academicJournals

Vol. 10(50), pp. 4584-4590, 10 December, 2015
DOI: 10.5897/AJAR2015.10396
Article Number: F8E66CB56337
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effect of stocking rate on biomass variation and lamb performances for barley stubble in Tunisian semi arid region and under conservation agriculture conditions

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Received 17 September, 2015; Accepted 15 October, 2015

The integration of livestock in the practices of conservation agriculture (CA) was assessed in Tunisian semi-arid conditions. Forty five Barbarine lambs (aged 220 ± 10 days, average body weight 20 ± 2.5 kg) were used in a performance trial, carried out in the experimental station of INRAT. During the experiment, lambs were grazing on a plot of barley stubble cultivated according to CA was divided into 6 fenced equal subplots and to each subplot was assigned a stocking rate of animals (15 and 30 lambs per hectare, SR15 and SR30 respectively). The biomass of stubble and its botanical composition were estimated 2 times, using quadrats sampling technique. Live weight was determined 3 times after the start of the experiment (three 15-days successive periods) to calculate live weight gain (LWG) and daily live weight gain (DLWG). The amount of biomass varied ($P < 0.05$) from 2204 to 2067 kg DM / ha for SR15 plots and from 2404 to 1826.5 kg DM/ha for SR30 ones. This decrease was higher with SR30 ($P<0.05$). Heads proportion decreased first, then leaves and finally stems. Biomass chemical composition declined with sampling period. During the first grazing period, lambs assigned to both treatments lost LW ($P<0.001$), mainly SR30 lambs as compared to SR15 ($P<0.05$, -610 and -110 g, respectively). The same trend was observed in DLWG ($P<0.05$). In the second period, the two groups exhibited similar LWG (about 2 kg) and DLWG (about 171 g/d). In the third period, SR15 lambs maintained their body weight, while SR30 group lost ($P<0.001$) about 400 g comparatively to the second period. It was concluded that under the studied feeding system, stubble grazing without supplementation allowed Barbarine sheep to maintain body conditions.

Key words: Lambs, barley stubble, stocking rate, conservation agriculture.

INTRODUCTION

In the Mediterranean Basin, livestock production and crop farming have always co-existed. Cereal stubble and straw are important feed resources mainly during summer season. A major concern for the crop/livestock

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systems in the arid or semi-arid lands is the competition for natural resources, especially for crop and other biological residues. In Tunisia, sheep husbandry (about 3.84 million ewes; OEP, 2013) is still playing an important role in rural population. Local sheep breeds are often assigned to extensive management system (OEP, 2013) including local feed resources such as crop residues (e.g. cereal straws and stubbles: about 1.5 million and 500 000 tones/year). These practices might not be independent of farming system evolution and development. In this connection, conservation agriculture (CA) based mainly on zero tillage is increasingly developed in the world (Valipour, 2014) and more and more adopted in Tunisia as it improves profitability of cereal and forage cropping. The total area cropped under CA context, mainly no-tillage increased from 27 ha 1999 to nearly 12 000 ha (INGC, 2014). The benefits from CA include social and economic advantages and combine production and environment protection. It promotes minimal disturbance of the soil (zero tillage), balanced application of chemical inputs and careful management of crop residues (Dumanski et al., 2006). In its compilation of definitions on sustainable agriculture, Gold (2007) reported that CA practices leave residue cover on the soil surface, substantially reducing the effects of soil erosion from wind and water. They also minimize nutrient loss, decreased water storage capacity, crop damage, and decreased farmability. The soil is left undisturbed from harvest to planting except for nutrient amendment. The same author reported that weed control is accomplished primarily with herbicides, limited cultivation, and with cover crops. The concept of CA is somewhat in line with other sustainable practices such as the low-input sustainable agriculture (LISA). Indeed, according to Parr et al. (1990), LISA are systems how “seek to optimize the management and use of internal production inputs (that is, on-farm resources) and to minimize the use of production inputs (that is, off-farm resources), such as purchased fertilizers and pesticides, wherever and whenever feasible and practicable, to lower production costs, to avoid pollution of surface and groundwater, to reduce pesticide residues in food, to reduce a farmer's overall risk, and to increase both short- and long-term farm profitability”. This suggest that LISA will have a physical productivity limited by the maximum on-farm resources that can be mobilized and that LISA can then be associated with lower output (Poux, 2008).

By the other hand, the integration of crop-livestock under CA holds promise to improve the efficiency and sustainability of production systems, but this is conditioned by good understanding of CA principals and appropriate use of corresponding packages. The farmer can introduce forage crops into the crop rotation, thus extending it and reducing pest problems. Forage species could be used as dual-purpose crops for fodder and soil cover. However, conflicts between the use of stubbles in livestock feeding or to cover the soil have to be resolved, particularly in drylands where fodder potential is low (FAO, 2006). This concept of CA seemed to be apparently incompatible with livestock extensive system and if it is adopted, competition with livestock feeding needs to be optimized.

The current study is part of a research program on livestock management under the context of CA which is not yet documented in the literature. Therefore, this experiment was designed to study the effect of stocking rate on stubble biomass variation and lamb growth.

MATERIALS AND METHODS

Study location

The trial was carried out in the experimental station of INRAT (24 km from Tunis, semi-arid: 350 mm of annual rainfall). Barley (variety Manel) was cropped using CA package. Indeed, barley was drilled (no tillage) in the 26th of December 2012 at a seeding rate of 100 kg/ha. A treatment by herbicide (glyphosate 100 g L^{-1}/ha) was applied in absence of later weeding. The plot was fertilized using ammonitrate (150 kg/ha). The harvest was made on the 24th of June 2013, at a cutting height of about 25 cm above ground. The registered grain yield was 1.4 t/ha.

Animals

Forty five 7-month-old Barbarine lambs (initial average weight 20 ± 2.3 kg) raised in the experimental station of Oueslatia (INRAT) were used for the experiment. They received an antiparasitic treatment and were vaccinated against enterotoxaemia. They were housed in collective boxes in a covered barn and marked on, using different colors of painting to be easily identified and separated per treatment and plot, before leaving for grazing. They had free access to clean water 3 times a day.

Experimental design, sampling and measurements

The experimental plot of 22500 m^2 was divided into 6 subplots of 3750 m^2 each, assigned randomly to two stocking rates (15 and 30 lambs per hectare, respectively for SR15 and SR30). Each treatment was triplicated using the six fenced subplots. Along with the 46 day-trial, lambs grazed twice a day (from 5.00 h to 8.00 h a.m. and from 16.00 h to 18.00 h or 17.00 h to 19.00 h) with a total grazing duration of 5 h per day. The grazing practice covered the period 19th July-3rd September 2013, with a total duration of about 46 days.

The biomass of stubble and the removal of particular fraction were estimated using quadrats sampling technique (0.25 m^2, 5 quadrats per subplot placed in zigzag to have representative samples) at the beginning of the trial and 14 days after. The cutting height was at about 4 cm from the soil. It was not possible to take samples at the end of the experiment because of the rain occurring towards the end of August and the beginning of September and the emergency of vegetation. Samples were immediately weighed and transported to the laboratory for immediate dry matter (DM) determination. Proportions of heads, leaves, stems and other vegetation were evaluated and samples were stored for chemical analysis.

In order to control lamb growing, the animals were weighed early in the morning (5.00 h am) before the start of grazing. Live weight was determined 3 times after the start of the experiment (each 15

Table 1. Variation of DM biomass with stocking rate and sampling period.

Variation		S 0	S 14	SEM	Significance
SR15	Biomass (kg DM/ha)	2204^{aA}	2067^{bB}	128.12	*
	Vegetation (%)	6.7 ^{aA}	3.6 ^{bA}	0.9	NS
	Heads (%)	33.6 ^{aA}	35.2 ^{aA}	1.84	NS
	Stems (%)	33.3 ^{aA}	36.1 ^{bA}	1.32	NS
	Leaves (%)	26.8 ^{aA}	25.1 ^{bA}	1	NS
SR30	Biomass (kg DM/ha)	2404 ^{aA}	1826.5^{aB}	132.7	*
	Vegetation (%)	5.7 ^{aA}	8.4 ^{aA}	0.99	NS
	Heads (%)	34.2 ^{aA}	26.6 ^{aB}	2.26	*
	stems (%)	31.9 ^{aB}	39.7^{abA}	1.71	*
	Leaves (%)	28.1 ^{aA}	25.2 ^{bA}	0.92	NS
SEM	Biomass (kg DM/ha)	131.05	111		
	Vegetation (%)	0.93	0.89		
	Heads (%)	2.19	2.03		
	Stems (%)	1.41	1.4		
	Leaves (%)	1.11	0.89		
Significance	Biomass (kg DM/ha)	NS	**		
	Vegetation (%)	NS	*		
	Heads (%)	NS	**		
	Stems (%)	NS	*		
	Leaves (%)	NS	**		

S0: Sampling at 0 days, S 14 : sampling after 14 days, a, b, c: Different letters in the same column mean different values; A, B, C: Different letters in the same line mean different values; SEM: Standard error of the mean; *: $P<0.05$; **: $P<0.01$.

days) and then lamb growth was followed for 3 successive periods of grazing. Live weight gain (LWG) and daily live weight gain (DLWG) were calculated.

Chemical analysis

Biomass samples were dried at 50°C ground to pass through a 1 mm-screen then were analyzed for ash and crude protein (Association of Official Analytical Chemists, 1984) and for lignocellulose fraction ADF (Van Soset et al., 1991).

Statistical analysis

Data were subject to analysis of variance using GLM procedure, (Statistical Analysis System software; SAS, 2002). The model included stocking rate (S) and period (P) effects and the interaction (S x P). SNK test was used to compare treatment effects. When P-value is below 5%, the treatment effect was considered significant.

RESULTS AND DISCUSSION

Stubble biomass

Estimated biomass yields are reported in Table 1. At the beginning of the experiment (S0), no difference was observed in biomass between the plots reserved to the 2 stocking rates (averaged 2304 kg DM/ha). Subplots assigned to the two stocking rates exhibited substantial decrease of biomass yield ($P<0.05$) in the second sampling time (S14: -137 and -577.5 kg DM/ha respectively with SR15 and SR30). Proportions of biomass components indicated in Table 1 showed that the proportions of heads decreased ($P<0.05$) in SR30 plots, but was maintained in SR15 ones. This decrease could be due to the sorting exerted by lambs which preferred heads while grazing (Brand et al., 1993). The same trend was observed by Yiakoulaki and Papanastasis (2005) who mentioned that sheep grazing on cereal stubble tend to consume heads first. Heads are selected first by sheep because they are higher in energy than the other parts of the stubbles (Houmani, 2002). Leaves proportions were not affected after 14 days of grazing in both SR15 and SR30 plots, while stems proportions increased ($P<0.05$) in SR30.

The observed values of stubble biomass are in the same range of that reported by Valderrabano (1991) and Cabello et al. (1992). It worthy to note that wide variation in stubble biomass amounts were observed in the literature and that several factors could affect the precision of measurements, mainly the size of quadrat.

Table 2. Chemical composition of biomass according to stocking rate and sampling period (% DM).

Variation		S0	S14	SEM	Significance
SR15					
	DM(%)	91.4^{aA}	92.1^{aA}	1.9	NS
	Ash	7.7^{aA}	7.4 ^{aA}	0.16	NS
	CP	4.6 ^{aA}	4.5 ^{aA}	0.12	NS
	ADF	45.3 ^{aA}	47.9 ^{aB}	0.81	*
SR30					
	DM(%)	92.7^{aA}	93.6^{aA}	2.1	NS
	Ash	8.1^{bA}	7.5 ^{aA}	0.27	NS
	CP	5.3 ^{bA}	4.3^{aB}	0.17	*
	ADF	46.6 ^{bA}	48.7^{aB}	0.97	*
SEM					
	DM	1.95	2.4		
	Ash	0.25	0.15		
	CP	0.17	0.10		
	ADF	0.93	0.98		
Significance					
	DM	NS	NS		
	Ash	*	NS		
	CP	*	NS		
	ADF	*	*		

S0: Sampling at 0 days, S 14: sampling after 14 days, a, b, c: Different letters in the same column mean different values; A, B, C: Different letters in the same line mean different values; SEM: Standard error of the mean; *: $P<0.05$.

Indeed, according to Treacher et al. (1996), a comparison of samples cut, using quadrats of 1.0 x 1.0 m (S) and 4.25 x 0.47 m (R), showed a large reduction in the coefficient of variation from 23% with S to 9% with R. The absence of later sampling times in our study did not allow to better understanding grazing evolution. Treacher et al. (1996) conducted a similar experiment on stubble grazing ewes. They noted that heads were selected first and disappeared after 4 to 8 days of grazing at stocking rates of 20 to 60 sheep/ha. They also recorded an increase of stems intake when most of the leaf had been removed. Houmani (2002) mentioned that the consumption of high-energy diets encouraged sheep to consume more stems. When the stems become very hard, sheep then tend to remove leaves.

Chemical composition variation

Nutrient contents of stubble are presented in Table 2. Dry matter proportion of stubble was similar among sampling times and stocking rates. Ash content did not change between S0 and S14 in both SR15 and SR30. However, it decreased ($P<0.05$) with the increase of the stocking rate in S0. Similar trends of contents were reported by Ben Said et al. (2011) in semi-arid regions from Tunisia. CP contents are relatively high in the beginning of the experiment in all the plots comparatively to literature. Indeed, the average content of this nutrient (4.9% DM at S0) is higher than which found by Avondo et al. (2000) for barely stubble (3.4% DM) and values relative to cereal straws (Houmani and Tisserand, 1999). This may be related to the richness of biomass in heads and thereby grains. The CP content was maintained in SR15 treatment, but decreased ($P<0.05$) by about one percentage unit 1% in SR30, 14 days after the beginning of the grazing period. Houmani (2002) conducted a similar experiment on ewes and concluded that the content of CP decreased with grazing frequency by the animals (-1.3 percentage unit), 16 days after the beginning of the experiment. This variation of the CP content of stubble is likely due to its level in grains, which decreases with the grazing duration. Also,the relatively high content of CP, even in the second sampling time, may indicate once more that the studied stocking rates were not very high. Rihani et al. (1991) suggested that the lower is the stocking rate, the higher is the digestibility and the CP content of the stubble.

The content of ADF seems relatively low (averaged 45.9% DM in S0) when compared to that of fibrous

Table 3. Variation in LW according to stocking rate and period (kg).

Variation	Period 1	Period 2	Period 3	SEM	Significance
SR15	-0.61^{bC}	2.05 ^{aA}	0.03 ^{aB}	0.51	***
SR30	-0.11^{aB}	2.07 ^{aA}	-0.4 ^{bC}	0.79	***
SEM	0.22	0.161	0.166		
Significance	*	NS	**		

a, b, c: Different letters in the same column mean different values; A, B, C: Different letters in the same line mean different values; SEM: Standard error of the mean; *: P<0.05; **: P<0.01; ***: P<0.001.

feedstuffs including cereal straws in Mediterranean regions (generally ADF content is above 50%, Susmel et al., 1994). This observation is in line with the relatively high content of CP and confirms the negative correlation between CP and ADF shown by Avondo et al. (2010). The ADF contents of stubble in the 3 plots in the first sampling time are similar (Table 2). In both treatments, ADF content increased by 2.6 and 2.1% units (P<0.05) for SR15 and SR30 plots respectively. This result is related to the changes in botanical composition between the 2 sampling time, exhibiting decreasing trends of head and leave proportions and a decrease in steam ones, mainly in SR30. The higher lignocellulosic fraction in steams comparatively to heads and leaves may be reflected in which of biomass. Our results confirmed the cell wall variation trends observed in Tunisia by Ben Said et al. (2011), for cereal stubble produced in CA condition.

Controversial literature data on the nutritive value of stubble are reported. Some differences are noted comparatively with results found by Ben Said et al. (2011) for barley stubble variation between June and September in Tunisian semi-arid regions and by Avondo et al. (2000) for the same speciesin southern Italy. Chemical composition of cereal stubbles is related to different factors such as region, cereal species and varieties and climate (Rao and Dao, 1994). The compilation of chemical composition results, mainly the relatively high content of CP and the low content of ADF are in line with morphological composition of stubbles which were especially high in heads and leaves as compared to data reported in Cobarellero et al. (1992) and Ben Said et al. (2011). Differences in head proportions are mainly related to the control level of the harvesting process and used machines. Variation in chemical composition between the two sampling times especially noted in SR30 may be due to selective behavior of lambs during grazing, which induced changes in morphological composition of stubbles and thereby in chemical composition (Ben Said et al., 2011). Indeed, animals start the grazing period by sorting heads and then leaves.

Lamb performances

LWG and DLWG according to stocking rate and period are presented in Tables 3 and 4 respectively. During the first grazing period, lambs from the both treatments lost Live weight (P<0.001), but this loss was higher (P<0.05) for SR15 than SR30 group (-610 and -110 g, respectively). The same trend was observed in DLWG (-23.3 and -4.1 g/d, respectively for SR15 and SR30, P<0.05). This result couldn't be ascribed to the nutritive value of stubbles but likely to the initial body conditions of lambs and the first period represents, actually, an adaptation period for experimental conditions. Also, it is not excluded that the sorting by lambs of high amounts of heads and grains in stubble biomass could have induced some digestive disturbances in this first period particularly rich in grains. These hypotheses are confirmed in the second period, since the two groups performed similarly as reflected by the LW (around 2 kg, Table 3) and the DLWG (171 g/d, Table 4). The last finding suggests that the biomass in the plots was not limiting and was sufficient for animals assigned to the two treatments. As expected, in the third period SR15 group conserved their body weights, while SR30 group lost (P<0.001) about 400 g comparatively with the second period (Tables 3 and 4).

Biomass estimation seemed to be in line with sheep performances. In addition, data presented in Table 5 indicated that generally in this feeding system, body state of animals was preserved. Furthermore, animals in both treatments registered a similar total LWG (around 1.5 kg). Thus, stubbles have contributed to safeguard livestock even in absence of supplementation. Similar findings were reported by Treacher et al. (1996) on ewes grazing barley stubbles at different stocking rates.

These results obtained under CA conditions, should be translated in terms of stubble management strategies to comply with CA principles and objectives, including soil cover (Abbas and Zitouni, 2010). Indeed, the effect of livestock is closely related to the rate of vegetation cover before grazing (Masmoudi, 2012), the stocking rate and the duration of grazing. Köller (2003) claimed that livestock could be fully integrated into conservation agriculture, when more than 30% of the residues from the previous cropare left on the ground as mulch. Also, the study of Masmoudi (2012) showed that the integration of livestock at different levels of stocking rates requires a rate of biomass cover higher than 78% before grazing.

Table 4. Variation in DLWG according to stoking rate and period (g/d).

Variation	Period 1	Period 2	Period 3	SEM	Significance
SR15	-23.3 ^{aB}	171.1 ^{aA}	4.7 ^{aB}	43.21	***
SR30	-4.1 ^{bB}	172.8 ^{aA}	-69.05^{bC}	71.22	***
SEM	8.45	13.42	23.77		
Significance	*	NS	**		

a, b, c: Different letters in the same column mean different values; A, B, C: Different letters in the same line mean different values; SEM: Standard error of the mean; *: P<0.05; **: P<0.01; ***: P<0.001.

Table 5. Effect of stocking rate on total TLWG and DLWG.

Variation	TLWG(kg)	DLWG (g/d)
SR15	1.479	32
SR30	1.483	32
SEM	0.61	10

SEM: Standard error of the mean.

Further studies are needed in different conditions and with different crops and animal species before claiming suitable residues amounts, as related to both animal and CA requests.

Conclusions

Irrespective of the stocking rate, lambs grazing barley stubbles for one month and half after harvest were able to meet their maintenance requirements and even to grow at a rate of 30 g/day. Under the experimental conditions of the current work, the two stocking rates resulted in similar performances of Barbarine lambs. This suggests that the available biomass could support higher stocking rates.

Conflict of Interests

The authors have not declaredanyconflict of interests.

ACKNOWLEDGMENT

This study is part of the IFAD-ICARDA CLCA Project. We are in debt to all students who contributed in this experiment

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