known for forage quality improvement. Indeed, due to their low lignin content compare to their counterparts; bmr genotypes have better digestibility levels (Cherneyet al., 1991; Grant et al., 1995) and in most lactation and feeding trials involving corn silage, bmr corn silage improved milk production and body weight gain (Keithet al., 1979; Sommerfeldtet al., 1979). InRepublic of Niger (RN), recently sorghum breeding efforts focused on stover quality enhancement through the use of bmr genes for lignin content reduction (Diakiteet al., 2018).However, bmr cultivation is new in the country, moreover farmers do not have access to the innovative double cutting technical packages.The main objective of this study was to assess the forage productivity of new sorghum lines and to identify a good sorghum biomass production between three cutting methods in order to mitigate persistent stover deficit for livestock feeding.

General fodder balance in republic of Niger from 2000 to 2024:-

According to RN (2020) official report, the overall fodder estimatebased on theoretical global needs for the whole resident livestock are 28,561,105 tcompared to available fodder (real) of 17,232,850 t of total dry matter(TDM) per year with a deficit of 11,328,258 t per year. As a direct consequence, farmers complained of feed shortage,struggle to feed the animals during the long dry season with the poorly nutritional stored crop residues (Abdou, 2010; Diakiteet al., 2019).The recurrence of fodder deficit issubsequent to drought over the past decades. There have been deficits in 14 years out of 23 years. Severe deficits occurred in 2009, 2021 with more 15 000 000 t. The qualitative and quantitative scarcity in animal feed in addition to agro-industrial by-products and agricultural by-products access limit the intensification of animal production. Figure 1 shows fodder balance for the last two decades.

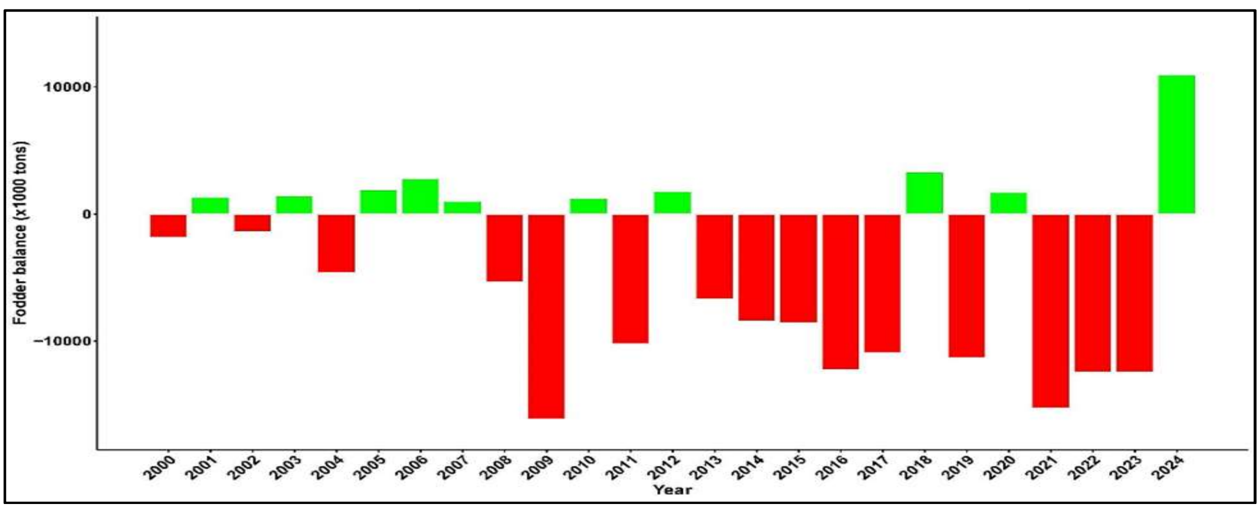

Figure 1: Fodder balance in the republic of Niger from 2000-2024. Source: RN (2025).

Material and Methods:-

Sites:-

The studies were conducted in RN on the national research institute experimental research farms in 2023 and 2024 (Kollo 2°18'07.8'' East; 13°20'09.3'' North).

Plant material:-

The plant material was composed of seven different lines. Among the entries, five were newly bred bmrrecombinant lines, one improved sorghum line and the local farmer preferred variety was used as a control.

Summary of OPVs bmr lines development: Parental lines exhibited brown (bmr) and white midrib (local lines) colors; crosses were done to transfer the brownmidrib color (donor) to the white midrib genetic background in order to produce F_1 progeny. F_{1s} wereselfed to produce segregating F_2population to identify recombinant F_2which were crossed to recurrent parental lines to produce BC_1F_1; a series of selfingrecombinant lines at each generation were conducted until lines $BC_1F_7$for line fixation leading to 99,609 of the recurrent local parent genome recovery.

Table 1: summary information on the sorghum OPVs lines used in this study during the 2023 and 2024 rainy cropping season in Niger.

Name	Pedigree	Sorghum type	Status
P35	Early hegari *bmr6*//Macia/MR732	*Brown midrib* sorghum	Improved variety
P50	Early hegari *bmr6*//Macia/Sepon-82	*Brown midrib* sorghum	Improved variety
P60	Early hegari *bmr6*//Macia/Macia	*Brown midrib* sorghum	Improved variety
P90	Early hegari *bmr6*//Irat-204/Irat-204	*Brown midrib* sorghum	Improved variety
P93	Early hegari *bmr6*//Wassa/CSM-63	*Brown midrib* sorghum	Improved variety
L28	MDK/L153-5	White midrib sorghum	Improved variety
HK	Hakorin Karoua	White midrib sorghum	Control

Biomass production experimental design:-

The agronomic experiments of the biomass cutting technic were conducted during 2023and 2024 rainy seasons.The experimental design was a split plot with three replications.

Table 2: Factors studies: Cutting period during the vegetative growth.

Treatments	Stover production systems	Cutting technic
TRT-1	Field cut 8 weeks after sowing	the biomass first cut was done on one $100m^2$. Sorghum plants were cut 10 cm above the soil in order to favor a regrowth of the stalks. The stover samples (leaves + stems) were dried in shade on shelves.
TRT-2	Field cut after the regrowth	
TRT-3	Field cropped in the normal growth conditions	

Field management:-

Each sorghum cultivar was planted twice on $100m^2$ separated by 3m. Sowing density was 0.80 m between rows and 0.30 m between hills on the row (0.80 m x 0.30 m). In each hill; 3 plants were maintained. The weeds controls were performed two times for the normal growth (TRT-3). A supplementary weed control was performed on the field cut during vegetative growth.The remaining $100m^2$ was left for a normal growing until maturity. For both the normal growth and the double cutting technic the NPK (15-15-15) at the rate of 100 kg/ha was applied before planting and urea (46%N) was applied (100 kg/ha) in two sets. The first set (50 kg/ha) was applied at tillering and the second one (50 kg/ha) at booting stage. Additionally, after the cut double cut technic50 kg/ha of urea (46%N) was applied after the observation of an effective regrowth.

Variables studied:-

The variables studied were:(i)stover yield, (ii) dry matter content, (iii) Crude proteins content, (iv) neutral detergent fiber, (v) acid detergent fiber and (vi) acid detergent lignin.

Table 3: Variables studied during the experiment.

Forage quality traits measured	
Stover yield (kg/ha)	Dry Matter Content (%)
Crude Proteins Content (%)	Neutral Detergent Fiber (%)
Acid Detergent Fiber (%)	Acid Detergent Lignin (%)

Statistical analysis:-
Statistical analyses were performed in XLSTAT using the linear model shown below:
Mean separation was done using Tukey (HSD) 95%.
Model: $Yijk=\mu+\alpha i+\beta j(i)+\tau k+(\alpha\tau)ik+\epsilon ijk$

Where:
- μ= overallmean
- αi= effect of treatmenti
- $\beta j(i)$= random effect of dogjreceivingtreatmenti
- τk= effect of timek
- $(\alpha\tau)ik$= treatment by time interaction
- Eijk= experimentalerror

Biomass nutrient content analysis:-
The biomass harvested, for each plot:double-cut and normal growth, was weighted and kept on shelves under shade for stover yield measurement. The NIRS technology was used for the stover nutrients estimation and following parameters were considered:(i) dry matter, (ii) crude proteins CP, (iii) neutral detergent fiber NDF, (iv) acid detergent fiber ADF, (v) acid detergent lignin ADL at the biotechnology laboratory of IER/Sotuba in Mali in 2024.
The data collected for each technic (TRT-1, TRT-2 and TRT-3) were stored in Excel spread sheet and analyzed using XLSTAT software.

Results:-
Cutseffect on agronomic performance:
On the stover yield
During this experiment, the first cut was performed 8 weeks after sowing. At this moment, all varieties were in active vegetative stage (visible flag leaf to the boot stage) and plant height varied from 141cm to 253 cm (Mean±SD = 179±0.45 cm). The one cut (TRT-3) technic provided the highest stover yield (figure 2).

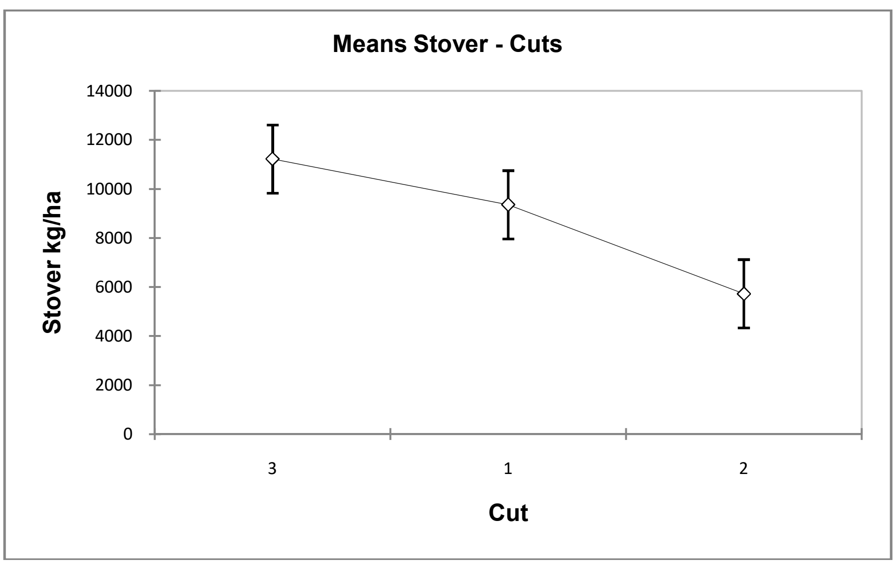

Figure 2: The TRT-3 produced the highest stover yield.

Legend: 1=TRT-1; 2=TRT-2; 3=TRT-3.

- **On the grain yield**

There was no grain production for TRT-1. There were reductions in grain yields inTRT-2. In contrast the grain yield production was normal for the TRT-3 which was the normal sorghum growing conditions (figure 3).

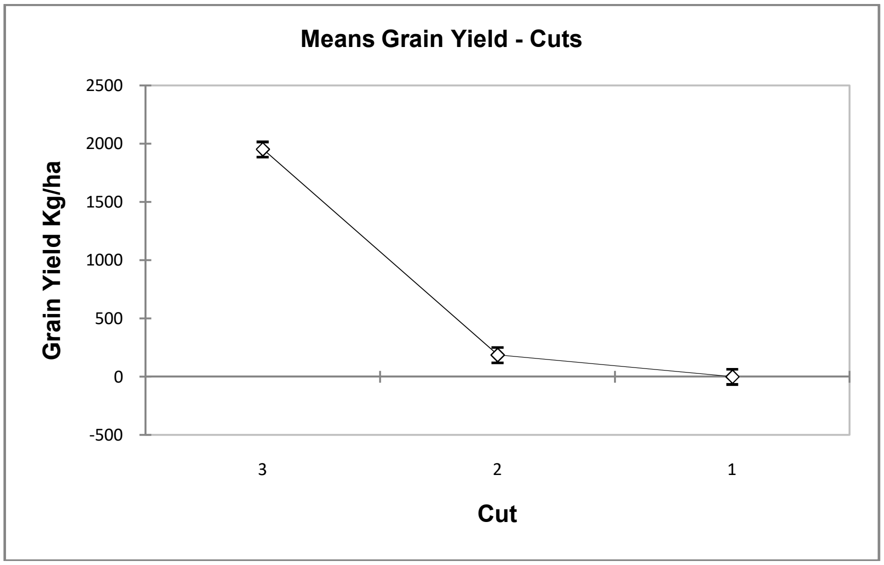

Figure 3: Grain yield for the TRT-1, TRT-2 and TRT-3.

Cuts effect on the stover quality:-

The results for the stover nutrients content revealed the high forage potential of the different sorghum lines in general. Indeed, good levels of dry matter, crude proteins were obtained while lignin content was reduced in the TRT-1 and TRT-2.Dry matter content varied from 92.5 % to 93.5%. TRT-3 contained the highest dry matter content followed by TRT-2 and TRT-1. It was obvious that the DM content increase with plant maturity (figure 4).Crude proteins varied from 8.64 % to 11.72 %. The highest CP content was found in the samples from the TRT-1 which was the first cut followed by TRT-2. The lowest CP content was obtained in TRT- 3 (figure 5).

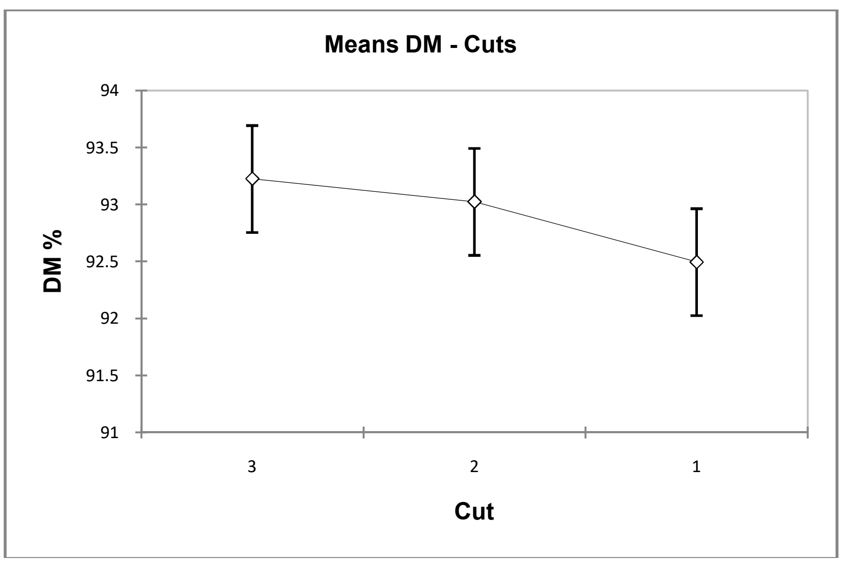

Figure 4: Dry matter content per treatment.

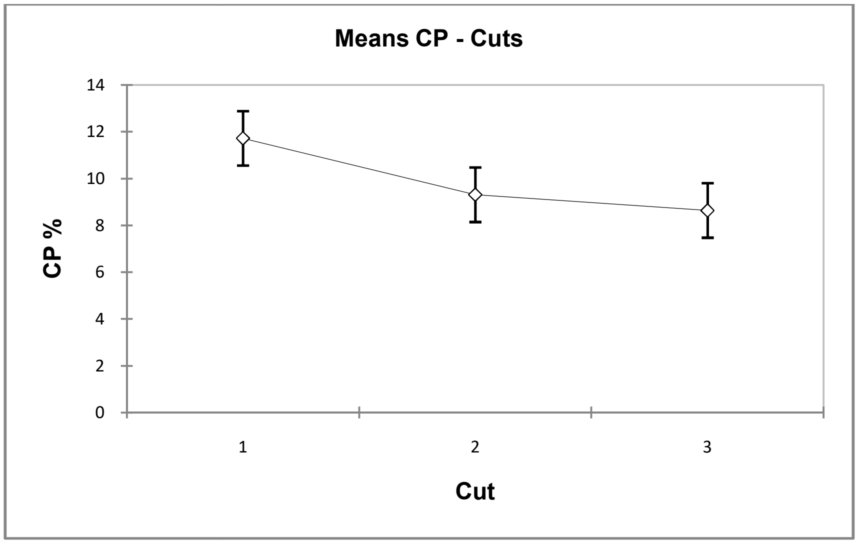

Figure 5: Crude proteins content per treatment.

Neutral Detergent Fiber (NDF); Acid Detergent Fiber(ADF); Acid Detergent Lignin (ADL) contents:-
The NDF, ADF and ADL constitute the major cell wall components. The NDF content varied from 62.89% to 63.02 % with TRT-1 having the highest content and TRT-2 the lowest content. The ADF content varied from 32.65 % to 32.82 %. TRT-3 had the highest content and TRT-2 the lowest content.The ADL content varied from 4.16 % to 4.89 %. The TRT-1 contained less lignin while the TRT-3 had the highest levels of lignin (figure 6).

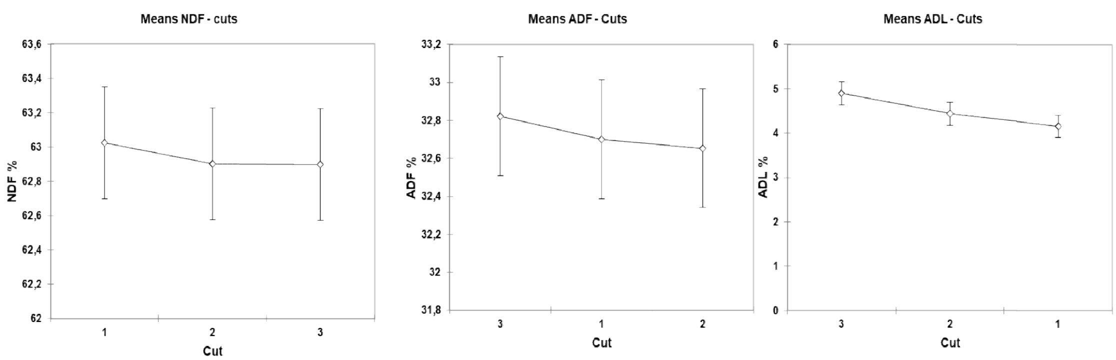

Figure 6: NDF, ADF and ADL contents per treatment.

Table 4: Summary statistics of means assessments.

Variable	Min	Max	Mean±SD	MS	F	Pr>F	
DM	92.49	93.22	92.91±0.37	64.41	9.63	0.08	*
CP	8.64	11.72	9.89±1.61	36.73	7.9	0.001	***
NDF	62.89	63.02	62.94±0.07	0.07	0.19	0.82	*
ADF	32.65	32.82	32.72±0.08	0.10	0.31	0.73	*
ADL	4.16	4.89	4.5±0.37	1.92	8.52	0.001	***
Stover	1951.93	11216.09	5258.29±169.98	4942.18	289.27	0.001	***

Discussion:-

Sorghum multi cutting system is very advantageous for dairy farms (Manjunatha et al., 2013; Iyanaret al., 2015).From field experiments data, the double cutting technicexperimented in Niger showed variability in the stover yield as well as for the forage quality traits (CP, ADL). Pahujaet al. (2013) reported that multi-cut sorghum types play a major role in meetingthe fodder demand in India. Moreover, Rudragoudaet al. (2020) demonstrated and popularized successfully the advantages of a multi cut fodder sorghum variety in the country. The current study reveals CP content ranging from 8.64 % to 11.72 % with TRT-1 having the highest levels of CP.These results shows that stover with high protein content can be obtained using the double cutting technic.Kushwaha et al. (2018) found similar results (7.73%) for the CP content in multi cuts sorghum stovers technic**.**On the forage quality, Zhao et al. (2025)showed that the CP, NDF, and ADF contents decreased significantly with harvest maturity. The results of the current study showed that the TRT-1 had better nutritional values followed by TRT-2 for CP and ADL. The results of the current study revealed that the TRT-3 technic contained the highest lignin content. On this, Patrick (2016) reported correlation between ADL contents as the crop advances age.

On bmr lines, Oliver et al.(2005) reported that bmr genes were found to have negative agronomic impact on grain and stover yields in grain sorghum lines but the yield-drag can be overcome with heterosis. Furthermore, the improvement of the stover quality due to bmr genes may raise the potential of bmr derived lines and compensate grain yield-drag. WhileMagnan et al. (2012) reported that in areas where stover value is high, crop residue yield has an implication in farmers' cereal variety selection indeed superior varieties with low biomass yield might not be selected by growers.(Diakite et al., 2019; CGIAR, 2011) reported that the good quality of biomass constitutes an important choice criterion for farmers and stover traders in Niger.Furthermore,Kinyangi(2014) reported that market availability has a positive and significant influence on agricultural technology adoption. Berazneva and Dyson (2013) supposed that in the context of African smallholder agriculture, crop residues have the most valuable application among on-farm resources.

Conclusion:-

The one cut system provided the highest stover yield while the double cutting technic provided better forage quality.Double cutting technic gives an opportunity for stover producers to harvesttwice on the same surface green leave fodder for dairies livestock. In addition, the dissemination of the double cutting technic may accelerate the adoption for the new cultivars since stover shortage was highlighted as main constraint for animal productivity in the country.

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