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PhD THESIS IN AGRONOMIC SCIENCES

Speciality: Animal Production Sciences

MANAGEMENT OF STUBBLE GRAZING IN CONSERVATION AGRICULTURE CONDITIONS: OPTIMIZATION OF STOCKING RATE AND GRAZING DURATION BY SHEEP

A thesis submitted by

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Dedication

In the name of **Allah**, the Beneficent and the Merciful. Praise and Gratitude be to Allah for upholding me with perseverance, wisdom and strength throughout this journey, and allowing everything to happen miraculously such that this thesis can be finished accordingly.

I dedicate this thesis to my mother **MabroukaJoubali** who shared a dream with me, who has always loved me unconditionally and who encouraged me to achieve my dream. Thank you for your love, wisdom and support.

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TABLE OF CONTENTS

ABSTRACT

In Tunisia, conservation agriculture represents an alternative to the traditional system and becomes a real challenge for farmers thanks to many reasons, such as the preservation of natural resources, the improvement of yields and also the reduction of production costs. However, the integration livestock-conservation agriculture seems difficult and incompatible with the aim of maintaining a "minimal" or "appropriate" cover crop on the soil. This has always been the source of conflict between the use of organic matter to feed the animals or to cover the soil. The development of conservation agriculture and its dissemination requires the resolution of this conflict, particularly in arid and semi-arid regions, where the production of biomass is low. Unfortunately, crop-livestock integration and optimization have been very rarely studied and few data are available in the international literature and even less in the Tunisian context.

The objective of this work was to:

- Study the effect of stocking rate (SR15 and SR30: 15 and 30 ewes / ha respectively) and type of agriculture (Conventional Agriculture: Conv-A vs. Conservation Agriculture: CA) on the dynamic of biomass and the zootechnical parameters of Barbarineewes grazing on durum wheat stubble (Experiment 1) in the experiment station of Bourbiaaand propose a model of livestock / CA integration and pasture optimization.

- Test the defined model through its effects on biomass dynamics, ruminal fermentation parameters and body weight variation of Barbarineewes grazing on durum wheat stubble (Experiment 2) in the experimental station of Bourbiaa.

- Contribute to the development of a practical grazing management tool to satisfy the requirements of CA by testing the 30/30 grazing model on the real conditions of the field.

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The different trials showed that:

- During grazing, the biomass as well as its botanical and chemical composition progress according to the same trend, both in Conv-A and CA. Overall, we didn't note any significant differences between the two stocking rates for biomass dynamic. Also, the ewes conserved their body weight and neither the type of agriculture nor the stocking rate affected the body weight of animals. On the other hand, the blood parameters measured during the first trial were similar between the two stocking rates except for Mg in Conv-A and glucose in CA. Also, we didn't found any significant differences between the two agricultures regarding blood parameters.

- The first trial allowed us to propose a grazing optimization model based on a stocking rate of 30 ewes, for a grazing period of 30 days (model 30/30). This model keeps around 40% of the initial biomass.

- This model tested in the second trial showed that overall, the intensity and orientations of ruminal fermentations were similar between the two types of agriculture.

- Then, we proposed a biomass prediction tool based on grazing duration. This linear model made it possible to predict the % of residual biomass according to the number of grazing days with a good precision (R2 = 0.71 and 0.81 respectively in experimental station and on farm under CA). The prediction of residual biomass (% DM) according to the grazing duration under CA showed a residual biomass of approximately 47.62% and 34.92%, respectively at the experimental station and on farm. The residual biomass found was higher than 30% (An average of about 490 kg DM/ ha in the experimental station), which suggests that the integration livestock/ CA is possible with grazing optimization.

- At the end of this work, we tested the 30/30 grazing model by sheep on the real conditions of the field in the context of conservation agriculture (CA). Results showed that the 30/30 grazing model reveled an average residual biomass left on the soil of about 54.8%. Also, results showed that it's possible to develop a linear model predicting biomass variation according to the duration of grazing for each plant species to be used as a tool for stubble management, but it needs a compilation of higher number of measurements to improve its precision.

Key words: Conservation agriculture, wheat stubble, livestock/ Conservation agriculture integration, biomass, sheep, grazing, performance, optimization.

RESUME

En Tunisie, l'agriculture de conservation représente une alternative au système traditionnel et devient un véritable défi pour les agriculteurs pour des raisons multiples, à savoir la préservation des ressources naturelles, l'amélioration des rendements et aussi la réduction des charges de production. Cependant, l'harmonie et l'intégration élevage-agriculture de conservation, semble difficile et dans certains courent de pensées incompatible avec l'objectif de maintenir une couverture végétale «minimale» ou «appropriée» sur le sol. Ceci a toujours été à l'origine du conflit entre l'utilisation de la matière organique pour nourrir les animaux ou pour couvrir le sol. Le développement de l'agriculture de conservation et sa dissémination nécessite la résolution ou l'atténuation de ce conflit, en particulier dans les régions arides et semi-arides, où la production de la biomasse est faible. Malheureusement, l'intégration et l'optimisation culture-élevage ont été très rarement étudiées et peu de données sont disponibles dans la littérature internationale et encore moins dans le contexte tunisien.

L'objectif de ce travail était de:

- Etudier l'effet de la charge animale (SR15 et SR30 : 15 et 30 brebis/ha respectivement) et des modes d'agriculture (Agriculture conventionnelle : A-Conv vs. agriculture de conservation : AC) sur la dynamique de la biomasse et les paramètres zootechniques des brebis de la race Barbarine pâturant sur chaume de blé dur (Expérience 1) et proposer un modèle d'intégration élevage/AC et d'optimisation du pâturage ;

- Tester le modèle défini à travers ses effets sur la dynamique de la biomasse, la ferlentationruminale et la variation du poids corporel des brebis de la race Barbrinepâturant sur les chaumes de blé dur (Expérience 2) ;

- Contribuer à l'élaboration d'un outil de gestion pratique du pâturage permettant de se conformer aux exigences de l'ACen testant le modèle de pâturage 30/30 sur les conditions réelles du terrain.

Les différents essais ont montré que:

- Durant le pâturage, la biomasse ainsi que sa composition botanique et chimique évoluent à la même allure aussi bien dans le cas de l'A-Conv que dans le cas de l'AC. Globalement, nous n'avons pas noté de différences significatives entre les deux charges animales en ce qui concerne la dynamique de la biomasse. Aussi, les brebis ont conservé leur poids corporel et ni le mode de culture ni la charge animale n'ont affecté le poids corporel des animaux. D'autre part, les paramètres sanguins mesurés lors du premier essai étaient similaires entre les deux charges animales à l'exception du Mg dans l'A-Conv et du glucose dans l'AC. Aussi, nous n'avons pas noté de différences significatives entre les deux types d'agricultures concernant les paramètres sanguins.

- Le premier essai nous a permis de proposer un modèle d'optimisation du pâturage basé sur une charge animale de 30 brebis, pour une durée de pâturage de 30 jours (modèle 30/30). Ce modèle permet de garder environs 40% de la biomasse initiale.

- Ce modèle testé lors du deuxième essai a montré que globalement, l'intensité et les orientations des fermentations ruminales étaient similaires entre les deux types d'agriculture.

- Aussi, nous avons proposé un outil de prédiction de la biomasse à partir de la durée du pâturage. Ce modèle linéaire permettait de prédire le % de biomasse résiduelle en fonction du nombre de jours de pâturage avec une bonne précision (R^2=0,71 et 0,81 respectivement en station expérimentale et en ferme sous AC). La prédiction de la biomasse résiduelle (% MS) en fonction de la durée de pâturage sous AC a impliqué une biomasse résiduelle d'environ 47,62% et 34,92%, respectivement en station expérimentale et en ferme. La biomasse résiduelle trouvée était supérieure à 30% (soit une moyenne proche de 490 Kg MS/ha en station expérimentale), ce qui suggère que l'intégration Elevage/AC est envisageable moyennant une optimisation du pâturage.

- A l'issue de ce travail, nous avons testé le modèle de pâturage 30/30 dans les conditions réelles du terrain dans le cadre de l'agriculture de conservation (AC). Les résultats ont montré que le modèle de pâturage 30/30 révélait une biomasse résiduelle moyenne d'environ 54,8%. De plus, les résultats ont montré qu'il est possible de développer un modèle linéaire prédisant la variation de la biomasse en fonction de la durée du pâturage pour chaque espèce végétale à utiliser comme outil de gestion des chaumes, mais il a besoin d'une compilation d'un nombre plus élevé de mesures pour améliorer sa précision.

Mots clés: Agriculture de conservation, chaumes de blé, intégration élevage-AC, biomasse, ovin, pâturage, performance, optimisation.

التّلخيص

تمثّل الزراعة الحافظة في تونس بديلاً للنظام التقليدي وقد أصبحت تحديا حقيقيا للمزارعين لأسباب متعددة وهي الحفاظ على الموارد الطبيعية ، وتحسين المردود ، وكذلك التخفيض من تكاليف الإنتاج. في حين أنّ اندماج الماشية و الزراعة الحافظةيبدو صعباً و عند البعض يتعارض مع هدف الحفاظ على الغطاء النباتي "الأدنى" أو "المناسب" على الأرض.
و يعد هذا دائما هو السبب الرئيسي للتعارض بين استخدام الكتلة النباتيّة لإطعام الحيوانات أو تغطية التربة.
إلاّ أنّ هذه الإشكاليّة لم تحظى بدراسات علمية و حقلية كافية تمكن من ترشيد إدماج تربية الماشية في الزراعة الحافظة والملائمة بين الإنتاج النباتي و تربية الماشية. إذ قلّما نجد بيانات علمية منشورة في هذا المجال على المستويين الدولي و المحلي.
يهدف هذا العمل إلى:

- دراسة تأثير الثقلالرعوي (15 و 30 نعاج / هكتار) وأنماط الزراعة (الزراعة التقليدية و الزراعة الحافظة) على تطور الكتلة النباتيّة و مؤهلات النعاج التي ترعىمحاصد القمح (التجربة 1) واقتراح نموذجاندماج بين الماشية و الزّراعة الحافظة

- اختبار النموذج المحدد من خلال آثاره على تطور الكتلة النّباتية ، والهضم في الكرش و تطور وزن النعاج التي ترعى محاصد القمح (التجربة 2)

- و في مرحلة ثالثة قمنا باختبار نموذج الرعي 30/30 من خلال تجربتين حقليتين بحيث اختبرنا هذا النموذج لدى مزرعتين كبيرتين من ولاية سليانة و قمنا كذلك بمحاكاة هذا النموذج لدى عدد من الفلاحين من ولايات مختلفة

أظهرت مختلف التّجارب أنّ:

- أثناء الرّعي ، تتطور الكتلة الحيوية وكذلك تركيبتها النباتية والكيميائية بنفس الوتيرة بالنّسبة للزراعة التقليديّة والزراعة الحافظة . بشكل عام، لم نلاحظ أي فروق بين الأثقال الرعويّة فيما يتعلقبتطور الكتلة النباتيّة. إضافة إلى ذلك حافظت النّعاج على وزنها ولم تؤثر أنواع الزّراعات و لا الثّقل الرّعوي على وزن الحيوانات. من ناحية أخرى ، كانت مكوّنات الدّم التي تمّ قياسها خلال التّجربة الأولى متشابهة بين الأثقال الرعويّة باستثناء المغنيسيوم في الزّراعة التّقليديّة والجليكوز في الزّراعة الحافظة. أيضا، لم نلاحظ أي فروق بين نوعي الزراعة فيما يتعلق بمكوّنات الدّم.

- سمحت لنا التجربة الأولى باقتراح نموذج تحسين للرعي يعتمد على معدل ثقل رعوي يبلغ 30 نعجة، لفترة رعي تبلغ 30 يومًا (نموذج 30/30). يحتفظ هذا النّموذج بحوالي 40٪ من الكتلة النباتيّة الأولية.

- أظهر هذا النموذج الذي تمّ اختباره في التّجربة الثانية، بشكل عام، أنّ اتّجاهات التخمّر كانت متشابهة بين هذين النّوعين من الزراعة.

-اقترحنا أداة تحدّد كميّة الكتلة النباتيّة اعتمادا على مدّة الرّعي. مكّن هذا النموذج من تحديد نسبةالكتلة النباتيّة المتبقيّةوفقا لعدد أيّام الرعي في إطار الزّراعة الحافظةو قد قدّرت الكتلة النباتيّة المتبقيّة بحوالي 47.62٪ و 34.92٪ ، على التّوالي في المحّطة التجريبيةوفي المزرعة أي أكثر من 30٪ (و هو ما يقارب 490 كلغ / هكتار في المحّطة التجريبية) ، ممّا يشير إلى إمكانيّة إندماجالماشية و الزّراعة الحافظة عن طريق تحسين الرعي.

في نهاية هذا العمل ، اختبرنا نموذج الرعي 30/30 في الظروف الحقيقية للحقل في نطاق الزراعة الحافظة. أظهرت النتائج أن نموذج الرعي 30/30 أظهر متوسط الكتلة النباتيّة المتبقية على التربة بحوالي 54.8٪. أظهرت النتائج أيضًا أنه من الممكن تطوير نموذج يحدّد تغيّر الكتلة النباتيّة وفقًا لمدّة الرعي لكل نوع نباتي، لكنه يحتاج إلى تجميع عدد أكبر من القياسات لتحسين دقته.

الكلمات المفاتيح: الزّراعة الحافظة،محاصد القمح ،اندماج الماشية والزّراعة الحافظة ، الكتلة النباتيّة ، الأغنام ، الرّعي ، الأداء ، التّحسين.

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

LIST OF ABBREVIATIONS

ADF : Acid detergent fiber
ADG : Average daily gain
BW : Body weight
BWC : Body weight change
C_2 : Acetic Acid
C_3 : Propionic acid
C_4 : Butyric acid
CA : Conservation agriculture
Ca : Calcium
CF : Crude fiber
Conv-A : Conventional agriculture
CP : Crude protein
CTAB : Bromine, cetyltrimethylammonium
DCP : Digestible crude protein intake
DLWG : Daily live weight gain
DOM : Digestible organic matter intake
GC : Gas chromatography
GLM : General linear model
K_2CO_3 : Potassium carbonate
LW : Live weight
Mg : Magnesium
N : Nitrogen
NaOH : Sodium hydroxide
NH_3-N : Ammonia nitrogen
OM : Organic matter
SAS : Statistical analysis software
SEM : Standard error of the mean
TA : Conventional tillage
VFA : Volatile fatty acid

GENERAL INTRODUCTION AND PROBLEMATIC

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The majority of cereals in Tunisia are cultivated in semi-arid climates, which are marked by a high daily temperature range, with hot summers and cold winters, and a low annual rainfall (200 to 400 mm/year) with an irregular monthly distribution. Tunisia is among the most vulnerable countries to the impacts of climate change (Vicente-Serrano, 2006) and has been described as a "hot spot of climate change" (Giorgi, 2006).Water scarcity, even in the absence of climate change, will be one of the most critical issues facing North African countries (especially Tunisia) in the future decades (Ashton, 2002). Indeed, water is the center of the main expected impacts of climate change on natural resources in the Mediterranean (El-Quosy, 2009). Results of the climate simulations made by GTZ (2007), according to the scenarios of the Intergovernmental Panel on Climate Change (IPCC), have shown that the expected effects of climate change in Tunisia will be as follows: i) the average annual temperature will increase by 1.1 ° C by 2030 and a potential temperature increase of 1.3 to 2.5 ° C will be noticed by 2100, ii) Drought intensity will increase, iii) 28% of water resources will decrease by 2030 and in particular groundwater reserves, and iv) 20% of useful agricultural areaswill be lost in 2030. In Tunisia's semi-arid regions, water availability is the main factor limiting the production of cereals including durum wheat. In these areas, durum wheat yield is strongly influenced by climatic conditions, including annual rainfall and distribution over the grain growing cycle. In this context, conventional farming accentuates this critical situation. Indeed, conventional tillage affects the soil quality; it has a negative impact on physical, biological and chemical proprieties of soil which reduces the productivity and the sustainability of agriculture. Tillage systems cause runoff and soil erosion. It also reduces crop residues, which helps to dampen the force of falling raindrops. Without crop residues, soil particles are more easily dislodged, displaced or "splashed". This process is just the beginning of the problem. Splattered particles clog the pores of the soil, isolate the soil surface and cause poor water infiltration. The amount of soil lost each year is directly linked to levels of crop residue remaining on the soil surface, soil structure and the intensity of tillage practice. If frequent tillage lasts several years, the impact becomes even more serious. A total decomposition of the structure and the overall quality of the soil is almost assured. A hardpan can develop, effectively cutting off root elongation and affects the development of crop and yield. Producers who reach this point may face high erosion rates and topsoil degradation, where almost all organic matter is found. The removal of topsoil by erosion leads to the loss of inherent soil fertility. While producers can provide the nutrients needed for crops to compensate for the inherent loss of fertility, the productivity of eroded soils can be restored by adding inputs only in the presence of favorable subsoil materials. In case ofunfavorable basements (limited rooting depth, coarse sand and gravel, or high soil densities), the ability to recover yield losses is low or non-existent. The impact on quality and the productivity of the soil is devastating and definitive. Excessive tillage can also deteriorate the overall quality of surface water. Sediment from soil erosion is a major pollutant for water quality. Sediments also transport phosphorus and nitrogen from the fields to lakes and streams, causing the phenomenon of "eutrophication" which represents an important problem in the quality of surface water. Conventional agriculture is a costly system which requires a lot of material resources in terms of soil productivity, soil quality, surface water quality, machinery and other labor requirements. Because of these negative impacts of conventional tillage, farmers are facing a critical situation and try to find an alternative to conventional agriculture which preserves the soil and ensures the sustainability of agriculture. In this context, conservation agriculture represents a solution to this situation.

No-tillage system contributes to the reconstitution of the soil, enhances its quality andimproves profits (Dumanski et al., 2006). The main features of CA production systems are crop yield optimization, farm income, and the reduction of the negative ecological effects of conventional agriculture. Conservation agricultural system is a concept that based on using herbicides in order to control weeds. It's also essential to reduce the production costs and the negative impact of tillage system (Basch*et al.*, 2012). In addition, conservation agriculture enhances water quality, reduces soil erosion and decreases GHG emission which are not possible in tillage system (Kassam *et al.*, 2010). Under CA, the control of weeds is ensured by the use of herbicides especially glyphosate. Actually, CA or No-tillage system is considered as a crucial step for farmers to ensure the sustainability of agriculture. The adoption of CA is well developed in America. However, the lowest adoption is in Africa in spite of the critical climate in African countries. Europe represents a low adoption of no-tillage system but it is higher than African regions. In Europe, the areas under reduced tillage (RT) are more than ten times higher than no-tillage or zero tillage(Basch*et al.*, 2008). The management of agroeco-systems is based on CA in order to enhance the productivity and ensure the sustainability Add to that, it increases profits, ensures the food security and preserves natural resources and the environment. CA is defined as a no-tillage system that preserves 30% of residues on soil surface. Conservation agriculture represents a method of seedbed that consists in preserving crop residues on soil surface which improves the soil quality, reduces erosion and increases soil organic carbon. The preservation of cover crop on soil represents a challenge for farmers thanks to its positive impacts.

Livestock represents an essential component in farming system especially in arid and semi-arid regions suffering from climatic change, erosions, increase of population and low productivity. In addition, livestock represents a source of income. The integration of livestock under conservation agriculture has several positive impacts: the diversification of inputs; the recycling of nutriments; the improvement of cultural rotations; the preserving of energy and the reduction of environmental problems caused by concentrated intensive livestock production (FAO, 2006). However, there is a problem between the use of crop residues to feed animals or to cover the soil. This conflict must be resolved and some studies suggested solutions in order to ensure the integration crop-livestock under conservation agricultural (CA) system. Unfortunately, the crop-livestock interaction in conservation agriculture has rarely been studied and few data are available in literature. In the current study, we tried to highlight the importance of livestock in CA, to propose benefits of this integration, to find compromise between soil covering and livestock feeding and to predict the residual biomass which must be left on soil as well as the stocking rate and the grazing duration using a stubble management tool .

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PART I: BIBLIOGRAPHICAL STUDY

CHAPTER I. SHEEP POPULATION AND BREEDING SYSTEMS IN TUNISIA

I. Introduction

Until the 1970s and 1980s, livestock breeding in the Maghreb was mainly extensive, of the pastoral type (Bourbouze, 2006). This Maghreb pastoralism was marked by the mobility of herds and men as well as by the persistence of a collective use of spaces (Bourbouze, 2000). Many factors are at the origin of the evolutions of this breeding, such as the climate, the anthropic activities, or the social changes. For example, in Tunisia, linked to population growth and climate change, rangelands decreased by 20% between the 1980s and 2000s(Kayouli, 2000). The scarcity of these resources, however, has not led to a decline in animal numbers, on the contrary. From 1960 to 2000, the sheep population has tripled to reach seven million (Elloumi et al., 2011). It has created an imbalance between the needs of the livestock and food availability allowed by the course. The practice of transhumance has been significantly reduced due to the extension of crops. The reduction of mobility has led farmers to practice long-term grazing sequences on the same rangeland, which can cause adverse changes in the natural vegetation. Climate and management changes in other parts of the world have contributed to the desertification of pastoral areas, hence the importance of adapting ruminant farming systems. The use of rangelands remains a suitable strategy for livestock farming in arid and semi-arid areas with high climatic variability (Ruppert et al., 2015). The supplementation can be achieved both by resources forage crops or the use of concentrates. The later is now very practiced in the Maghreb (Bourbouze, 2006). On the other hand, the development of grassland-based systems seems limited (van Vuuren and Chilibroste, 2013).Tunisia maintains a fairly varied sheep breeding and it is widely distributed throughout the national territory. However, despite its importance and its contribution to the satisfaction of an ever-increasing demand for red meat and the income security of a large part of the peasant population, this type of breeding remains the business of the farmers without or with little soil.In many small farms, sheep farming is often the only means of livelihood for the family.However, the small size of farms, the transformation of production systems (planting olive trees), the loss of grazing land (reduction of rangelands, the disappearance or reduction of fallow land) and the succession of several years of drought make it virtually impossible to increase animal performance. Thus, sheep meat production remains less intensive than milk and beef production. These factors are combined with the weakness of the economic organization within the sheep industry, to constitute an obstacle to the development and promotion of this production. In fact, the sheep meat trade is made up of a live circuit in Tunisia that uses traditional channels (Hammami et al., 2007).

II. Sheep population composition in Tunisia

1. The different sheep breeds in Tunisia

1.1.Barbarine sheep breed

The Barbarine breed originates from the Asian steppes. According to Mason (1967), this breed was introduced in Tunisia by the Phoenicians 400 years before Jesus Christ. It is known under the pre-nomination of “Arab sheep”. It is definitely installed in Tunisia from the year 1050 (Khaldi, 2004 in: Bedhiaf-Romdhani S., 2008). It is distributed in all the bioclimatic regions of the country from the North to the arid and desert. It presents a white coat with a head black, red or very rarely white. The head is medium with large horns in the male and they are absent in the female, and it has semi-horizontal ears. The profile is straight, slightly convex in the male (Tlimate, 1996 ; Ben Gara, 2000). This breed is also characterized by the presence of a tail where reserves are accumulated as fat. It has the ability to easily mobilize its reserves during the periods of food shortage. According to Khaldi (1984), the body weight varies between 45 and 55 kg for females and between 65 and 80 kg for males. The height at the withers is between 55 and 70 cm for females and between 60 and 80 cm for males (Ben Gara, 2000). A Barbarine ewe produces 0.85 lambs annually in the north and 0.7 lambs in the center and the south. When the food is available, fertility can reach 95% and prolificacy 125% (Ben Hamouda, 1981). Under these conditions, the productivity per ewe can then reach 1.2 lambs / year. Sheep are generally culled after five productions (Photo 1) (Ben Gara, 2000).

Photo 1: Barbarine sheep breed

1.2. Queue Fine de l'Ouest sheep breed

The Western Fine Tail breed is also called "Bergui", from Algeria named "Ouled Djellal" and currently located in the western region of Tunisia (Khaldi et al, 2010). It's characterized by long legs. The coat is usually white, sometimes mottled brown, with a fleece that is less widespread than in the Barbarine race but more homogeneous and fine (Photo 2). The height at the withers is from 60 to 70 cm. The body weight of rams is between 65 to 80 kg and that of females is between 45 and 55 kg. The head is medium, devoid of horns. It has a long and almost drooping ears. The neck is moderately long and well attached. The body is cylindrical and the tail is thin from its base to its tip. (Ben Hamouda, 1981).

Photo 2: Queue Fine de l'Ouest sheep breed

1.3. Noire de Thibar sheep breed

This breed was the result of a crossing between the Queue Fine de l'Ouest and the Merino of Arles breeds at the beginning of the 20th century. It is presented in Tunisia and the Middle East, in the Medjerda basin and in Beja. It is a slaughter animal, which has a medium size, a thin tail and coarse wool. This breed has an elongated head without horns. It has also a thin, horizontal or slightly erect ears and a black fleece (Photo 3) (Tlimate, 1996). The adult weights range from 50 to 60 kg and 70 to 80 kg respectively for females and males. This breed has a characteristic of black coat and a small size compared to other breeds of sheep. The prolificacy rate is from 110 to 120% and the average daily gain reaches 220g. The wool production is between 2 and 5 kg per fleece.

Photo 3: Noir de Thibar sheep breed

1.4. The Sicilo-Sarde breed

This breed is located in the Northern regions of the country (Beja and Bizerte). It results from crossing between Sarda and Comisana dairy sheep (Photo 4). It is the unique dairy breed in Tunisia and is located in humid and semi- humid regions. The weight of the female is 45 kg and 70 kg for the male. The height at the withers varies between 60 and 80 cm. Sicilo-Sarde breed is characterized by a low milk productivity, which varies between 60 and 120 kg/year (Moujahed et al 2009), largely related to a rather traditional management, with a mixed type of exploitation (milk and meat) characterized mainly by a low feeding level and a mode of late weaning. Indeed, feeding is based on pasture (stubble, barley, pasture), with frequent use of hay, straw and concentrates during the periods of feed deficit (Rouissi et al 2008). Moujahed et al. (2009) found that in most of Beja Sicilo-Sarde farms, whatever the mode of feeding, milk production is low compared to the original breeds or dairy sheep in the Mediterranean basin. In addition, this production is limited, even under conditions where food resources are not limited. This seems to suggest a low genetic potential of the herds. On the other hand, the chemical composition of milk, particularly, fat and protein, is in the range of the values corresponding to Mediterranean dairy breeds.

Photo 4: SiciloSarde sheep breed

2. Evolution of sheep population in Tunisia

Since the beginning of the 1960s, there has been a steady increase of the sheep population which attended 4.096 million ewes in 2008 (Figure 1). During the last decades, the sheep population fluctuated. Indeed, it decreased from 4.096 to 3.841 million ewes between 2008 and 2013. In 2014, the sheep population registered a slight increase and reached 3.889 million ewes. During the next three years, the sheep population registered a decrease to attend 3.737 million ewes in 2017. In 2018, the number of ewes was estimated at 3.800 million female units, registering therefore a slight increase of about 2% compared to the previous season (OEP, 2018). Sheep farming in Tunisia is fairly distributed throughout the national territory. Data from the 2004/2005 Structure Survey indicate that 37% of them are in the North, 39% in the Center and 24% in the South. This distribution shows that the highest concentration rate is found in the Center and the South (63%). However, these two large regions are marked by insufficient rainfall and poor water resources for irrigation (OEP, 2018).

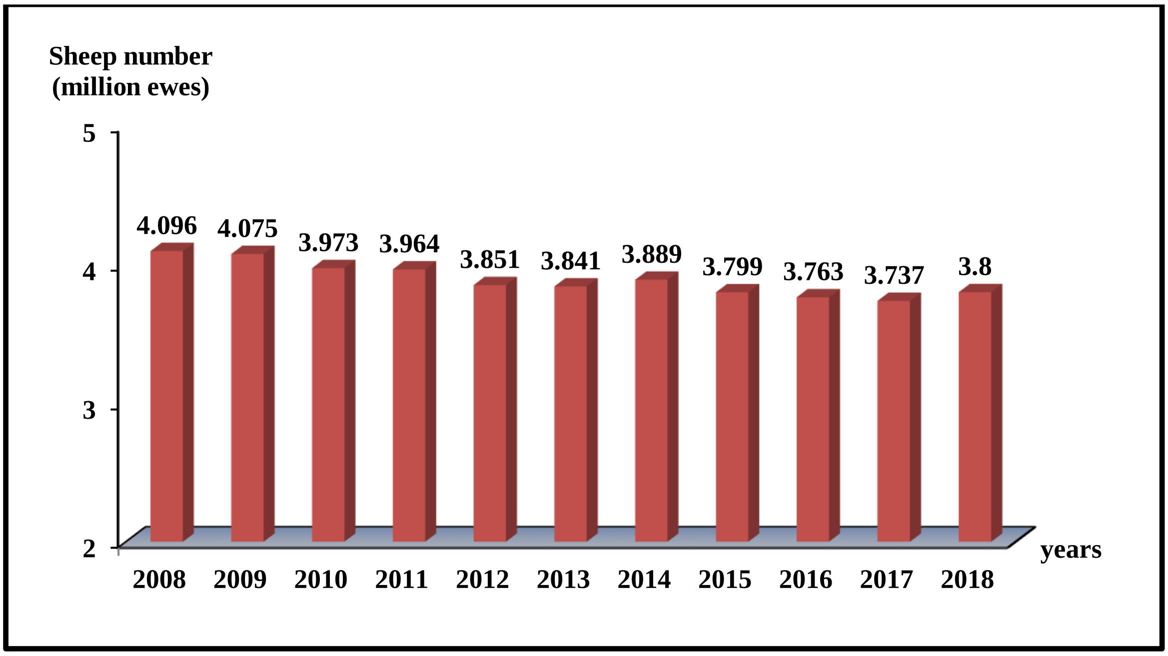

Figure 1: Evolution of sheep population in Tunisia between 2008 and 2018

3. Distribution of sheep farming in Tunisia

In Tunisia, the sheep breeding is distributed throughout the country. Nearly 60% of the national sheep population is composed of Barbarine breed and 35% of Western thin tail, while Noire de Thibar represents only 5%. In 2018, it was noted that the number of ewes in Tunisia is distributed according to these bio-geo-climatic stratas (38% in the North, 42% in the Center and 20% in the south (Figure 2), with specific farming system adapted to each region (DGEDA, 2018).

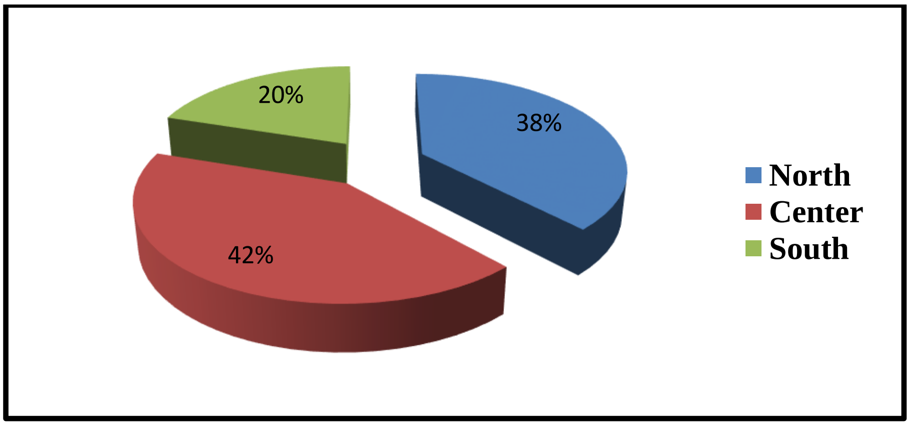

Figure 2: Geographical distribution of ewes in Tunisia

4. Sheep meat production, consumption and marketing in Tunisia

4.1. Sheep meat production

The production of sheep meat during the last decade fluctuated. The highest quantity was registered in 2019 (52.92 thousand tons) and the lowest one was registered in 2013 (48.5 thousand tons). In 2018, the production slightly decreased to attend 50.6 thousand tons as compared to 2017 (Figure 3). The fluctuations of sheep meat production is related to several factors such as the fragility of the small size heards, the transformation of the production systems (plantation of olive trees), the loss of natural grazing areas (reduction of the rangelands, the disappearance or reduction of the fallow land) and the variations of the climatic conditions with succession of several years of drought. All these factor make it very difficult to get substantial increase of animals' performances (Hammami, 2007).

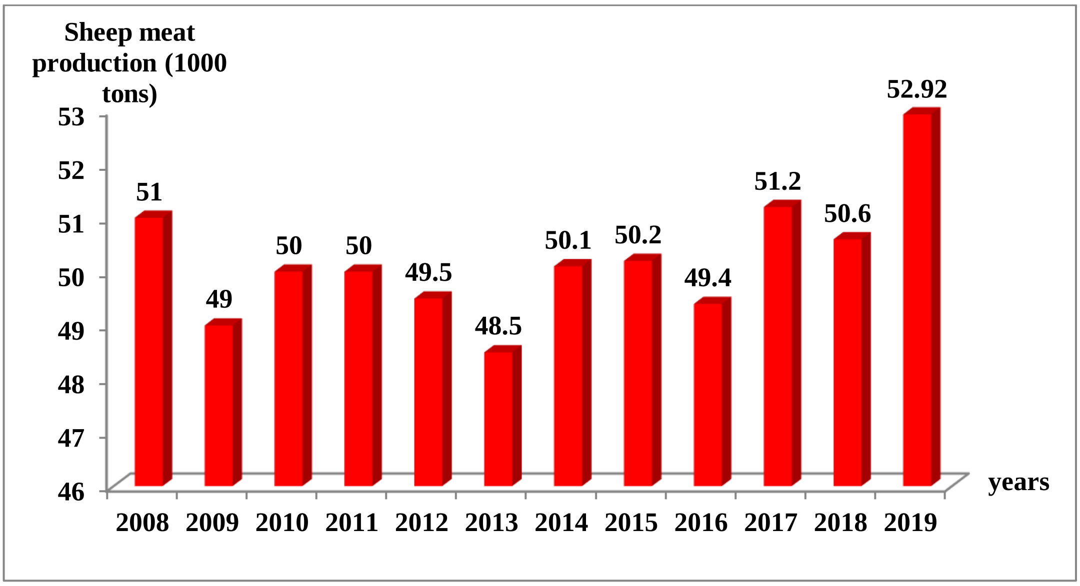

Figure 3: Evolution of the production of sheep meat in Tunisia (DGPA, 2019)

4.2. Consumption of sheep meat in Tunisia

The consumption of sheep meat in Tunisia fluctuated also from one year to another. In 1985, the registered consumption was about 5.2 kg/person/year. This level decreased to attend 2.9 kg/person/year in 2000. In 2005, the consumption of sheep meat registered a slight increase (3.3 kg/person/year) and then decreased again in 2010 (2.9 kg/person/year). However in 2015, the consumption of sheep meat increased to reach 3.9 kg/person/year (Figure 4). Generally, these low consumption levels are linked to several factors such as the changes in consumption tithe last years, to the increase of the selling prices of meat in relation with the increase of production costs and the absence of classification criteria of meat pieces. In addition, these conditions were compounded by the development of the poultry industry which in 2014 represented 60% of the overall marketed meats (200 thousand tons). Indeed, white meats are marketed with affordable prices and pieces are categorized, which promoted their consumption instead of the red meat (INS, 2015).

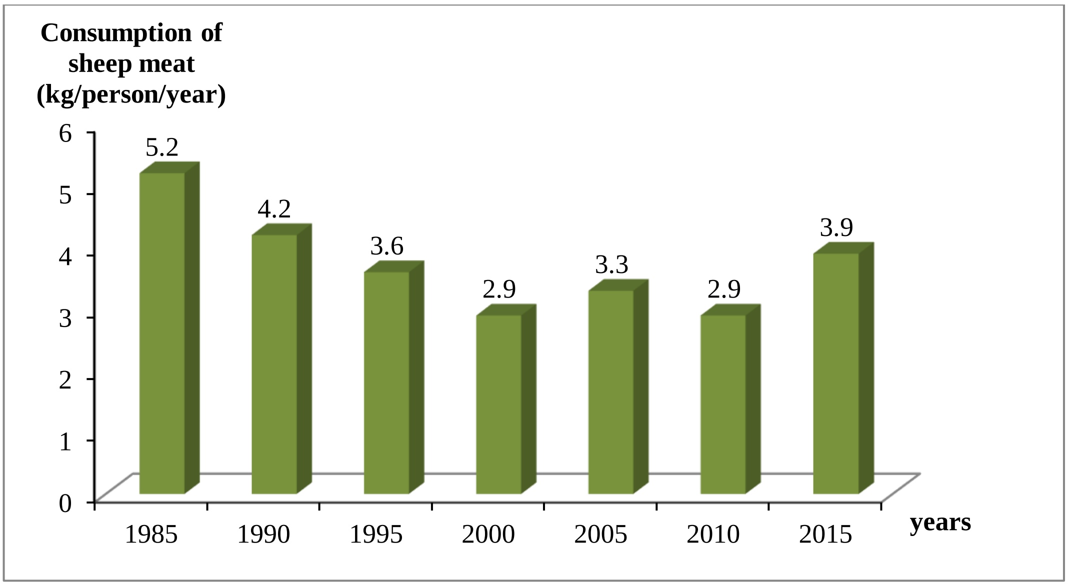

Figure 4: The consumption of sheep meat in Tunisia

4.3. Sale prices of sheep meat

The sale price of sheep meat increased during the last years. In 2008, the registered sale price of lamb meat was about 5 Dt/kg of LW and then it increased to attend 11.1 Dt/kg of LW in 2019 (Figure 5).

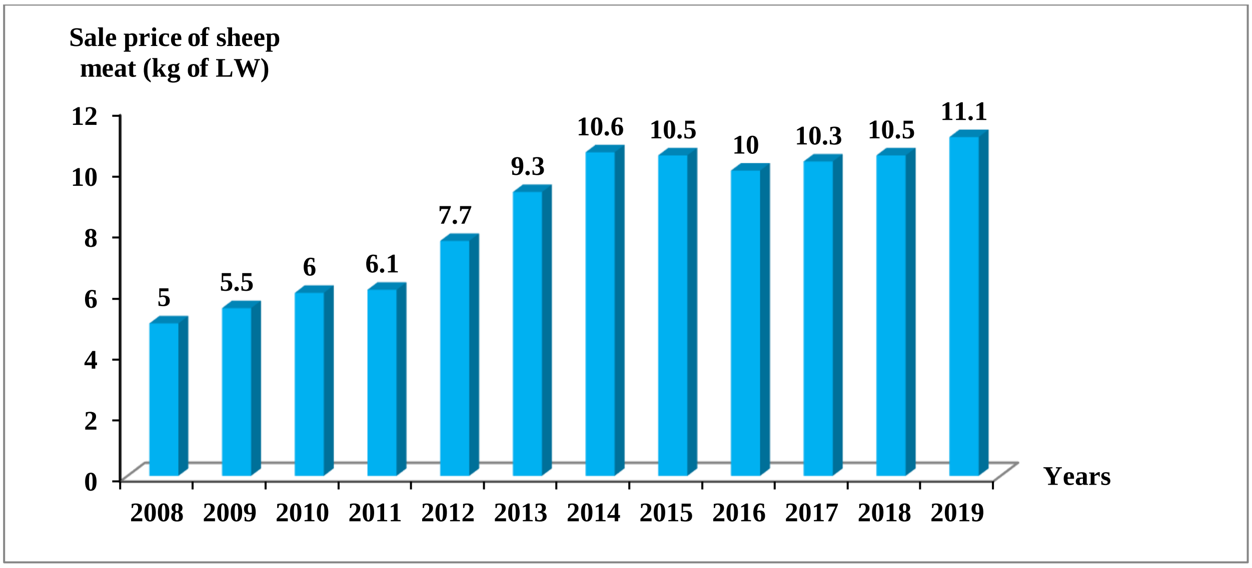

Figure 5: Sale price of sheep meat (ONAGRI, 2019)

III. Sheep breeding systems in Tunisia

1. Problems of feed availability for sheep

Sheep farming, generally conducted extensively, is mainly located in small and medium family farms. Livestock feeding is based mainly on pastoral resources, but the area of rangelands has recorded an alarming decrease, largely as a result of agricultural intensification: Extension of cereals and arboriculture, as well as market gardening on developed and irrigated areas. The lack of fodder generally reserved for cattle, its poor quality as well as the decrease of the contribution of pastures and rangelands in the feeding scheduleresult in a massive use of concentrated feeds for ruminants, particularly dairy cattle, but also sheep and goats at 33% (CNEA, 2005).

1.1. Rangeland degradation

Pastoral areas generally intended for exploitation by sheep herds are threatened with degradation and desertification. The consequences and the quantification of these two phenomena are presented in Table 1.The result is an alarming reduction in the area of rangelands in the north, center and south of the country.Indeed, the contribution of rangelands in the feeding scheduledropped dramatically (-39% between 1964 and 1990) thus creating an imbalance between animals' requirements and the number of forage units allowed by these resources (Kayouli, 2000) and an increase of stocking rate per hectare. In fact, Tunisia has the highest density in Africa for sheep farming: 40.3 sheep/ km2 (Snoussi and M'Hamdi, 2008).

Table 1: Problem of desertification and the quantification of rangeland degradation phenomenon

(MARHP, 2010)

Threatened area	Geographical location	Causes of desertification	Phenomena of desertification	Land degradation process	Consequence of desertification	Quantification of degradation
4.5 M ha of rangeland	North	inappropriate exploitation	Degradation of rangelands quality	rarefaction of palatable species	Reduction of rangeland area	Flora degradation
	Center	Overgrazing Livestock size Drought	Regeneration deficit of vegetation cover	Decrease of the production/ ha	Destabilization	Overexploited areas
	South	Land clearing and cultivation technique	Destabilization of the soil	Fragility	Erosion	Nb. ha cereals / year

1.2. Restricted use of fodder in small ruminants

Livestock development has not had a ripple effect on forage production, both quantitatively and qualitatively. These crops are primarily intended for feeding cattle even in large farms with large sheep herds. Fodder, used as silage, hay and green do not exceed 10% of total UAA. Silage has not developed sufficiently, despite all the popularization that has been devoted to it. According to Djemali and Kayouli (2003), the areas reserved for silage represent only 4% of the total forage area. Fodder is the subject of excessive speculation which imposes considerable costs on productions in the dry season. Forage prices, including hay and straw, are determined by the market; when the supply is abundant, in the rainy year, these prices decrease appreciably, but they record excessive increases during the years of drought, especially when it is prolonged over two and sometimes even three successive years (Khaldi et al, 2008). The price of the fodder unit for fodder and straw can reach, in difficult seasons 5 to 8 times more than the barley forage unit (benefiting from a floor price) for the concentrate feed, which exerts a great pressure on this commodity and become the object of speculative maneuvers (CNEA, 2005). The prices of a hay bale in April 2018 increased compared to those of the same period in 2017. This increase affected all regions with an increase of about 27% in the North and 30% in the Sahel, Central and South regions. Noting that the prices of a hay bale in April 2018 varied according to regions between 7.5 DT and 13 DT (Flehetna, 2018). This could explain the choice of farmers to devote almost all the quantities of roughage to cattle breeding. The use of hay in the feeding schedule of sheep is adopted only during critical physiological periods. Nationally, the areas under forage production have declined significantly from 392,000 to 300,000 hectares, during the period between 1996 and 2003 (Snoussi and M'Hamdi, 2008). Currently, these areas remain limited and develop very slowly. They are in the order of 319 200 ha in autumn 2017 including 45 000 irrigated hectares. Indeed, agricultural policies have rather privileged the cereals sector at the expense of the forage sector. It was not until 2002 that forages were considered a strategic production hence the renewal of the pastoral strategy for a new decade (2002-2011). According to Kayouli (2000), the limited development of forage crops could be explained by their lack of diversity. In fact, cereal fodders (oats, barley) are usually used alone or mixed with vetches (Vicia sativa). The limited size of smallholder farms also makes the mechanization difficult, which prevents small and medium farmers to grow fodder. Add to these factors, the use not only of imported seeds, which are often not adapted to local conditions, but also of raw materials used in the manufacture of concentrate for ruminants, especially dairy cattle. This limits the development of forage crops.

1.3. The use of concentrate feed

The use of concentrated feed is especially justified by fluctuating, low and undiversified national forage production. Due to the lack of local raw materials, these concentrated feed heavily rely on imported ingredients including corn, soybean meal and barley. The quantities of imported raw materials vary according to several factors, the most important of which is the climatic one, which conditions in part the resources available locally and consequently the quantities needed to fill the gap in livestock requirements. Imports of raw materials mainly for livestock feed mainly concern barley, corn and soybean meal (Brahmi et al., 2010).

2. Livestock production systems of sheep farming in Tunisia

Despite many constraints, breeding allows Tunisia to achieve its goal of self-sufficiency in milk and meat. But unlike milk, the gap between meat production and the actual or potential requirements now is the main structural component of the deficit in animal production.

Successive droughts, the dispersion of farms, their border crossing to Libya and Algeria, the small size of herds and the very high proportion of uncontrolled slaughter of young animals and especially of productive females explain this deficit.

The grain barley subsidy policy was adopted to safeguard the herd during the drought season at the start and the maintenance of animal resources afterwards, in order to ensure tolerable prices of food resources. This strategy ensures the maintenance of livestock during the years of scarcity (Darghouth and Gharbi, 2011). The constant and significant use of concentrates has led to an increase in the sheep population which is no longer correlated with the availability of natural resources.

Currently, there are three main farming systems for ruminants:

2.1. Extensive livestock farming

Herds are conducted in a traditional way. Grazing is the main source of food. This dominant mode of farming includes three types of herds: family, farm and transhumant:

- Family herds, small-sized (10 animals at most), concentrated around towns and villages. These herds do not have pasture areas except in summer when they graze on the stubble.
- Farm herds, medium-sized, are sedentary and graze on rangelands generally owned by the farmer. They are often driven by shepherds.
- Transhumant herds are often large-sized. Transhumance is an economic choice that owners adopt to deal with different problems caused by lack of food. The movement is exclusively towards the north of the country, where food availability is better (Djemeli et al., 1992).

2.2. Intensive livestock farming

Herds are conducted under an improved aspect. This improvement concerns both fodder rangelands by using various forage crops and the conduct of reproduction (Sayari, 2005).

2.3. Integrated livestock farming

These are farms geared towards the production of milk and meat. Fodder is grown under irrigated or dry conditions. The oasis system falls into this category. Concentrates are self-produced or purchased from the outside. In the cereal plains areas of the North, large herds predominate. They are more than 100 heads of sheep; usually belong to large private farmers or to farms in the organized sector (cooperatives, agribusiness, pilot farms, Value Enhancement and Agricultural Development Company). The existence of these herds is linked to the presence on the one hand, of the fallow in the rotations and on the other hand to cereal farming which allows to complete the forage calendar in the plain. Some farmers with few rangelands often resort to the transhumance or renting farms (FAO, 2001).

IV. Conclusion

In Tunisia, sheep farming plays an essential role in the social and economic level. Barbarine sheep breed occupied the greater place. However, sheep farming has known several changes during the last decade because of to climatic, economic, social and environmental factors (Ben Salem, 2011).These changes have mainly resulted in the transition from an essentially pastoral system based on extensive use of rangelands by livestock to more complex production systems integrating livestock with cropland in addition to rangeland (Rekik and Ben Hammouda, 2000; Jemaa et al., 2016). These changes differ from one region to another.

This evolution has led to a greater integration of livestock in forage and cereal crops, as well as a trend towards greater integration of sheep into irrigated systems. In the central and southern regions, the process of evolution has resulted in the substitution of the pastoral system by the agro-pastoral system, which is more dependent on the use of concentrated feeds(Elloumi et al., 2011).

However, in the recent years, sheep breed in Tunisia is faced with several difficulties and has seen a steady decline due to many economic, technical and social factors. The degradation of pasture and rangeland has increased and affected as a consequence the sheep population in Tunisia. In this case, an efficient management strategy of sheep farming is an essential step to enhance livelihood of the rural population. However, farmers adopt different herd management practices; their amelioration should be well targeted taking into account the great diversity and specific characteristics of existing production systems. For this reason, a typology of these systems, as well as their respective feeding strategies through Tunisia, is absolutely necessary.

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CHAPTER II. CONSERVATION AGRICULTURE AND LIVESTOCK INTERACTION: CURRENT CHALLENGE

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Abstract

The availability of food presents a major constraint, especially for sheep and cattle farming in the arid and semi-arid regions of the Mediterranean where cereal monoculture dominates. The climatic variability is at the origin of the low production of biomass and especially due to its spatiotemporal irregularity. To increase the biomass yield produced, soil moisture must be increased and managed. This can only be achieved by increasing the organic matter of the soil which needs to keep a permanent cover crop on soil surface. The integration of livestock into cereal farming is based mainly on grazing of stubble and crop residues. The adoption of conservation agriculture (CA) as an alternative to the traditional system of cereal farming, and the integration of crop-livestock under CA conditions aims to improve the sustainability and food production. The adoption of conservation agriculture concept with the necessity to leave the soil covered with residues, introduces a new constraint to livestock management. The integration crop-livestock under CA context is not well documented in the literature. This article is a result of studies which focus upon the adoption of conservation agriculture and the integration of livestock into CA practice on the one hand and it suggests some approaches to optimize this integration.

Key words

Conservation agriculture, crop-livestock integration, optimization.

1. Introduction

In order to preserve water and soil resources and to ensure the sustainability of agriculture, farmers are facing a major challenge which is consisting on the development of a new approach to achieve theses purposes (Jat et al., 2011). In this context, conservation agriculture (CA) is defined as minimal soil disturbance (no-till) and permanent soil cover (mulch) combined with rotations. This agricultural management mode is increasingly developed in many parts of the world (Valipour, 2014) and is more and more adopted in developing countries such as Tunisia which suffers from the climate' variability. The total area cropped under CA context in Tunisia, increased from 27 ha in 1999 to nearly 12 000 ha actually (INGC, 2014). This modern agricultural practice is compatible with the global orientations dealing with enhancing food production and environment protection. Including forage in crop rotation in cultivation systems may provide diversified resources contributing to cover feeding needs, mainly for ruminants. In addition, Livestock integration into conservation agriculture could represent several benefits such as the diversification of inputs; the recycling of nutriments; the improvement of cultural rotations; the preserving of energy and the reducing of environmental problems caused by concentrated intensive livestock production (FAO, 2006). However, this integration seems to be incompatible with the aim to maintain a "minimum" or a "suitable" crop cover of the soil and represents a conflict between the use of organic matter to feed animals or to cover the soil. This conflict needs to be resolved, especially in arid and semi-arid regions, with low production of biomass (FAO, 2006). Unfortunately, the crop-livestock interaction in conservation agriculture has rarely been studied and few data are available in the literature. In the current revue we tried to highlight the importance of livestock in CA and to propose research appropriate approaches for optimizing animal integration and finding compromise between on the one hand soil covering and on the other hand livestock feeding.

2. History and adoption of conservation agriculture

Conservation agriculture is defined as a crop production system which aims at sustaining the agro-ecosystem, preserving natural resources and reducing the environmental problems (Hobbs et al., 2008; Kassam et al., 2009).This alternative is based on three principles: (i) A minimum soil disturbance by direct seeding, (ii) a permanent soil cover (mulch) and (iii) crop rotations or associations with leguminous (FAO, 2012). Conservation agriculture is considered as a system presenting an interaction with households, crops and livestock (Hobbs, 2007). The first direct seeding without any preliminary preparation of the soil has been practiced in the end of 1940s in the USA, in connection with unfavorable environmental conditions caused by catastrophic wind erosion in the great American plains. In the Maghreb and the Middle East areas, the debate between the negative impact of tillage and soil disturbance started in the 1950s (Chatterton and Chatterton, 1997). In European Mediterranean countries, reducing tillage intensity began in the 1960s, primarily for cost reduction purposes. Kassam et al., (2015) mentioned that conservation agriculture covered globally in 2013 an area of about 155 Mha corresponding approximately to 11% of arable cropland. They showed that Africa presented an area of 1.22Mha in which 65% are smallholders (Figure 1) .

The North- Western parts of North America and the southern parts of South America (Figure 2) present the highest level of CA above 50%. The CA area has increased between 2008-09 and 2013 in the North America regions from 40 Mha to 54 Mha respectively mainly dominated by the USA, which present an area of 35.6 M ha in 2013 and is still at a significantly lower level (21.5%) in terms of the percent of the cropland (Figure 2). In South America, the adoption of CA presents approximately the 100% in Argentina, Paraguay, Uruguay and Southern Brazil. The increase of CA superficies was about 33.9 % between 2008-09 and 2013 mainly dominated by Brazil with 31.8 Mha in 2013 (Kassam et al, 2015).

In European countries (Figure 3), CA area increased by 30% from 1.6 Mha to 2.0 Mha respectively in 2008/09 and 2013 presenting 2.8% of the arable cropland. The number of countries adopted CA has also increased from 11 countries in 2008/09 to reach 14 countries in 2013. The adoption of CA is more observed in Spain, Italy, Finland, France, UK, Switzerland and Germany especially in Spain and Italy in which the development of CA in perennial crop has surpassed the adoption rate in annual crop system (Kassam et al., 2015).

The adoption of CA in Asian countries has developed considerably from 2.6Mha in 2008-09 to achieve 10.3 Mha in 2013 mainly dominated by China (6.67 Mha). Added to that, the number of regions adapted CA has increased from 2 to 11 countries respectively in 2008-09 and 2013 (Figure 4) . In central Asia, Kazakhstan presented an area of 10.5Mha under reduced tillage in the northern drier provinces and 2 Mha of this area adopted the "real" CA with the permanent soil cover and rotations (Kassam et al., 2015). In Syria and Iraq, superficies under CA system has continued to increase because of the lack of fuel (Piggin *et al.,* 2015). The area of CA in Turkey and Syria increased in only few years to reach 45000 ha and 30000ha respectively in 2013 (Figure 4). The development of CA in Syria is explained by the increased availability of no-till seeders locally produced. Actually, Syria is becoming an exporter of these seeders to other countries. This is also thanks to the efforts of development and promotion activities by certain organization such as GIZ, ICARDA and ACSAD. In DPR Korea, we noted the presence of two successive crops (rice or maize or soya as summer crop, winter wheat or spring barley as winter crop) within the same year, through direct drilling of the second crop into the stubble of the first. In the Indo-Gangetic Plains across India, Pakistan, Nepal and Bangladesh, the adoption of CA in the wheat-rice cropping system was considerable, however only modest adoption of no –tillage practice and "real" CA. In India, farmers practiced the zero tillage technique in the rice-wheat double cropping system and implied crops such as maize, cotton, pigeon pea and chickpea in the rainfed upland areas (Kassam et al., 2015).

In Africa (Figure 5), the adoption of CA in Morocco and particularly Tunisia was modest. It increased only by 2000 ha in Tunisia from 6000 ha in 2008/09 to reach 8000 ha in 2013 (Kassam et al., 2015). However, it remains unchanged in Morocco and presented an area of 4000 ha. The adoption of conservation agriculture in Tunisia has grown modestly over 10 years to cover a total of 12,000 ha of superficies in 2009-10. The objective was to expand these superficies to 100,000 ha of wheat in 2014, especially in the regions with of high erosion risks. The main objectives to establish the conservation agriculture were to increase grain production, to control the erosion, to enhance water use efficiency and to increase sustainability and conservation without developing major infrastructures. Many institutions contributed to establish this project such as the Institute for Agricultural Research of Tunisia (INRAT) and the National Institute for Field Crops (INGC) with the collaboration of some French and American projects on conservation agriculture and other regional organizations like the International Center for Agricultural Research in the Dry Areas (ICARDA) and the International Maize and Wheat Improvement Center (CIMMYT). The adoption of conservation agriculture in Tunisia is considered as a strategic challenge in order to develop agriculture well adapted to an environment characterized by a soil degradation, erosions and a water scarcity in the majority of agro - ecological regions of the country (Angar et al., 2017). In this context, the adoption of CA practices provides several advantages related to the soil protection, the soil fertility and the productivity. It improves also the economic results (Angar et al., 2017). This can be explained by the reduction or the elimination of high energy consumption of different farm operations such as tillage which minimize the human labor especially for soil preparation. The equipment costs in particular the number and power of tractors, are also significantly reduced. This is also observed with smallholder farmers who generally use manual labor or animal traction (Friedrich and Kienzle, 2007).

In the sub-Saharan Africa (Figure 5), various innovative participatory approaches are developed to produce CA equipment especially for smallholders. Besides, vulgarization and learning sessions are being encouraged to explain to farmers the importance and the benefits of CA and how CA can be adapted to local situations. Thanks to indigenous and scientific knowledge and equipment design from Latin America, China, Bangladesh and Australia and to certain organizations such as CIMMYT, ICRISAT, ICRAF, CIRAD, ACT, FAO and NGOs , farmers in 15 Sub-Saharan countries are adopting CA (in Kenya, Uganda, Tanzania, Sudan, Swaziland, Lesotho, Malawi, Madagascar, Mozambique, South Africa, Namibia, Zambia, Zimbabwe, Ghana and Burkina Faso). In African countries, the adoption of CA is becoming a challenge for smallholder farmers because of climate change, erosions, water scarcity, labour shortages and high energy costs. In Sub-Saharan Africa, CA was practiced in 7 countries in 2008/09. However, this number increased to attend 12 countries in 2013. The total area of CA in Sub-Saharan Africa was estimated by 1.22 M ha in 2013, while it was about 0.48Mha in 2008/09 (Kassam et al., 2015).

3. Principles of conservation agriculture

Conservation agriculture represents an alternative of the tillage system based on soil disturbance and the use of machinery. In this context, the no-tillage system is a method of agro-ecosystem management which enhances the sustainability of agriculture and improves profits.

Conservation agriculture is based on three principles (Figure 6):

- Minimum soil disturbance
- Permanent soil cover (mulch)
- Crop rotations or associations with leguminous (Scopel et al., 2013).

3.1. Reducing or suppressing soil tillage

Lahmar et al. (2006) mentioned that the suppression of soil tillage enhances the cohesion between soil aggregates, reduces the mineralization of organic matter and insure the development of the soil biota. They mentioned that some farmers reduce tillage especially when they adopt the no-tillage system recently.

3.2. The permanent soil cover

One of the principles of Conservation agriculture is to maintain a cover crop (mulch) on soil surface. The crop residues enhance the soil structure by preserving it against aggressions and erosions. Adopting a cover crop on soil surface maintains the soil moist (Lal, 1997), control weed growth and provide habitat and food for organisms (Blanchart et al., 2006). Under semi-arid conditions, regions suffer from climatic change, drought, water scarcity and limit of biomass. When livestock is abundant, there may be a competition between preserving crop residues as a cover crop or using it to feed animals(Corbeels et al., 2010).

3.3. Crop rotations or associations with leguminous

The succession ofwinter and spring crops causes the disruption of weed cycles. So, their development becomes difficult. In order to limit weed flora, it's important to diversify crop rotations and preserve the soil from the transmission of fungal diseases or the development of some pests. Crop rotation is one of the important conditions to enhance the sustainability of agriculture and preserving natural resources (Scopel, 2012).

4. Integration crop-livestock under conservation agriculture system

A main goal of conservation agriculture is to increase the production of biomass which facilitates the integration of livestock into agricultural systems. The management of crop residue is the key to ensure a successful adoption of conservation agriculture system. Köller (2003) claimed that livestock could be fully integrated into conservation agriculture, when more than 30% of the residues from the previous crop are left on the soil as mulch. A high level of crop residue can reduce the plant emergence and a low level of residues doesn't ensure the protection of soil surface against climate agents (rain, wind, temperature and radiation). Consequently the main concern of CA-livestock integration is to resolve this conflict.

4.1. Conflict and challenge of crop-livestock integration

One of the reasons of integration crop-livestock is the population increase in many countries such as in sub-Saharan Africa which may reach 1.2 billion in 2025 (Tarawali et al., 2004). This induces a high demand for crops and livestock to satisfy population requirements. In this context, when farmers increase their herds, crop residues become an important feed resources for animals. The study of Naazie and Smith (1997) has shown that crop residues are not considered as a resource to feed animals. This causes a food deficiencies. In addition, the climate change especially in dry Mediterranean countries suffering from water shortage and temperature rise affected the agricultural system (Sivakumar et al., 2005; Jat et al., 2012). Indeed, the adoption of mixed crop-livestock systems insures an environmental and economical sustainable agriculture (Ryschawy, 2012). In the dry savannas, the integration of crop-livestock provides reciprocal advantages. While crop residues considered as fodder for animals, livestock insures traction and manure which increase the crop production (Ezeaku et al., 2015). In this context, crop and livestock are considered as two complementary systems to insure a sustainable agriculture. However, the conflict of the integration crop-livestock under conservation agriculture system is the use of crop residues as a mulch to cover the soil or to feed animals. In light of this, it's substantial to estimate and to control the stocking rate and the grazing duration, the composition and the fertility of soil and the timing of grazing. The challenge consists of the integration of crop and livestock into conservation agriculture system while ensuring livestock feed and a soil cover (Mclntire et al., 1992). In this context, Bashour et al., (2016) confirmed the necessity to estimate the "optimum quantity of mulch" that can feed animals and cover the soil surface at the same time in order to ensure a high productivity, environmental and socio-economic impacts.

4.2. Integration crop-livestock under conservation agriculture and competition for crop residues

The crop-livestock interaction in conservation agriculture system has rarely been studied and few data are available in the literature (Calatrava and Franco, 2011). Livestock is an essential component of farming system, particularly in arid and semi-arid regions, where it represents an important source of incomes. The availability of feeding resources is a major constraint, especially for cattle and sheep. The direct seeding under the permanent soil cover presents the ability to ensure the forage autonomy by producing green or dry forage (Hay or silage), without affecting the system. The cover crop is used as animal fodder, in a second way it's used to improve the soil in order to increase biomass yields (Fassino and Maire, 2012).

It is possible to enhance the soil cover as a fodder for animals. Indeed, ruminants are particularly preferred due to their ability to valorize forage and crop residues particularly high in cell wall and nutrients.The integration of crop-livestock under CA system insures the diversification of producers' incomes allows the nutrient recycling and improves crop rotations (Landers, 2007). The success of this integration will benefit from synergy of these two activities by diversifying incomes from animal products, controlling the weeds and improving yields (Sánchez, 1995). In this context, the adoption of conservation agriculture practices could represent a new role concerning producing forage for animals, which contributes to crop fertilization by producing organic manure (Fassino and Maire, 2012). The moving of animals allows the transfer of minerals and organic matter between plots. The integration of crop-livestock may also improve the economic stability of farmers and could capitalize and make them less dependent on the socio-economic environment (Escribano, 2006). Production systems that integrate successfully breeding to agricultural activities presents several benefits from this integration, with a positive direct impact on the farming systems. The adoption of conservation agriculture and the necessity to keep crop residues on soil is a constraint for livestock (Abbas and Zitouni, 2011). Indeed, in direct seeding systems, crop residues are recommended to be kept and used not as a fodder but as a cover for the soil. The plots cannot be grazed after the harvest of grains. This represents a major constraint in regions where breeding systems are based on grazing (Mrabet, 2001), mainly during the summer. Thus, this contradiction induces a decrease of livestock feed resources (Abbas and Zitouni, 2011) when CA is adopted and in these conditions, the adoption of the direct seeding system is difficult in front of the high pressure of animals on crop residues (Mrabet, 2001). This presents a constraint for the adoption of conservation agriculture techniques in regions where livestock is considered as a main component. Consequently the competition between agriculture and livestock is to be appropriately managed to be compatible with the conservation agriculture practice (Landers 2007) by optimizing the grazing (Moujahed et al., 2015). If the production system privileges one component, the beneficial effects of synergy will be lost which damages the farm system.

4.3. Ensuring complementarities

The competition on crop residues between sowing under cover and livestock presents a main problem for all farming systems even for farmers who don't have herds. Indeed, they can sell the grazing rights to other which represent an important cash inflow for small structures (Mrabet, 2001). To solve this problem, Abbas and Zitouni (2011) indicated that the proposed solutions must be the least expensive, since they are replacing fodder resources, certainly with low quality but usually free. Crop and livestock are very complementary and not competitive. In this connection, several alternatives are available such as: The assessment of the amount of residues necessary for soil protection and the valorization of the remaining amount that can be used for livestock feed, the insertion of cover crops that can be used to protect the soil and livestock feed in the context of crop rotation plan, the reservation of permanent fodder plots for direct pasture, the reduction of herd size by removing animals which can't be used for traction, the conservation of fodder surplus, and the temporary transhumance of animals to other areas. Landers (2007) mentioned that the establishment of a good livestock management is so important in order to increase the production of grain and even to enhance livestock productivity. The respect of stocking rate capacity prevents overgrazing and ensures a good permanent soil cover. The herd's size must be well studied by considering the availability of forage and the capacity to produce it. The increase in production and productivity of pastures is also possible in conservation agriculture.

5. Optimization of crop residues and stubble grazing in CA context

To ensure the sustainability of agricultural system, the optimization of crop residues and stubble grazing presents a primordial step. Hence, estimating the crop residues introduced and retained considering the soil characteristics, the climate and the cropping system without damaging the next crop or creating any biological and chemical imbalance. Also, optimizing the quantity of crop residues that can be left on soil under conservation agricultural conditions while preserving the crop-livestock system especially in regions where crop residues are used to feed animals (Gupta and Dadlani, 2012).Moujahed et al. (2015) confirmed that livestock can be integrated under conservation agriculture without threatening animals' performances. They mentioned in their study that biomass was not limited and enough to satisfy all nutrient requirements of lambs and contributed to safeguard livestock even in absence of supplementation. Abbas and Zitouni, (2011) mentioned that it's necessary to study the stubble management strategies under conservation agriculture system as related to its principal objective which is to maintain a soil cover. Hence, farmers are considered as the main decision makers concerning the development of their productivity and the provision of their livestock requirements. Jaleta et al. (2015) mentioned that the use of crop residues to cover the soil presents a challenge in Ethiopia. In western Kenya, Castellanos-Navarrete et al., (2015) reported that farmers adopted a strategy which is based on the use of 72% of maize residues to feed cattle, 22% left on soil and 5% used as a compact with manure (table 1). In the central highlands of Mexico, Beuchelt et al., (2015) mentioned that 70 to 95% of crop residues used to feed cattle and only 1 to 30% of stubble grazing kept on soil as mulch (table 1). Livestock presents an important component; it performs several functions such as enhancing the soil quality by the use of manure and preparing the soil by traction and transport. For smallholder farmers, livestock presents a source of incomes and a strategy in case of low harvest (Kazianga and Udry, 2006). Considering the increase of demand for livestock products, the improvement of productivity becomes a major goal especially for smallholder systems (Tittonell et al., 2009) and this requires a great optimization of the integration crop-livestock under conservation agricultural system. Baqir et al. (2018) studied the optimization of crop-livestock interaction and the effect of rotations on biomass yield under CA system and the conventional tillage (TA) in system in the region of Syria in the two years 2010-2011 and 2011-2012. They mentioned that during the second year of transition into CA system, they noted the presence of grains for barley intercropped with atriplex and salsola and they observed signs of improvement in the amount of grain and straw produced. They also mentionedthat if we don't consider the opportunity cost of mulch, the grain yield would have been more important in the first year under conservation agriculture conditions (Table 2).

Straw averages were more than double in CA system compared to those of conventional tillage (TA). The same trend of yield grains was observed by Bashour et al. (2016) under CA practice in the region of Lebanon for barely and vetch mixture. In the semi-arid and dry Mediterranean areas, for barley and wheat, to preserve 30% of cover crop on soil surface, they needed 0.5 t/ha of crop residues (Dicky et al., 1985; British Columbia, Ministry of Agriculture, 2015). Baqir et al. (2018) observed that in the second season (2011/2012) and under a barely and ervilia seeded mixture (Table 3), they estimated an average of straw biomass production in order of 2.7 t/ha to cover 30% of soil surface. They mentioned that the optimum quantity that could be left was 2 t/ha to provide 30% of ground cover.

6. Case studies

6.1. Evolution of cereal stubble composition

The morphological composition of cereal stubble is very variable. According to Rihani et al. (1991), it's composed of 4% epics, 54% leaves and 42% steams. Houmani (2002) mentioned proportions of 21% leaves, 69% steams and 10% grains. The stubble not only contains cereal residues resulting from harvest, but they are also composed of some weeds (Gerbaud et al., 2001). Consequently, the morphological composition of stubbles varies also according to bioclimatic zone (Ben Saïd et al., 2011; figure 7) and the harvest technique. Generally, epics present the lowest proportion of the total biomass.
Moujahed et al. (2015) studied the variation of barely stubble composition after harvesting and 14 days later and the effect of two stocking rates (15 and 30 lambs per hectare SR15 and SR30 respectively) on biomass variation for barely stubble in Tunisian semi arid region and under conservation agriculture conditions. They found that the proportions of heads decreased ($P<0.05$) for SR30 groups but was maintained in SR15 ones after 14 days of grazing (Table 4). This can be explained by the selective behavior of lambs that preferred heads while grazing and the highest pressure exerted in SR30 plots of stubble. In the same trend, Yiakoulaki and Papanastasis (2005) confirmed that sheep have a tendency to consume heads first while stubble grazing. This is due to their richness in energy compared with other parts of stubble (Houmani, 2002). Moujahed et al. (2015) mentioned that 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. These results are confirmed with those reported by Valderrabano (1991) and Cabello et al. (1992).

6.2. Chemical composition variation of cereal stubble

Cereal stubbles are considered by farmers as a fodder resource, with a low nutrient value. Indeed, they are high in crude fiber and low in crude protein, minerals and vitamins. So, they don't satisfy maintenance requirements of animals. The chemical composition of stubble is affected not only by the harvest technology and the previous crop, but also by the climate. Stubbles from early maturing variety of cereals present higher proportions of ADF, NDF and lignin and less energy and protein contents than stubbles from late maturing variety. The chemical composition of stubble is not affected by tillage (Rao et Dao, 1994). The table 5 illustrated the nutritive value of cereal stubble in Mediterranean semi-arid region.

The morphological composition and the nutritive value of stubble vary among grazing. In this context, Houmani, (2002) mentioned in an experiment conducted on ewes that the proportions of CF increased during grazing but not significantly. This is explained by the increase of steams proportions in stubble. The CP contents decreased significantly with grazing frequency from 4.7 to 2.2% DM during the last grazing period (after 48 days). This decrease is due to the decrease of grain proportions, which decreased with the increase of grazing frequency of animals (Table 6).

In the same context, Moujahed et al. (2015) studied the variation of nutrient contents of stubble among period according to stocking rates (SR15 and SR30) under conservation agricultural condition (Table 7). They mentioned that CP presents a moderate level at the first period (4.9% DM) which was higher than values found by Avondo et al. (2000) for barely stubble (3.4% DM) and values relative to cereal straws (Houmani and Tisserand, 1999). This could be explained by the richness of biomass in heads and thereby grains. Moujahed et al.

(2015) mentioned that CP contents vary between stocking rates (Table 7). Indeed, they found that proportions of CP 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. They concluded that this variation of the CP content of stubble is likely due to its level in grains, which decreases with the grazing duration. Moujahed et al (2015) suggested that stocking rates don't affect Ash contents between the first 14 days of grazing (Table 7). However, it decreased (P<0.05) with the increase of the stocking rate. The same trends for contents were found by Ben Said et al. (2011) in semi-arid regions from Tunisia. In the same experiment, Moujahed et al (2015), mentioned that ADF contents of stubble increased by 2.6 and 2.1% units (P<0.05) for SR15 and SR30 plots respectively (Table 4).This is due to the variation of botanical composition between the 2 sampling periods in terms of the decrease if heads and leaves and the increase of steams proportions especially in SR30. Rao and Dao, (1994) reported that chemical composition of cereal stubbles is related to several factors such as region, cereal species, varieties and climate. Ben Said et al (2011) explained that the selective behavior of lambs during grazing, consisting in prefering heads and then leaves, affects the morphological composition of stubble and therefore induce a variation in chemical composition between the two sampling times especially in high stocking rates.

6.3. Effect of the integration crop-livestock in conservation agriculture conditions

6.3.1. Effect of stocking rates and period on animal performances

Moujahed et al (2015) studied the effect of stocking rates and period (SR15 and SR30) on Live Weight Gain (LWG) (Fig 8a) and Daily Live Weight Gain (DLWG) (Fig 8b) of lambs under conservation agriculture conditions. They found that animals lost their live weight (P<0.001), higher (P<0.05) in SR15 than in SR30 group (-610 and -110 g, respectively). The same trend was also observed in DLWG (23.3 and -4.1 g/d, respectively for SR15 and SR30, P<0.05). In the second period (15 days after), lambs for both stocking rates registered a positive DLWG (around 171g/d) resulting in an increase in LW (around 2kg). In the last period (30 days after the beginning of the experiment) , SR15 group maintained their body weight. The SR30 group registered a decrease by about 400g in LW compared to the second period. Authors mentioned that the loss of body weight at the beginning of the experiment can be explained by this adaptation period in which lambs select heads and grains causing some digestive disturbances for animals . The increase in animals' body weight in the second period confirmed that biomass was not limited and satisfy all nutrient requirements of lambs and contributed to safeguard livestock even in absence of supplementation. The same results were found by Treacher et al. (1996).

Abbas and Zitouni (2010) mentioned that it's necessary to study the stubble management strategies under conservation agriculture system as related to its principal's objectives which is to maintain a soil cover. In this context, Köller (2003) affirmed that the integration of livestock into conservation agriculture system is possible when we left 30% of residues from the previous crop on soil.

6.3.2. Effect of stocking rates on the rate of biomass cover

Masmoudi (2012) studied the effect of different stocking rates on percentages of cover crops in conservation agriculture system. Thus, he mentioned that the biomass cover rates vary between 52.67 and 54.66% respectively for 3.5 and 2.5 UGB/ha levels of stocking rates. However, it was around 78% in the ungrazed plot (Figure 9). Results found by Masmoudi (2012), confirmed that there was no significant effects of stocking rates on the rate of biomass cover in grazed plots. Indeed, the effect of livestock depends on the rate of residues before grazing. The study of Masmoudi (2012) also showed that the integration of livestock at different levels of stocking rates requires a rate of biomass cover higher than 78% before grazing.

7. Conclusion

In order to limit environmental problems, to maintain the soil fertility, to enhance food production and to increase incomes, the integration of conservation agriculture into programs of research and development is considered as an important alternative to solve several problems faced by farmers. Generally, the total area of CA is still relatively lower than areas adapting tillage technique. This situation is going to change. Indeed, the adoption of CA is spreading throughout the world and increasing to reach 10 Mha per year since 2008-2009 (Kassam et al., 2015). The adoption of conservation agriculture in regions suffering from climate change and the integration of animals into CA system are considered as a strategic challenge in order to find a compromise between the use of organic matter to feed animals or to cover the soil. In this connection, conservation agriculture presents the most important component to establish a real change in production system.

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Table 1. Cases of crop-livestock integration under conservation agriculture

Country	Crop	Animal	Practices	Authors
Coteaux de Gascogne located in south-western France in the Pyrenean Piedmont	Grass	Beef cattle	Mixed crop-livestock system is defined and a system in which either more than 10% of the dry matter fed to animals comes from crop byproducts or stubble, or more than 10% of the total value of production comes from non-livestock farming activities.	Ryschawy et al., 2012
Tunisia	Barely	Lambs	Grazing animal on barely stubble	Moujahed et al., 2015
Western Kenya	Maize	Cattle	- Grazing animal on maize stubble - - Adoption of a strategy which is based on the use of maize residues to feed cattle, 22% left on soil and 5% used as a compact with manure.	Castellanos-Navarrete et al., (2015
Central highlands of Mexico	Maize and barely	Cattle, sheep, goats	- Grazing animal on maize and barely stubble - Adoption of a strategy which is based on the use of 70 to 95% of crop residues to feed cattle and only 1 to 30% of stubble kept on soil as a mulch	Beuchelt et al., (2015)
Syria	Barely intercropped with atriplex and salsola Ervilia intercropped with atriplex and salsola;	----------	- Optimization of crop-livestock interaction under CA system - Barley and vetch rotation intercropped with atriplex and salsola	Baqir et al., (2018)
Algeria (Sétif)	Bread wheat	Ewes Cattle	- Grazing of animals at different stocking rates under CA system	Masmoudi, 2012
Brazil (Cerrado biome)	Brachiariaspp	Beef cattle	- Grazing animal on stubble biomass under zero tillage system	Landers, 2007

Table 2. Yields (kg/ ha) for conservation agriculture (CA; P.12) and tillage agriculture (TA; P.13) for 2010/2011 and 2011/2012 seasons.

(Baqir, 2018)

	CA		TA	
	2010/2011*	2011/2012**	2010/2011*	2011/2012**
Grain Yield (barely/evilia)	250	980	280	1040
Straw yield	380	2300	690	2040
Grain value	135	392	151.2	416
Straw value	53.2	414	96.6	367.2

* Ervilia intercropped with atriplex and salsola; ** barley intercropped with atriplex and salsola; P.12: Plot number 12; P.13: Plot number 13.

Table 3. Yields (kg/ ha) for conservation agriculture (CA; P.12) and tillage agriculture (TA; P.13) for 2010/2011 and 2011/2012 seasons.

	CA		**TA**	
	2010/2011*	**2011/2012****	**2010/2011***	**2011/2012****
Grain Yield (barely/evilia)	170	870	130	590
Straw yield	910	2760	460	1300
Grain value	54.4	469.8	41.6	318.6
Straw value	54.6	651.4	27.6	306.8

(Baqir, 2018)

*Seeded with barley intercropped with atriplex and salsola; ** seeded with a mixture of barley (30%) and ervilia
(70%) and intercropped with atriplex and salsola; P.11: Plot number 11; P.14: Plot number 14.

Table 4. Variation of DM biomass with stocking rate and sampling period

Variation	Botanical composition	S0	S14	SEM	Significance
SR15	Biomass (kgDM/ha)	2204aA	2067bB	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	
SR30	Biomass (kgDM/ha)	2404 aA	1826.5 aA	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 (kgDM/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 (kgDM/ha)	NS	**		
	Vegetation (%)	NS	*		
	Heads (%)	NS	**		
	Stems(%)	NS	*		
	Leaves (%)	NS	**		

(Moujahed et al,2015)

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.

Table 5. Nutritive value of cereal stubble in semi-arid region

Type of ressources	**Chemical Composition (%DM)**		
	Ash	**CP**	**CF**
Barelystubble	5.89±1.54	4.59±0.56	37.52±4.68
Wheatstubble	4.94±0.54	3.48±0.79	41.01±3.53

(Tedjari et al, 2008)

Ash : Mineral content ; CP : Crudeprotein ; CF : Crudefiber

Table 6. Effect of grazing frequency of sheep on chemical composition of cereal stubble (%)

	Grazing frequency of sheep on stubble						
	0	1	2	3	4	5	6
DM	92 .2±0.5[a]	91.9±1.4[a]	91.2±0.8[a]	91.6±0.4[a]	91 .2±1.0[a]	92.2±0.6[a]	91.1±1.1[a]
OM	91.1±1.2[a]	91.9±1.5[a]	92.0±0.6[a]	90 .7±0.7[a]	91.3±1.1[a]	91.2±1 .3[a]	89.4±1.2[a]
CF	44.5±1.2[a]	45 .7±0.8[a]	46.5±1 .6[a]	46.7±1.4[a]	46.7±1.3[a]	46.5±0.6[a]	47.9±1.0[a]
CP	4.7±0.3[a]	4.3±0.5[a]	3.4±0.3[b]	3.0±0.4[bc]	2.6±0.4[cd]	2.4±0.2[d]	2.2±0.2[d]

(Houmani, 2002)

DM: Dry matter;MO:Organic matter;CB: Crude Fiber; CP: Crude Protein; Different letters in the same line mean different values

Table 7. Chemical composition of biomass according to stocking rate and sampling period (% DM)

Variation	Chemical composition	S0	S14	SEM	Signifiance
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	*	*		

(Moujahed et al., 2015)

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.

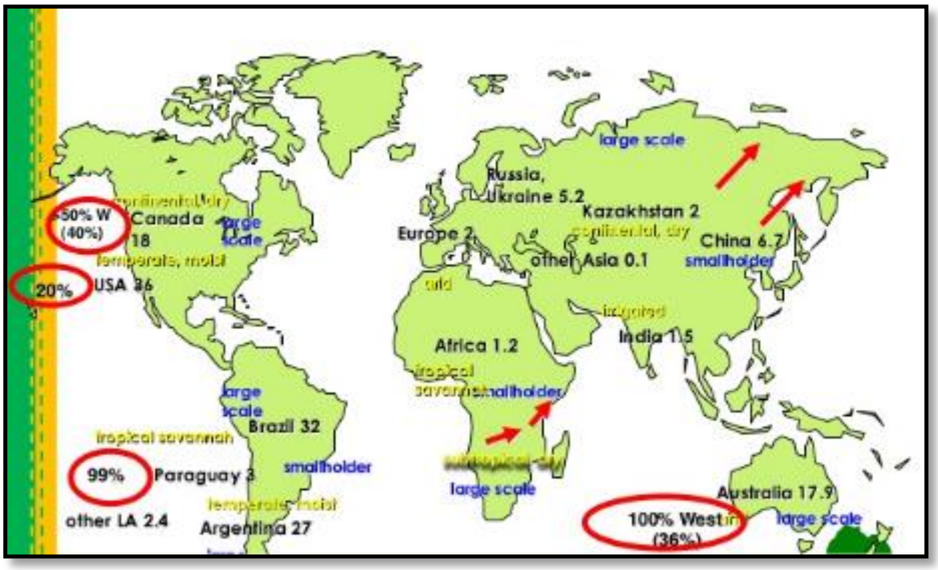
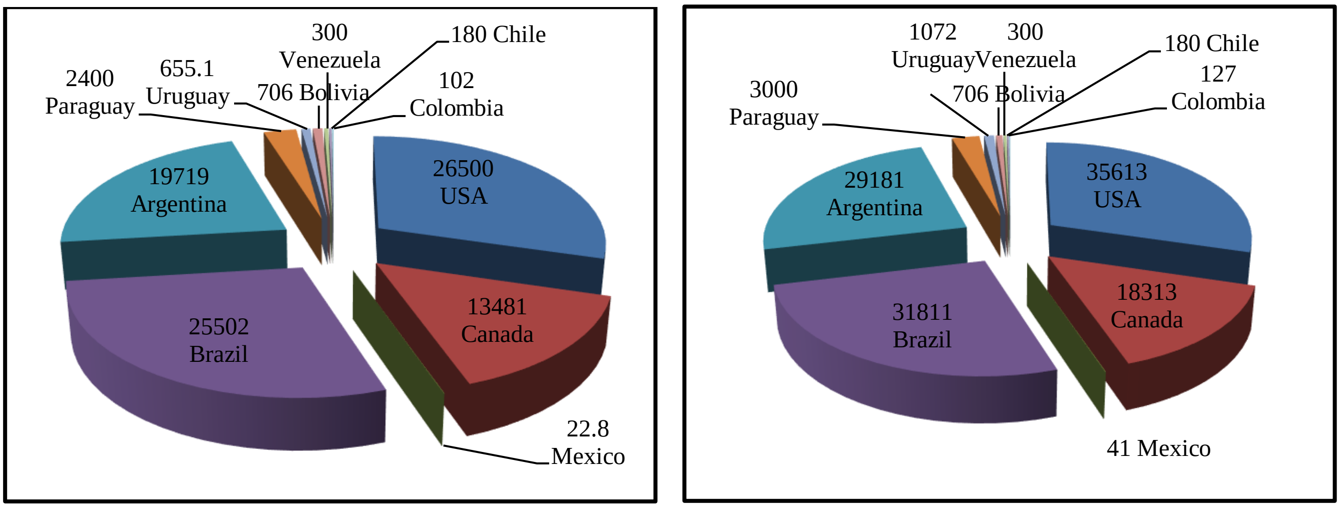
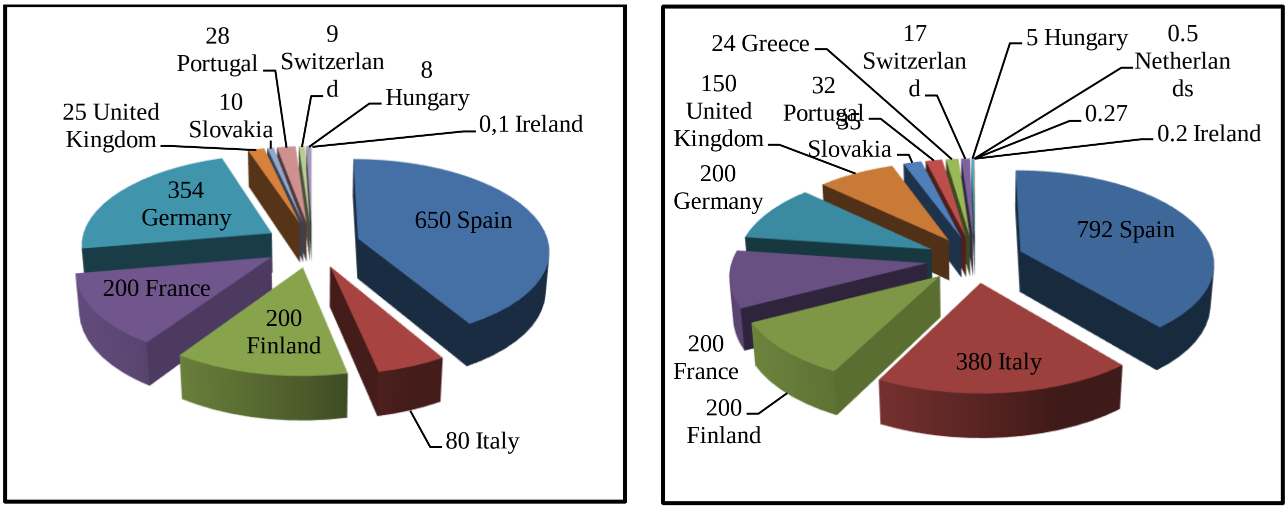


Figure 1: Global overview of CA(Kassam, 2015)



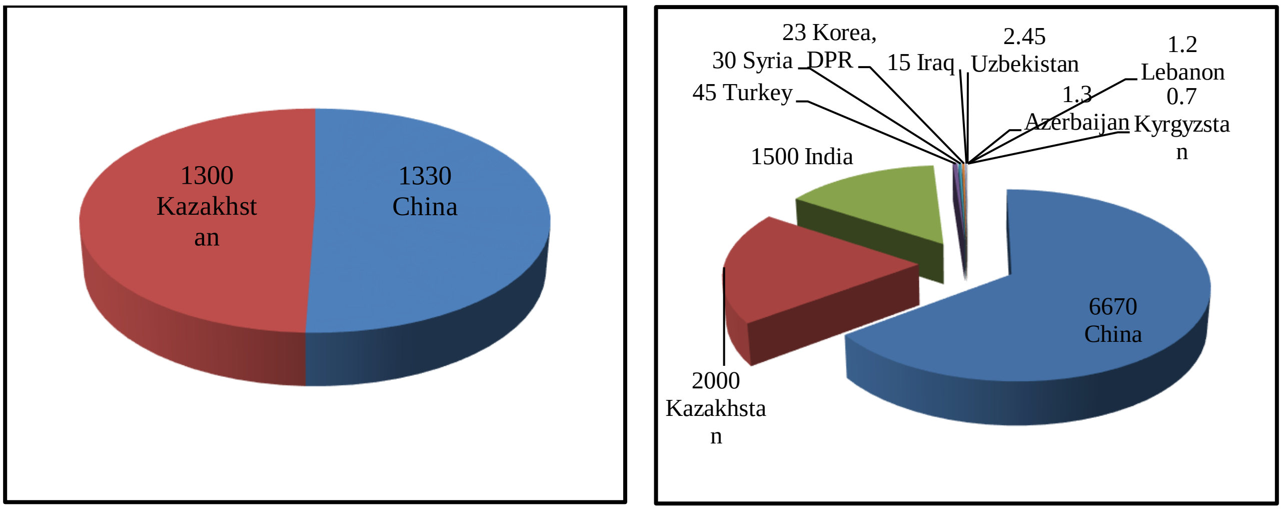
(a) (b)

Figure 2: CA adoption in North and South America (Mha) between 2008-09 (a) and 2013 (b)



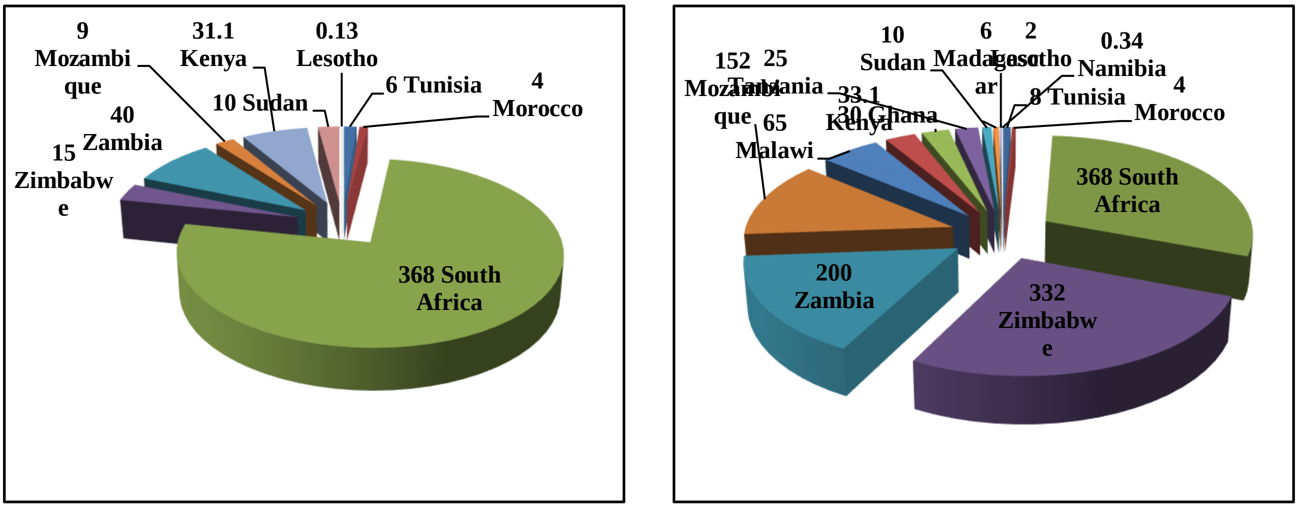
(a) (b)

Figure 3: CA adoption in Europe (Mille ha) between 2008-09 (a) and 2013 (b)



(a) (b)

Figure 4: CA adoption in Asia (Mille ha) between 2008-09 (a) and 2013 (b)



(a) (b)

Figure 5: CA adoption in Africa (Mille ha) between 2008-09 (a) and 2013 (b)

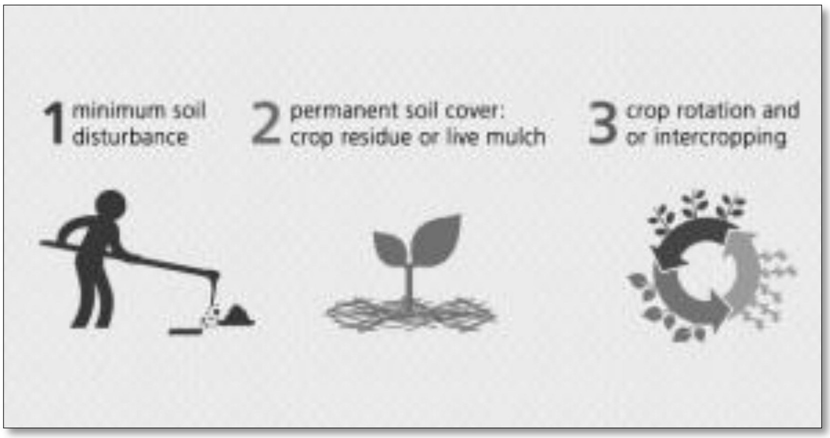


Figure 6: Principals of Conservation agriculture (FAO, 2014)

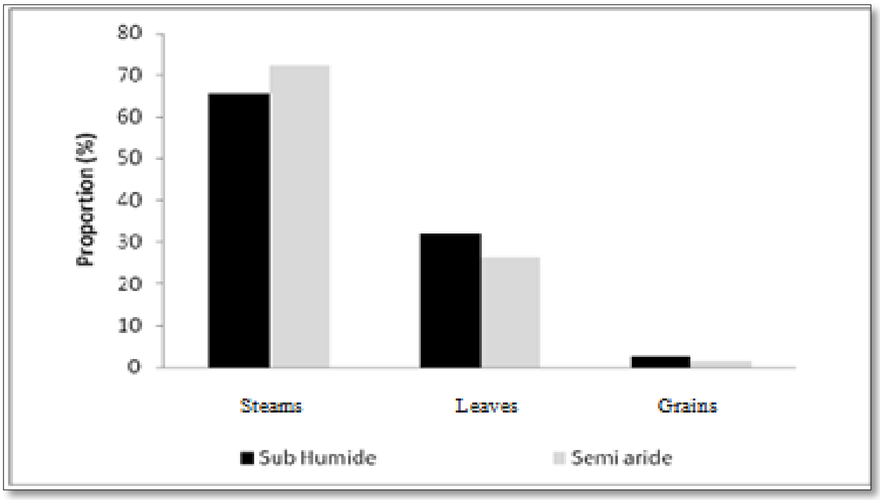
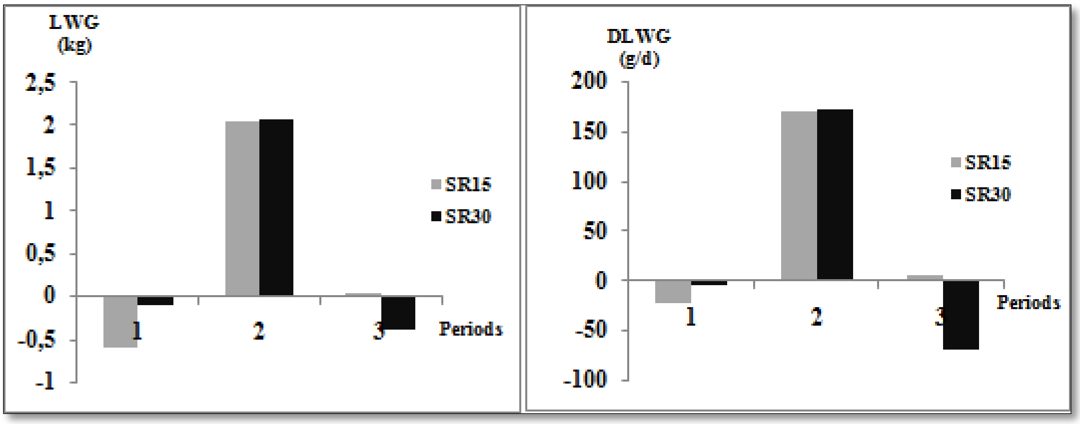


Figure 7: Morphological composition (% of fresh weight) of stubble in both bioclimatic zones
(Ben Saïd et al., 2011)



(a) (b)

Figure 8: Variation in LWG (a) and DLWG (b) according to stocking rates(Moujahed et al., 2015)
1: Weighing at 0 days; 2: Weighing after 15 days; 3: Weighing after 30 days; SR15: 15 lambs/ha; SR30: 30 lambs/ha

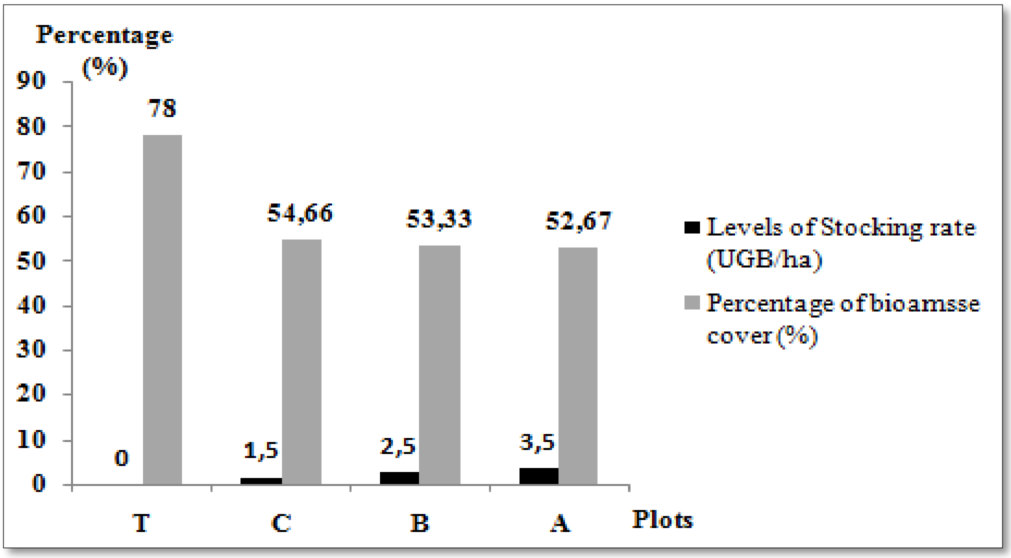


Figure 9: Evolution of biomass cover rate according to stocking rate (Masmoudi, 2012)

PART II. EXPERIMENTAL AND ANALYTICAL STUDY

GENERAL INTRODUCTION AND OBJECTIVES OF THE STUDY

In order to ensure the sustainability of agriculture, and to preserve the natural resources, farmers are facing a challenge and try to find a new agricultural system replacing the traditional one. Indeed, conventional agriculture represents a costly system which requires a lot of material resources in terms of soil productivity, soil quality, surface water quality, machinery and other labor requirements. In this context, conservation agriculture represents an alternative and a solution to this situation. Conservation agriculture is defined as a new concept which aims at improving and protecting land resources (Dumanski et al., 2006). It also prevents soil erosion and compaction, saves labor and decreases the energy costs (Koepke, 2003) through its three principals: (i) The maintain of permanent soil cover, (ii) Zero or minimum tillage and (iii) Crop rotations

Livestock represents an essential component in the agriculture system. However, there is a problem between the use of crop residues to feed animals or the cover the soil. This conflict must be resolved and some studies mentioned solutions in order to ensure the integration crop-livestock under conservation agricultural (CA) system. Unfortunately, the crop-livestock interaction in conservation agriculture has rarely been studied and few data are available in literature.

The objective of this work was to:

- Study the effect of stocking rate (SR15 and SR30: 15 and 30 ewes / ha respectively) and type of agriculture (Conventional Agriculture: Conv-A vs. Conservation Agriculture: CA) on the dynamic of biomass and the zootechnical parameters of ewes grazing on wheat stubble (Experiment 1) and propose a model of livestock/CA integration and pasture optimization.

- Test the defined model through its effects on biomass dynamics, ruminal digestion and body weight variation of ewes grazing on wheat stubble (Experiment 2).

- Contribute to the development of a practical grazing management tool to satisfy the requirements of CA.

I. Introduction

The common methodology part focuses on the characterization of the experimental site, the description of the experimental protocol and the measured parameters.

II. Study locations

1. Characterization of the experimental site

The experiment was carried out in the station of Bourbiaa in the governorate of Ben Arous (36 ° 37 'N, 10 ° 08' E, 60 m altitude)

1.1. Climatic characterization of the site

The study area is located in the upper semi-arid bioclimatic stage (Figure 1).

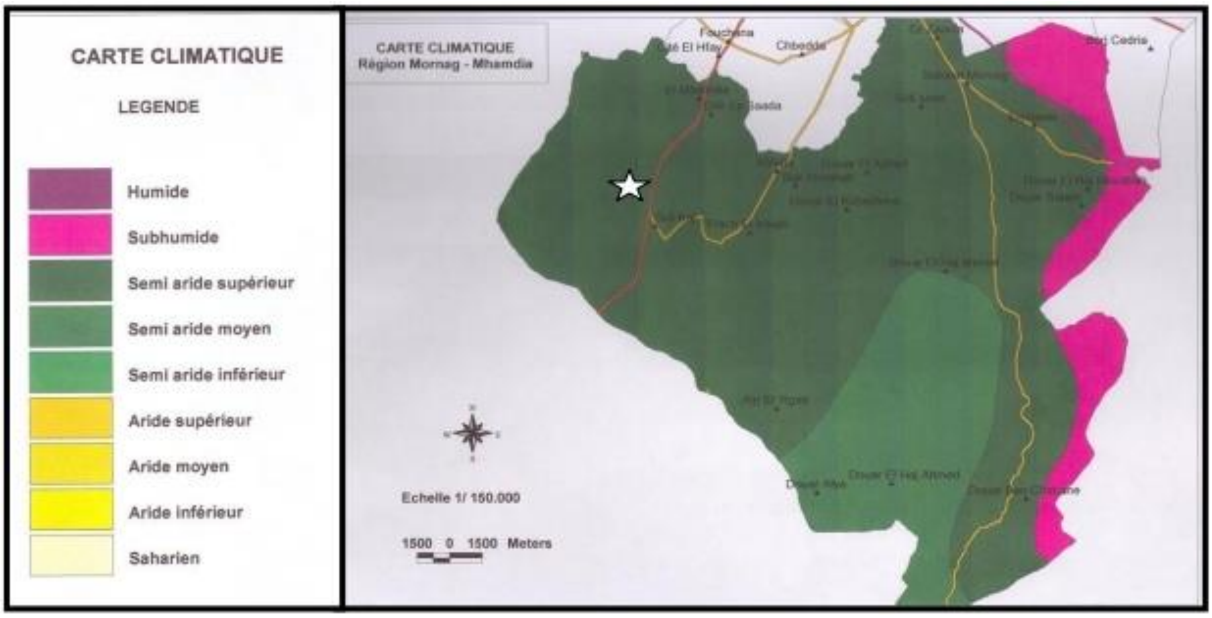


Figure 1: Location of the study site in the bioclimatic map of the Morneg-Mhamdia region (south of Tunis).

1.1.1. Annual rainfall

The experimentation station of Bourbiaa is characterized by an annual rainfall of 470 mm (average of 20 years), with a significant inter-annual variability. The highest annual rainfall was recorded in 2003 (823 mm), while the lowest rainfall recorded in 2001 (288 mm) (Figure 2)

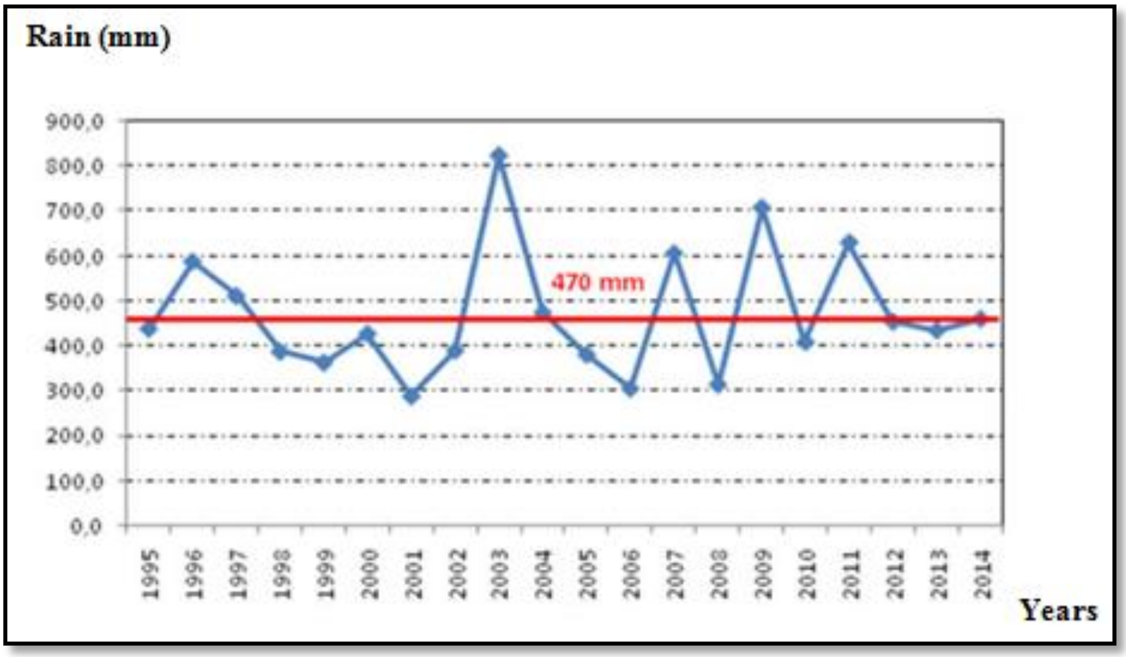


Figure 2: Annual rainfall (in mm) of the station of Bourbiaa during twenty years (1995-2014).

1.1.2. Monthly rainfall and temperature

The experimental site is characterized by a variable monthly rainfall. According to Figure 3 and on an average of twenty years, the rainiest months are December (63mm) and January (75mm). While the least rainy months are June (15 mm), July (4mm) and August (16 mm). The lowest minimum temperatures were recorded during the months of December, January, February and March, with respective values of about 7.0°C, 6.0°C, 5.7 °C, and 7.3 °C. However, June, July and August recorded the highest maximum temperatures, with 32.5 °C, 35.8 °C and 36.1 °C respectively. It should be noted that the inter-annual variability of the temperature is low (Figure 3).

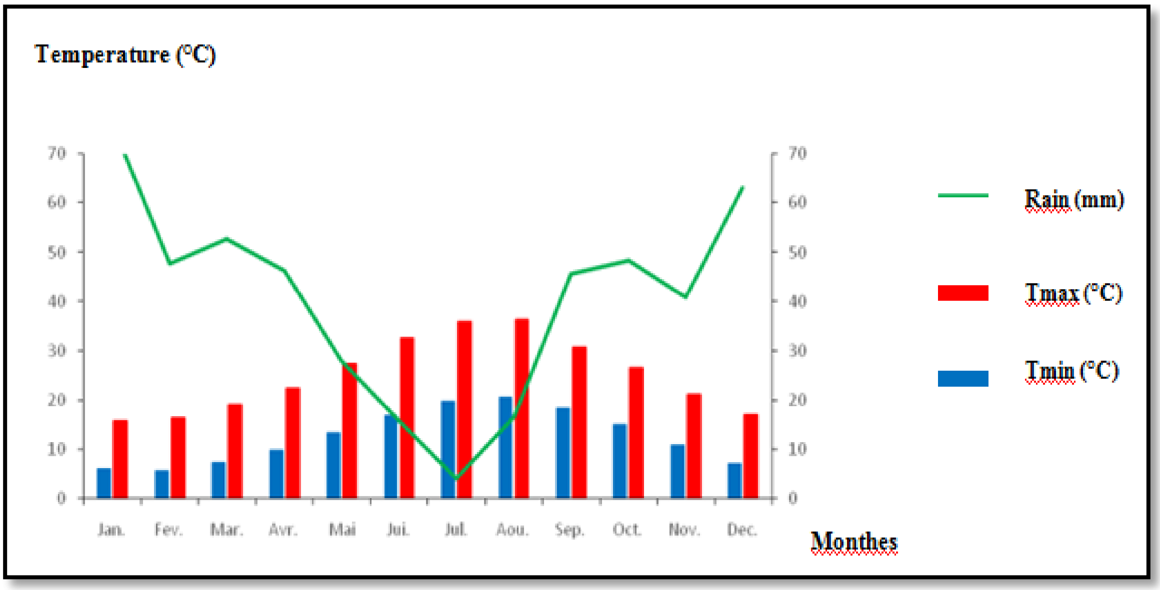


Figure 3: Monthly rainfall (in mm), minimum and maximum temperatures (°C) of the experimental station of Bourbiaa (average of twenty years: 1995-2014).

1.1.3. Ombrothermal diagram of the Bourbiaa station

The ombrothermal diagram of the station of Bourbiaa during twenty agricultural seasons (from 1995-1996 until 2014-2015) is represented in figure 4.

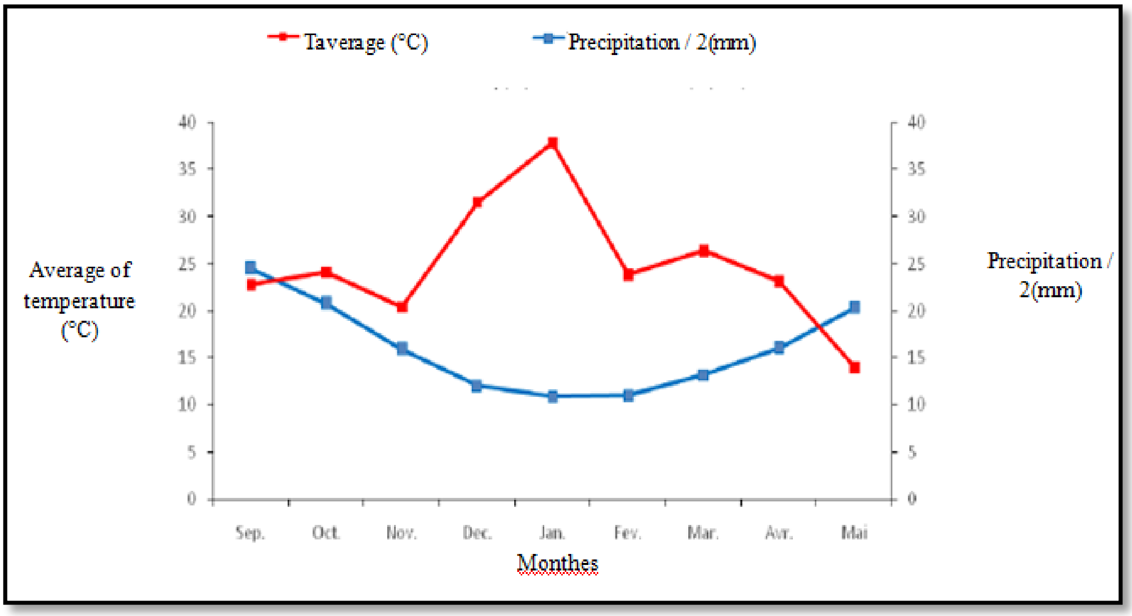


Figure 4: Ombrothermal diagram of the Bourbiaa region calculated from climatic data from twenty crop years (1995-1996 to 2014-2015).

It emerges that the period of active vegetation in this region extends from November to April with a period of maximum growth of vegetation which extends from November to February and a shorter period of vegetative growth during the months of March and April. Indeed, the region of Bourbiaa is considered as a favorable zone for the growth of cereals, since the favorable climatic conditions coincide with their period of growth.

1.1.4. Water deficit curve of the region of Bourbiaa

The determination of the period of water deficit for cereals in the locality of Bourbiaa is presented in figure 5

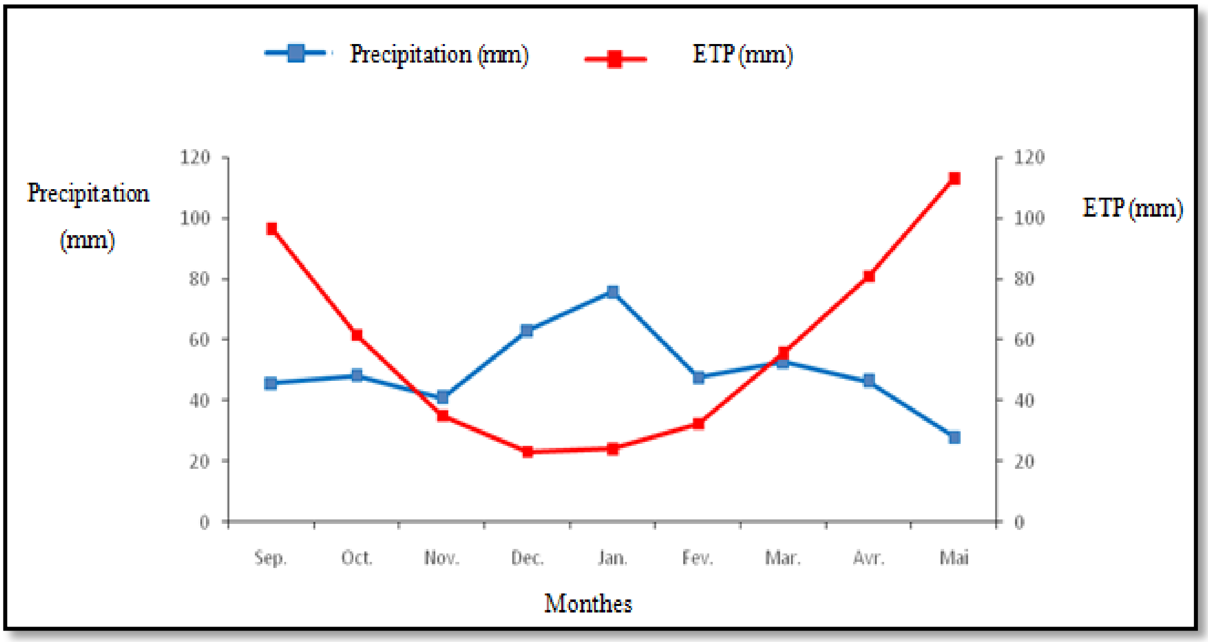


Figure 5: Curve of the water deficit (mm) of the region of Bourbiaa calculated from climatic data of twenty agricultural years (from 1995-1996 until 2014-2015).

Considering the agricultural calendar of cereals, the water deficit curve shows that the region of Bourbiaa is characterized by two periods of water deficit. The first period begins from September to November and the second period starts from March until the end of the cereal cycle. This second period usually coincides with anthesis stages and grain-filling of cereals.

1.2. Soil characteristics

Generally, the soil of Bourbiaa region has a clay texture with 180 mm m-1 total available water and 1.8 g l-1 water salinity. The Soil Organic Matter content (SOM %) in the surface layer is 1.22 and 0.75 in the depth. The bulk density varies from 1.25 to 1.55 from the surface layer to the depth (M’hamed et al., 2014) (Figure 6)

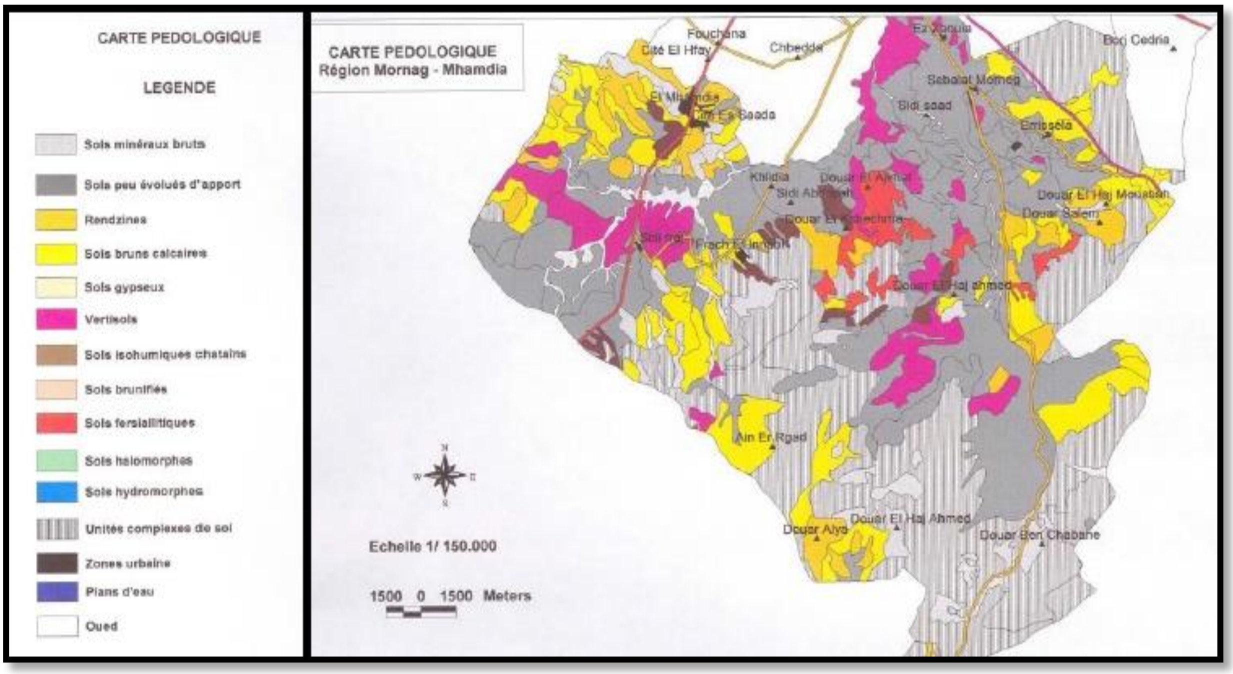


Figure 6: Soil map of the region of Bourbiaa

III. Vegetal material

The farming system is an integrated cereal (durum wheat and barley). The variety (Karim) of durum wheat "Triticum durum Desf" was used. Karim is a variety of durum wheat spring, which was selected and published in Tunisia by INRAT in 1980. It comes from a cross 21563 / AA "S' '// Fg"S " CM 9799, which was carried out by CIMMYT. It is a variety with high yield potential. It is characterized by its good lodging resistance and its average tolerance to septiosis. In fact, it is the most widely grown durum variety in Tunisia and covers about 50% of the area under durum wheat (Ammar et al., 2013).

IV. Animal material

The farm of Bourbiaa accounts 120 ewes. The livestock production system is extensive. Ewes from Barbarine sheep breed were used in the two trials. The Barbarine sheep is the dominant breed in Tunisia characterized by its fat tail (1.5 to 7kg) which represents an energy reservoir used in periods of feed shortage. This fat-tailed breed is known by its metabolic and digestive adaptation to critical environmental conditions (water scarcity, heat stress, salinity…) (Ben Salem et al., 2011). Ewes were selected (Initial average weight 38±1.86 kg) from the experimental station of Bourbiaa (INRAT) and they were divided into 8 homogeneous groups of 5 ewes each in the trial of 2014 and they were divided into 6 homogenous groups of 5 ewes each in the trial of 2015. Animals received an antiparasitic treatment and were vaccinated against enterotoxaemia. They were housed in collective boxes and marked on, using different colors of painting to be easily identified and separated per treatment and plot before leaving for grazing. They had access to water 3 times a day.

V. Experimental design

1. Experiment 1

The trial was carried out in the experimental station of INRAT (24 km from Tunis, semi-arid: 350 mm of rainfall). During the experimental period, animals were grazing on stubble of durum wheat cultivated according to conventional and conservation agriculture. Two plots were considered, each one divided into 4 fenced subplots: 2 of them present 1665 m^2 for a stocking rate of 30 ewes/ha and the two others have a surface of 3750 m^2 for a stocking rate of 15 ewes/ha. Bread wheat from the variety Karim was sowed in the 30thof December 2013 at a density of 120 kg/ha. Two plots of 1 ha each were reserved to the trial respectively for Conv.A and CA conditions. In CA plot, a treatment by herbicide (glyphosate 180 g ai/acre équivalent à 3L du produit commercial /ha) was applied before sowing. The two plots were weeded chemically using a commercial product (480 g AI/ha, equivalent to 1L of commercial product/ha) by the end of February. The 2 plots were fertilized using Ammonitrate (200 kg/ha) and DAP (100 kg/ha). Wheat was harvested in the 1st of July 2014 at a cutting height of about 25 cm. The registered grain yield was of about 0.995 and 1.018 T/ha respectively for Conv.A and CA (Figure 7). Two main studied factors were: Agriculture practices (Conv.A and CA) and stocking rates (Stoking rate 1(SR15): 15 ewes/ha and Stoking rate 2 (SR30): 30 ewes/ha). Stocking rate levels were repeated four times using the eight fenced subplots. During the experiment, ewes grazed twice a day (from 5 h to 8 h and from 16 h to 18 h or 17h to 19 h) with a total grazing duration of 5 hours per day. The experiment lasted from the 17-07-2014 to the 14-09-2014 with a total duration of about 60 days and during the second month; ewes received a supplementation composed of 250 g of concentrate (17% Soybean meal, 79 of barley grain, 4% of MVS).

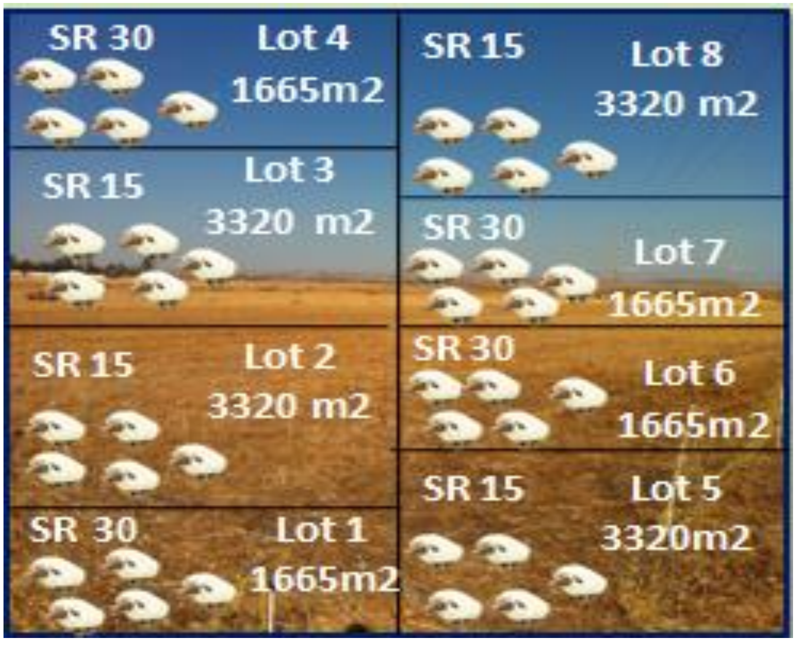


Figure 7: Experimental device

2. Experiment 2

The trial was carried out in the experimental station of INRAT (24 km from Tunis, semi-arid: 350 mm of rainfall). During the experimental period, animals grazed on stubble of bread wheat cultivated according to Conv.A and CA. Two plots last year crop: vetch produced in CA conditions) of 0.5 ha each were respectively reserved to the trial (Previous crop: Vetch; agricultural practice: CA since 3 years). Each one was divided into 3 electrically fenced subplots and each subplot had an area of 1665 m^2 for a stocking rate of 30 ewes/ha (Figure 8). In the 2 plots, durum wheat from the variety Karim was sowed in the $25^{th}$of November 2014 at a density of 160 kg/ha. In CA plot, a treatment by herbicide (glyphosate 180 g of AI equivalent to 3L of commercial product/ha) was applied before sowing. The 2 plots were fertilized using Ammonitrate (150 kg/ha) and DAP (100 kg/ha*). The two* Plots*were*weeded *with*2.4.d (2 applications). Wheat was harvested on the 12^{th} of June 2014 at a cutting height of about 30 cm. The registered grain yield was of about 1.3 and 1.5 T/ha respectively for Conv.A and CA. One main factor was studied: Agriculture practices (Conv.A and CA) and 3 groups of 5 ewes each were reserved for each agricultural practice (3 groups in the correspondent 3 subplots for each agricultural practice). During the experiment, ewes grazed twice a day (from 5 h to 8 h and from 16 h to 18 h or 17h to 19 h) with a total grazing duration of 5 hours per day. The experiment lasted from the 15-07-2014 to the 28-08-2015, with a total duration of about 45 days.

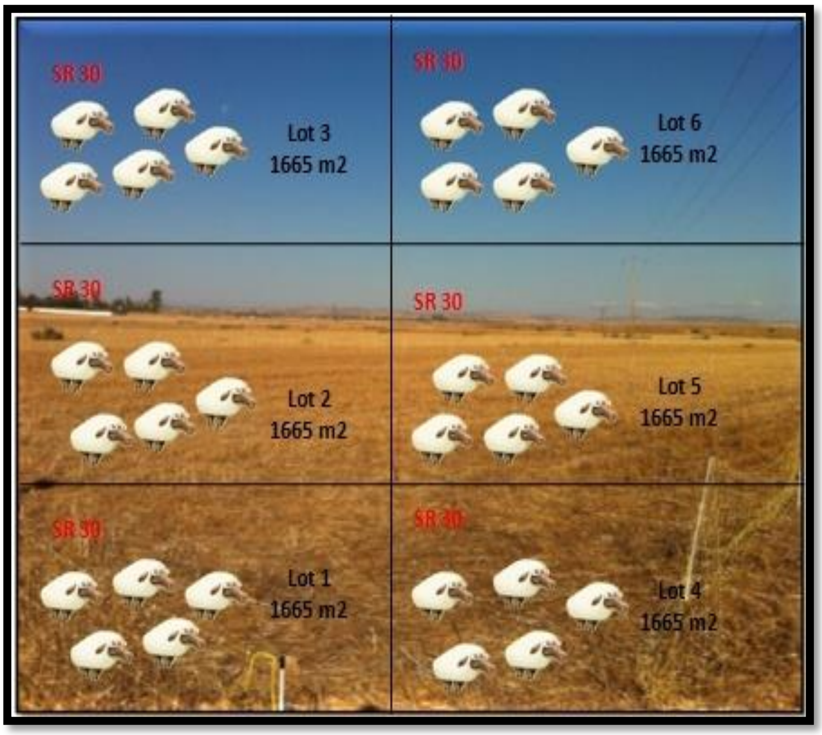


Figure 8: Experimental device

VI. EXPERIMENTAL METHODS

1. Biomass measurement

In the two experiments,the biomass of stubble and the removal of particular fraction were estimated using quadrats sampling technique (1 m^2, 5 quadrats per subplot placed to have representative samples) at the beginning of the trial and each 15 days after. The cutting height was at about 5 cm from the soil.Samples were immediately weighed and transported to the laboratory (INAT) for immediate DM determination. Proportions of heads, leaves, stems and other vegetation parts were evaluated and samples were stored for chemical analysis.

2. Live weight measurement

To monitor the ewes live weight variation, the animals were weighed early in the morning (5h) before the start of grazing. Live weight was determined 4 times after the start of the experiment (every 10 days). Live weight and daily live weight gain by period (LW and DLWG respectively) were calculated.

3. Chemical analysis

Biomass samples *were* oven-*dried* to a constant weight at 50°C ground to pass through *a 1* mm screen then were analyzed according to AOAC method(Association of Official Analytical Chemists, 1984) for Ash and crude protein (CP) and according to Van Soest et al. (1991) method for Acid Detergent Fiber fraction (ADF). Ruminal NH3-N was determined by the method of Conway (1962). Rumen VFA concentrations and molar proportions of individual VFA were analyzed by gas chromatography (Jouany, 1982).

3.1. Common dermination methods for all trials

3.1.1. Classical chemical analysis

a. Dry matter content (DM)

Dry matter is determined by drying the sample in an oven at 105 ° C to a constant weight. The difference in weight (before and after drying) corresponds to the loss of moisture and the residue represents the dry matter of the food. The analytical dry matter content is determined in the same way by accurately weighing 3 g of crushed sample.

b. Mineral (Ash) and organic matter (OM) content

They are determined by the total calcination of the samples in a muffle furnace at a temperature of 550 ° C for 6 hours. the loss of weight observed during the calcination corresponds to the organic matter and the residual ash corresponds to the mineral matter of the sample.

c. CrudeProtein content (CP)

The nitrogen content (N) is determined according to the Kjeldahl method. The sample is hot-mineralized with sulfuric acid (density 1.83, purity 95%) in the presence of a selenium catalyst. the organic nitrogen is transformed into ammoniacal nitrogen which is displaced by sodium hydroxide (70 ml of 50% NaOH), vaporized in the form of ammonium sulphate, and received in a standard solution of boric acid (4%); Finally, it is titrated with a solution of hydrochloric acid (0.1N). Assuming that the CPs are composed of proteins containing 16% nitrogen (N), the CP content (%) corresponds to % N * 6.25.

3.1.2. Analysis of cell wall components

a. Acid Detergent Fiber (ADF) content

This fraction is determined by hydrolysis of the sample in the presence of a sulfuric acid solution and a detergent (CTAB = bromine, cetyltrimethylammonium). The hydrolysis of the sample (1 g, 200 ml of solution) is carried out for one hour in a Fibertec type apparatus (Tecator). From this residue are removed the fat (rinsing with acetone) and insoluble ash (calcination in an oven at 550 ° C for 4 hours). The ADF fraction corresponds approximately to cellulose and lignin.

3.2. Specific determination methods for certain trials

3.2.1. Determination of blood metabolites

In the case of experiment 1, Blood samples had been taken from the jugular vein of each ewe in vacutainer tubes (10 ml) during the second month (each 15 days, at 8.00 h) and stored at -20°C until analyzed for specific metabolites.The concentration of different blood metabolites (Cholesterol (mmol/l), Creatinine (µmol/l), Glyceamia (mmol/l), Urea (mmol/l), Ca (mmol/l), Mg(mmol/l), Phosphore (mmol/l)) have been determined on an automatic biochemical analyzer.

3.2.2. Determination of volatile fatty acids (VFA)

In the case of experiment 2, the VFAs were determined by gas chromatography (GC) according to Jouanry's method (1982). The GC is a method of separating gaseous or vaporizable compounds by heating without decomposition. The volatile compounds are injected at the inlet of a column filled with porous granules impregnated with a liquid characterized of a high solubilization power which constitutes the stationary phase. The column is swept by a gas called vector gas (in our case it is) which constitutes the mobile phase.

The components of the injected solution are in equilibrium between the gas phase and the resulting surface of the stationary phase where they are dissolved. According to their affinity with the stationary phase, their retention time is variable. The output speed is constant for the same component and allows its identification.

3.2.3. Determination of ammonia nitrogen (N-NH_3)

In the case of experiment 2, the ammonia nitrogen is determined according to the method of Conway (1962). The principle of this method consists in a simple gaseous diffusion of the volatilized substance. The ammonium nitrogen is moved by a basic medium consisting of K_2CO_3 (450 g of K_2CO_3 in one liter of distilled water) and taken up by a boric acid solution (10 g of boric acid, 200 ml of ethanol 95 °, 700 ml of distilled water, 10 ml of blue indicator: 1g methylene blue + 500mg methylene red + 500ml alcohol 95 °).The nitrogen is then titrated with hydrochloric acid (0.01N).

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CHAPTER II. WHEAT STUBBLE FROM CONVENTIONAL OR CONSERVATION AGRICULTURE GRAZED BY EWES: BIOMASS DYNAMICS AND ANIMAL PERFORMANCES

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Wheat Stubble from Conventional or Conservation Agriculture Grazed by Ewes: Biomass Dynamics and Animal Performances

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ABSTRACT

Hajer, G., Cyrine, D., Salah, B.Y., Mohamed, C., Sourour, A., Hichem, B.S. and Nizar, M. 2020. Wheat stubble from conventional or conservation agriculture grazed by ewes: Biomass dynamics and animal performances. Animal Nutrition and Feed Technology, 20: 187-200.

This experiment aimed to determine the effect of stocking rates and cropping systems (conventional agriculture; Conv A *vs.* conservation agriculture; Cons A) on biomass dynamics and animal performance parameters of ewes grazing on wheat stubble. Forty Barbarine ewes were divided into eight homogeneous groups and allotted equally to the two cropping systems. Two stocking rates of 15 (SR15) and 30 (SR30) ewes/ha were tested for each cropping system, during a period of 60 d. Stubble biomass and BW variations were monitored at periodic intervals. Blood was sampled thrice during the study period at 15 d intervals. Results showed that the stubble biomass exhibited a gradual decrease ($P<0.0001$) with the progression of the duration by margins of -85.6 and -81.3% on DM basis, respectively, in Conv A and Cons A, as compared to initial biomass. Further, the biomass was also significantly ($P=0.03$) affected by the cropping system with a higher values in Conv A than Cons A. The variations in biomass chemical composition showed that the CP content decreased ($P<0.0001$) with advancing of period, while that of ADF increased ($P<0.0001$). Additionally, there was a significant effect ($P=0.0002$) of cropping mode evident in the nutritional composition. Overall, the animals maintained their average BW between the beginning (47.16 kg) and the end (47.36 kg) of the experiment. The blood parameters measured were well within the ranges of normal values for sheep. The stocking rates did not show impact on any of the parameters, with the values being generally similar between stocking rates and cropping systems. It is concluded that while the stocking rate had no effect on the measured variables, conservation agricultural system seemed to keep a higher proportion of residual biomass at the end of the experiment as compared to conventional agriculture.

Keywords: Conservation agriculture, Conventional agriculture, Ewes, Stocking rates, Wheat stubbles

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187

INTRODUCTION

In arid and semi-arid regions from southern countries of the Mediterranean, agriculture is an important source of income and the bases of food security for rural populations. However, the farming systems are facing different constraints including erosion expansion, soil degradation, water scarcity and soil fertility regression (Jat *et al.*, 2012). The situation is compounded by the impacts of climate changes on the agricultural livelihood systems that are caused mainly by rainfall decrease and variability and the increase of temperature (Sivakumar *et al.*, 2005). These factors are responsible for deficiency of animal feed resources, depletion of water sources and the loss of biodiversity. These effects, in turn, are threatening the efficiency and sustainability of production systems for mainly those relying on livestock husbandry.

Soil preparation involving frequent mechanized activities for crop production and the lack of vegetation cover on soil surface increase the risks of erosions and contribute to soil degradation (Jat *et al.*, 2012). To overcome the weaknesses of conventional agriculture, strategies to improve the efficiency of production systems, protecting the natural resources and reducing the production cost has become an objective to achieve. In this context, conservation agriculture (Cons A) has emerged in many countries (e.g. Australia, Argentina, Brazil, Canada and USA, etc.) as a new paradigm to produce with minimum inputs and disturbance of natural resources. Cons A is based on three principles namely, minimal soil disturbance (zero tillage), permanent soil cover (mulch), and crop rotation. These practices aim to reduce the environmental pollution, to preserve natural resources and to enhance sustainability of the production system (Hobbs *et al.*, 2008; Kassam *et al.*, 2009). In the south of the Mediterranean basin, more than 75% of farms are small and livestock is present in almost all production systems. The average size of the farms is 2-5 ha and are home to small flocks of small ruminants, predominantly sheep and occasionally few dairy cattle (1-3 heads). Under such conditions, the integration crop-livestock has several benefits; it improves the crop/forage yield by rotations, ensures the recycling of nutrients and diversifies the incomes of farmers. Cereal stubbles are excessively grazed by livestock during summer season. Therefore, there is a problem of lack of tradeoffs for the use of crop residues as mulch to increase the organic matter content of soils and its uptake by animals as feed resource. How much stubble biomass to leave on the ground and how much to offer to grazing livestock are key questions need to be addressed for a wide scale adoption of Cons A. In this context, the potential integration crop-livestock under Cons A conditions has been rarely investigated and only few reports on this topic are available in the literature. The objective of this study, therefore, was to investigate whether the cropping mode (conventional agriculture *vs*. conservation agriculture) could influence the biomass dynamics and the responses of ewes to wheat stubble grazing in the semi-arid regions at different stocking rates.

MATERIALS AND METHODS

Study location

The experiment was carried out in the experimental station of the National Institute of Agricultural Research of Tunisia (INRAT) which is 24 km away from Tunis and characterized by a semi-arid climate, 350 mm of annual rainfall. During the experimental period, animals grazed on stubbles of bread wheat cultivated according to conventional agriculture (tillage-based cropping) and conservation agriculture (zero tillage-based cropping).

Two plots of 1-ha each were used. Each plot was divided into 4 fenced subplots. Two subplots each covering 1665 m^2 were assigned to a high stocking rate of 30 ewes/ha (SR30) and the two others each having an area of 3750 m^2 were assigned to a stocking rate of 15 ewes/ha (SR15). The bread wheat variety ACSAD was cultivated on December 30, 2013 at the rate of 120 kg/ha. The two 1-ha-plots were cropped through conventional practices (tillage-based, Conv A) and conservation agriculture (zero-tillage-based, Cons A). In Cons A plot, a treatment by herbicide (glyphosate 180 g/L/ha equivalent to 3 L of commercial product/ha) was applied before sowing. The two plots were weeded chemically using a commercial product (480 g AI/ha, equivalent to 1 L of commercial product/ha) at the end of February 2014. These plots were also fertilized by ammonium nitrate (200 kg/ha) and DAP (100 kg/ha). Wheat was mechanically harvested on July 1, 2014 at a cutting height of about 25 cm. The grain yield was of about 0.995 and 1.018 tons/ha, respectively, for Conv A and Cons A.

Animals and experimental design

A total of 40 Barbarine ewes (4 years old; LW 43.0$\pm$3.67 kg; 1-month pregnant) were selected from the flock of the INRAT experimental station at Bourabiaa. They were divided into eight equal groups. The experimental ewes were treated against gastrointestinal parasites and were vaccinated against entero-toxaemia before the start of the experiment. They were housed in collective boxes in a covered barn. Each group of ewes was marked by a different painting colour to facilitate their monitoring while grazing and their housing in corresponding box. They had access to clean and fresh water three times a day in boxes. A complete randomized design was used to test the effects of two agriculture practices (Conv A and Cons A) and two stocking rates i.e. SR15 and SR30.

During the experiment, ewes grazed twice a day for a total grazing time of 5 h per d (from 5.00 to 8.00 am and from 4.00 to 6.00 pm or 5.00 to 7.00 pm). The grazing period was from 17 July to 14 September 2014, with a total duration of 60 d. During the second month (from 15 August to 14 September), each ewe was daily supplemented with 250g concentrate (17% soybean meal, 79% of barley grain, 4% mineral and vitamin supplement).

Sampling and measurements

The biomass of stubble was estimated using the quadrats sampling technique (1 m^2, 5 quadrats per subplot randomly placed to have representative samples) at the beginning of the experiment and after each 15 d period until the end of the experiment. The cutting height of stubble was about 4 cm from the ground. Eight control samples were taken around the experimental area, outside the fences and corresponded to zero grazing stocking rate treatment. Samples were immediately weighed and transported to the laboratory at the National Institute of Agronomy of Tunisia (INAT) for the determination of DM. In order to control their BW change, ewes were weighed early in the morning (5.00 am) before going to the field for grazing. The BW recorded 6 times every 10 d after the start of the experiment. Blood samples (10 mL) were taken from the jugular vein of each ewe in vacutainer tubes fortnightly during the second month (at 8.00 am) and stored at -20°C until analyzed for specific metabolites.

Chemical analysis

Biomass samples were dried at 50°C in a ventilated oven for 48 h and then ground to pass through a 1-mm screen. Ground samples were analyzed for ash and CP) (AOAC, 1984) and for ADF according to Van Soest *et al*. (1991). Blood samples were centrifuged (3000 rpm for 10 min) then plasma/serum was collected and samples of blood serum were stored at -20°C until they will be analyzed. The serum samples were analyzed for cholesterol, creatinine, glucose, urea, calcium, magnesium, and phosphorous on an automatic biochemical analyzer.

Statistical analysis

The GLM procedure of SAS (2002) was used for variance analysis using the repeated measurement procedure. The following model was used:

$$Y_{ijk}=\mu+A_i+B_j+C_k+(AB)_l+(AC)_m+(BC)_n+(ABC)_q+e_{ijk}$$

Where, Y is the dependent variable, μ is the overall mean, A_i is the effect of period (i=1-7), B_j is the effect of cropping system (Conv A or Cons A) (j=1-2), C_k is the effect of stocking rates (SR15 or SR30) (K=1-2), $(AB)_l$ is the effect of the interaction between period and cropping system $(AC)_m$ is the interaction between period and stocking rate, $(BC)_n$ is the interaction between cropping system and stocking rate, $(ABC)_q$ is the effect of the interaction between period, cropping system and stocking rate, e is the residual error. The LSMEAN test was used to compare treatment effects. The difference between the means of two treatments was considered significant when P value is below 0.05.

RESULTS AND DISCUSSION

Variation of stubble biomass

Biomass estimation according to stocking rates (SR15 and SR30) and cropping system (Conv A and Cons A) are presented in Table 1. Irrespective of cropping system and stocking rates, stubble biomass decreased ($P<0.001$) among periods. In Conv A, the stubble biomass yield ranged between 1292 and 1532 kg DM/ha at the first sampling time, respectively, for SR15 and SR30 and then decreased to reach 201 and 205 kg DM/ha, respectively, for SR15 and SR30 groups. The decrease rate was much more pronounced in the second sampling time and higher for SR30 than SR15 (-543 and -879 kg DM/ha, respectively). The same trend of biomass dynamic was observed in Cons A. Indeed, the stubble biomass yield ranged between 1162 and 1143 kg DM/ha at the first sampling time and dropped to 201 and 230 kg DM/ha, 60 d after, respectively, for SR15 and SR30. The stubble biomass dynamicsas highlighted in Table 1 shows that irrespective of sampling time, no differences were observed between Conv A and Cons A except in the first period in which the biomass was lower ($P<0.001$) under Cons A than Conv A (1153 and 1412 kg DM/ha, respectively). In this experiment, the cropping mode significantly affected the total stubble biomass. However, this parameter did not affected by the stocking rates. Masmoudi (2012) came up with same conclusion in an experiment conducted in Algeria under Cons A in which animals grazed wheat stubble at different stocking rates. The relative variations in values and trends on the variation of stubble biomass and

Table 1. Stubble biomass (kg DM/ha) as affected by the cropping mode[†] and stocking rate[‡]

Period (d)	Conv A		SEM	P value	Cons A		SEM	P value	Cropping mode		SEM	P value
	SR15	SR30			SR15	SR30			Conv A	Cons A		
0	1292.5^{a}	1532.2^{b}	104.2	0.02*	1162.4	1143.3	76.3	0.85	1412.4^{m}	1152.9^{n}	66.8	0.0007***
15	749.4	652.8	56.7	0.35	689.5	586.5	65.9	0.32	701.1	638.0	43.2	0.39
30	539.9	440.1	30	0.33	502.9	442.1	28.8	0.55	490	472.5	20.6	0.81
45	302.3	267.2	21.2	0.74	258.4	238.6	11.9	0.86	284.8	248.5	13	0.64
60	201.3	204.9	12.2	0.97	201.4	230.0	17.7	0.78	203.1	215.7	10.6	0.86

Significance[§]

Parameter	Period	Cropping mode	Stocking rate	P×CM	P×SR	CM×SR	P×CM×SR
Biomass	<0.0001***	0.03*	0.62	0.08	0.28	0.57	0.59

[†]Cropping mode: conventional agriculture (Conv A) and conservation agriculture (Cons A).
[‡]Stocking rate: 15 ewes/ha (SR15) and 30 ewes/ha (SR30).
[§]Significant effects of period (P), cropping mode (CM), stocking rate (SR) and their interactions (P×CM, P×SR, CM×SR, P×CM×SR).
[a,b/m,n]Means in the same row, within a comparison criterion, with different superscript are statistically different: *$P<0.05$; ***:$P<0.001$.

the behavior of grazing animals could be explained by differences in terms of cereal species, technical itinerary, crop yields and grazing practices (animals, stocking rates and grazing duration).

Variation in chemical composition

Data on chemical composition of stubble are reported in Table 2. The ash, CP and ADF contents varied among the periods ($P<0.001$). The ash content increased with the progress of the experiment ($P<0.001$). Under Conv A, the ash concentration (on DM basis) ranged from 7.22 and 7.82 per cent in the first period and reached 9.08 and 10.47 per cent at the end of the experiment with SR15 and SR30 treatments, respectively. Under Cons A, the ash content of stubble biomass had increased from 7.05 per cent at the first sampling time to 9.06 per cent at the last sampling period with the SR15. However, the content of this nutrient did not change with the higher stocking rate, i.e. SR30. The proportion of CP in stubble biomass decreased among periods irrespective of cropping system and stocking rate ($P<0.001$). The ADF content of stubble increased with time ($P<0.001$, Table 4) in both Conv A and Cons A, and also the two stocking rates.

Under Conv A, ADF concentrations increased by 4.3 and 3.7 percentage units, respectively, for SR15 and SR30 treatments while under Cons A conditions, ADF content increased by 5.61 and 5.46 percentage units, respectively, for SR15 and SR30. Except for the second period in Conv A, ADF proportion varied ($P=0.04$) between the two stocking rates. Statistically, the type of cropping system substantially affected ($P<0.001$) the ADF contents of the stubble.

The increase of ash content during the experiment could be explained by the trampling of ewes which increased the dustiness of the stubble especially at the last period when the biomass is less abundant. However, Moujahed *et al.* (2015) did not observe any significant change of ash content of stubble assigned to the same stocking rates used in the current experiment. The CP content of stubble at the first sampling time averaged 4.55 and 4.82 per cent, respectively, for Conv A and Cons A. Similar figures have been reported by Moujahed *et al.* (2015). In our study, whatever the cropping mode and stocking rate, the CP proportion decreased with sampling time. Moujahed *et al.* (2015) showed that the proportion of CP decreased 14 d after the beginning of the grazing period. However, it did not change with SR15 treatment. They mentioned that the high proportion of CP content in the beginning of the experiment may be linked to the richness of biomass in heads and thereby grains. The evolution of CP content is related to the proportion of grains, which decreases with the increase of the grazing duration (Moujahed *et al.*, 2015). Unlike the decrease of CP with grazing time, ADF proportion increased irrespective of the stocking rate and the cropping mode. This observation highlighted the negative correlation between CP and ADF proportions (Avondo, 2000). Similar findings have been reported by Moujahed *et al.* (2015) who showed that ADF content of barley stubble had increased in SR15 and SR30 plots, respectively, between the first sampling time and after 14 d. They

Table 2. Chemical composition of stubble biomass as affected by the cropping mode[†] and stocking rate[‡]

Period (d)	Nutrients (%)	Conv A SR15	Conv A SR30	SEM	P value	Cons A SR15	Cons A SR30	SEM	P value	Cropping mode Conv A	Cropping mode Cons A	SEM	P value
0	DM	90.26	90.11	0.11	0.44	89.96	90.09	0.06	0.49	90.19	90.02	0.06	0.23
	Ash	7.22	7.82	0.23	0.38	7.05	7.16	0.08	0.87	7.52	7.10	0.13	0.39
	CP	4.42	4.67	0.25	0.37	4.88	4.76	0.14	0.68	4.55	4.82	0.14	0.16
	ADF	47.45	48.85	0.71	0.15	46.30	45.84	0.33	0.63	48.15^{x}	46.07^{y}	0.46	0.003**
15	DM	90.27	90.27	0.07	0.99	90.04	89.97	0.07	0.68	90.27	90.01	0.06	0.05
	Ash	7.14	7.72	0.15	0.40	7.30	7.26	0.15	0.95	7.43	7.28	0.11	0.76
	CP	3.91	3.61	0.17	0.29	4.19	3.75	0.11	0.12	3.76	3.97	0.10	0.30
	ADF	49.40^{a}	51.33^{b}	0.72	0.04*	47.06	48.47	0.51	0.15	50.37^{x}	47.77^{y}	0.54	0.0003***
30	DM	90.58^{a}	90.18^{b}	0.13	0.04*	89.76^{m}	90.24^{n}	0.18	0.01*	90.38^{x}	90.00^{y}	0.12	0.006**
	Ash	7.89	8.32	0.12	0.54	8.33	9.12	0.30	0.25	8.11	8.73	0.18	0.20
	CP	3.52	3.48	0.15	0.87	2.90	3.25	0.08	0.22	3.50^{x}	3.07^{y}	0.10	0.03*
	ADF	50.29	50.07	0.19	0.82	49.46	49.45	0.58	0.99	50.18	49.46	0.31	0.29
45	DM	90.09	90.31	0.06	0.26	90.49	90.24	0.10	0.20	90.20	90.36	0.06	0.22
	Ash	7.95	7.27	0.19	0.32	6.96	7.27	0.15	0.65	7.61	7.11	0.13	0.31
	CP	3.20	3.20	0.06	0.99	3.13	3.68	0.15	0.05	3.20	3.41	0.08	0.29
	ADF	50.42	51.61	0.31	0.22	51.57	50.29	0.39	0.18	51.02	50.93	0.24	0.89
60	DM	89.87^{a}	90.65^{b}	0.17	0.0001***	89.90	89.82	0.05	0.67	90.26^{x}	89.86^{y}	0.10	0.004**
	Ash	9.08^{a}	10.47^{b}	0.70	0.04*	9.06	8.72	0.64	0.62	9.78	8.89	0.47	0.07
	CP	3.71^{a}	3.11^{b}	0.17	0.03*	3.38	3.29	0.05	0.74	3.41	3.34	0.09	0.72
	ADF	51.73	52.55	0.60	0.39	51.91	51.30	0.22	0.52	52.14	51.61	0.32	0.43

Significance[§]

Parameters	Period	Cropping mode	Stocking rate	P×CM	P×SR	CM×SR	P×CM×SR
DM	0.18	0.001**	0.27	0.02*	0.24	0.69	0.0003***
Ash	<0.0001***	0.22	0.15	0.27	0.80	0.49	0.35
CP	<0.0001***	0.65	0.62	0.08	0.07	0.29	0.36
ADF	<0.0001***	0.0002***	0.17	0.05	0.33	0.05	0.65

[†]Cropping mode: conventional agriculture (Conv A) and conservation agriculture (Cons A).
[‡]Stocking rate: 15 ewes/ha (SR15) and 30 ewes/ha (SR30).
[§]Significant effects of period (P), cropping mode (CM), stocking rate (SR) and their interactions (P×CM, P×SR, CM×SR, P×CM×SR).
[ab/mn/xy]Means in the same row, within a comparison criterion, with different superscript are statistically different: *P<0.05; **P<0.01; ***:P<0.001.

ascribed this change to the variation of the botanical composition of stubble and the difference of disappearance kinetics of the various components of stubble. Stubble heads or grains disappeared first, then leaves and finally stems leading to the increase of ADF proportion.

Performances of ewes

Data on BW as affected by cropping system, sampling time and stocking rate are presented in Table 3. Under both Conv A and Cons A, the ewes lost weight during the first grazing period with both the stocking densities, SR15 and SR30. In the second period, ewes from the two groups exhibited positive BW change. During the second month of the experiment along which grazing ewes were receiving concentrate, the BW of these animals was quite stable until the end of the experiment. Irrespective of the weighing time and the cropping mode, BW of the ewes was not affected by the increase in stocking rate. To summarize, neither cropping mode nor stocking rate had affected ewes' BW.

Since the first grazing period, the ewes were losing weight. This is likely not related to the nutritive value of stubbles but rather to the initial body (health) state of the ewes. Moujahed *et al.* (2015) confirmed

Table 3. Body weight (kg) of grazing ewes as affected by the cropping mode[†] and stocking rate[‡]

Period (d)	Conv A		SEM	P value	Cons A		SEM	P value	Cropping mode		SEM	P value
	SR15	SR30			SR15	SR30			Conv A	Cons A		
0	48.63	44.54	1.85	0.25	47.13	48.34	1.56	0.74	46.59	47.74	1.20	0.65
10	45.63	42.04	2.07	0.30	44.51	45.02	1.36	0.88	43.84	44.77	1.22	0.70
20	46.03	43.45	2.02	0.46	45.60	44.97	1.43	0.85	44.74	45.29	1.22	0.82
30	45.87	44.15	1.96	0.62	46.67	46.68	1.42	0.99	45.01	46.68	1.20	0.50
40	45.85	44.47	1.99	0.69	47.71	46.83	1.46	0.80	45.16	47.27	1.23	0.39
50	46.71	45.11	1.98	0.64	48.07	46.81	1.42	0.71	45.91	47.44	1.21	0.53
60	47.62	45.55	1.93	0.55	48.66	47.60	1.45	0.76	46.59	48.13	1.21	0.53

Significance[§]

Parameter	Period	Cropping mode	Stocking rate	P×CM	P×SR	CM×SR	P×CM×SR
Body weight	0.56	0.15	0.14	0.99	1	0.25	0.99

[†]Cropping mode: conventional agriculture (Conv A) and conservation agriculture (Cons A).
[‡]Stocking rate: 15 ewes/ha (SR15) and 30 ewes/ha (SR30).
[§]Significant effects of period (P), cropping mode (CM), stocking rate (SR) and their interactions (P×CM, P×SR, CM×SR, P×CM×SR).

in a similar experiment on grazing lambs under the context of Cons A that the weight loss is related to body conditions of animals and not to the nutritional value of barley stubbles. Also, they claimed that during the first period, animals had been in an adaptation phase to the experimental conditions. This can explain the instability of the body weight of animals. In the second period, ewes had recovered to the extent that they gained weight. Stubble biomass in plots was not limiting and enough abundant during the first month even with the high stocking rate (SR30). Results showed that stubble biomass seemed to be sufficient and overcome ewes' requirements even in absence of supplementation in the first month may be thanks to the presence of grains of epics. During the second month, the biomass was less abundant with a low quality and it is the concentrate that has allowed the ewes to maintain their body weight. Masmoudi (2012) mentioned that there is a close relationship between livestock on the one hand and the cover crop before grazing, the stocking rate and the grazing period on the other hand. The author affirmed that livestock could be integrated when more than 78% of mulch was left on soil before grazing. In this context, Jarecki and Lal (2003) mentioned that conservation agriculture required 30% of the soil surface being covered with previous crop residues

Blood metabolites

The concentrations of blood metabolites and select minerals are presented in Table 4. For the three sampling times (each 15 d, from d 30 to d 60), the blood profile did not change except for urea ($P=0.0001$) and for Ca ($P<0.0001$). In the context of Conv A, the variation of blood metabolites and minerals was similar between the two stocking rates except for Mg in the last period (d 60) ($P=0.007$, 2.45 and 3.26 mg/dL, respectively, for SR15 and SR30). Under Cons A, only glucose content in the first period (d 30) varied between SR15 and SR30 ($P=0.01$, 56 and 68.5 mg/dL, respectively, for SR15 and SR30). Cropping mode (Conv A vs Cons A) and stocking rates (SR15 vs SR30) did not affect the concentrations of blood metabolites and minerals.

The concentration of serum cholesterol averaged 71.6 mg/dL and it was in line with reference intervals (51.8 and 75.9 mg/dL) reported in the literature (Dubereuil *et al.*, 2005). However, Deghnouche *et al.* (2011) reported in their study on Ouled Djellal sheep breed a cholesterol concentration of about 48.7 mg/dL. Ndoutamia and Ganda (2005) mentioned that the Kirdimi sheep breed presented a higher concentration of cholesterol (83 mg/dL) than the two other sheep breeds (73 mg/dL and 65 mg/dL, respectively, for Peulhs and Arabe sheep). Similarly, the average concentration of serum creatinine measured in this study was 1.3 mg/dL and is in the range of values reported in previous studies (Baumgartner and Pernthaner, 1994; Radostits *et al.*, 2000; Dubreuil *et al.*, 2005). However, it was higher than the concentration (0.9 mg/dL) reported by Deghnouche *et al.* (2011). The average concentration of blood glucose was estimated to 65.6 mg/dL and it is in reference interval (41.4-75.7 mg/dL) reported in the literature (Brugera-Picoux, 1987; Radostits *et al.*, 2000; Dubereuil *et*

Table 4. Blood parameters (mg/dL) of grazing ewes as affected by the cropping mode[†] and stocking rate[‡]

Period (d)	Parameters	Conv A		SEM	P value	Cons A		SEM	P value	Cropping mode		SEM	P value
		SR15	SR30			SR15	SR30			Conv A	Cons A		
30	Cholesterol	71.2	70.5	2.33	0.90	69.7	72.5	3.90	0.64	70.8	71.1	2.24	0.95
	Creatinine	1.25	1.35	0.04	0.32	1.27	1.2	0.03	0.47	1.30	1.23	0.03	0.30
	Glucose	61.4	67.7	2.48	0.22	56[m]	68.4[n]	2.40	0.01*	64.6	62.2	1.71	0.52
	Urea	23.6	25.6	1.39	0.39	25.8	26	1.08	0.93	24.6	25.9	0.87	0.43
	Ca	10.9	11.2	0.38	0.77	10.1	10.8	0.36	0.38	11.0	10.0	0.27	0.26
	Mg	2.6	2.8	0.09	0.52	3.0	2.5	0.14	0.05	2.67	2.77	0.08	0.64
	Phosphorous	5.0	5.3	0.20	0.52	5.7	5.8	0.17	0.82	5.13	5.80	0.14	0.06
45	Cholesterol	69	67.5	2.04	0.80	69	69.4	2.48	0.91	68.2	69.1	1.56	0.85
	Creatinine	1.31	1.35	0.05	0.66	1.23	1.25	0.04	0.82	1.33	1.24	0.03	0.23
	Glucose	68.8	66.1	3.26	0.60	70.2	69.6	2.90	0.91	67.5	69.9	2.20	0.54
	Urea	28	28.2	1.14	0.93	30.7	28.6	1.13	0.41	28.1	29.6	0.80	0.38
	Ca	10.2	10.4	0.57	0.73	9.6	9.8	0.56	0.81	10.3	9.72	0.40	0.34
	Mg	2.7	2.6	0.16	0.89	2.6	2.4	0.16	0.51	2.64	2.52	0.11	0.58
	Phosphorous	5.4	5.2	0.34	0.71	6.2	5.3	0.27	0.08	5.28	5.73	0.22	0.23
60	Cholesterol	78.2	78.3	2.82	0.98	71.4	72.7	3.89	0.84	78.2	72.0	2.38	0.16
	Creatinine	1.32	1.32	0.06	0.98	1.37	1.44	0.07	0.49	1.32	1.40	0.05	0.25
	Glucose	65.9	63.2	2.35	0.60	64.4	65.4	2.39	0.85	64.6	64.9	1.65	0.93
	Urea	23.8	24.9	1.23	0.64	22.2	23.6	0.92	0.58	24.3	22.9	0.78	0.41
	Ca	11.9	13.0	0.24	0.17	11.7	12.1	0.20	0.63	12.4	11.9	0.16	0.42
	Mg	2.45[a]	3.26[b]	0.20	0.007**	2.9	2.5	0.17	0.20	2.85	2.68	0.13	0.42
	Phosphorous	6.1	5.7	0.27	0.42	5.5	5.7	0.23	0.68	5.88	5.56	0.18	0.38

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Significance§

Parameter	Period	Cropping mode	Stocking rate	P×CM	P×SR	CM×SR	P×CM×SR
Cholesterol	0.11	0.52	0.85	0.45	0.97	0.65	0.98
Creatinine	0.12	0.54	0.50	0.17	0.96	0.64	0.48
Glucose	0.12	0.95	0.29	0.66	0.06	0.36	0.92
Urea	0.0001***	0.63	0.65	0.39	0.60	0.51	0.85
Ca	<0.0001***	0.11	0.15	0.97	0.82	0.88	0.76
Mg	0.45	0.60	0.76	0.62	0.37	0.005**	0.25
Phosphorous	0.54	0.22	0.47	0.12	0.30	0.77	0.40

†Cropping mode: conventional agriculture (Conv A) and conservation agriculture (Cons A).
‡Stocking rate: 15 ewes/ha (SR15) and 30 ewes/ha (SR30).
§Significant effects of period (P), cropping mode (CM), stocking rate (SR) and their interactions (P×CM, P×SR, CM×SR, P×CM×SR).
abcMeans in the same row, within a comparison criterion, with different superscript are statistically different: *P<0.05; **P<0.01.

al., 2005). The same trend was observed by Ndoutamia and Ganda (2005) in Arab sheep (55 mg/dL). However, they showed higher values of glucose concentration for Peulhs (78 mg/dL) and Kirdimi (128 mg/dL) breeds of sheep. Serum urea levels changed significantly with grazing time. It averaged 25.3 mg/dL on d 30, then increased at d 45 and decreased in the last period (d 60) to reach 23.6 mg/dL. The average blood urea levels were in line with reference intervals reported by Ndoutamia and Ganda (2005). The decrease of urea content at the end of the experiment can be explained by the physiological state of ewes. Indeed, during pregnancy, urea concentration decreased with the increase of nutrient requirements of the placenta and the foetus. The same trend was observed in the study conducted by Hafaf *et al.* (2012) on pregnant ewes of Ouled Djellal breeds of sheep. They observed a decrease in urea content from 33.9 mg/dL at the beginning of the pregnancy to attend 21 mg/dL after 120 d of pregnancy. In this context, they mentioned that the urea concentration decreases especially at late pregnancy when the nutrient requirements of the placenta and foetus reach their maximum levels. In addition, these authors pointed out that the low levels of urea observed during the pregnancy period may indicate some dietary deficiencies or some disturbances in liver function. The average concentrations of cholesterol, creatinine, glucose and urea in grazing ewes' blood are in the range of concentrations generally observed in sheep. This confirmed that under our experimental conditions; irrespective of period, cropping mode and stocking rate, the ewes were in satisfactory nutritional conditions and stubble biomass supplemented with concentrate meet the nutrient requirements of Barbarine ewes. The concentration of blood calcium changed over time. It increased from an average of 10.5 mg/dL on d 30 to attend 12.2 mg/dL at the last period, on d 60. The average concentrations of calcium in the blood serum of Barbarine sheep were within the standard physiological intervals (Kaneko *et al.*, 1997; Stevanovic *et al.*, 2015). This also confirms that biomass quantity and quality was sufficient to satisfy all the needs of animals until the end of the experiment. The levels of magnesium and phosphorus were in line with reference values (Kaneko *et al.*, 1997; Stevanovic *et al.*, 2015). In brief, stubble biomass supplemented with concentrate provided needed amounts of the major minerals for grazing ewes.

CONCLUSION

The trade-off between mulching to increase soil fertility and stubble biomass uptake by livestock is a prerequisite for the adoption of Cons A by farmers in the dry areas. Results of the current study confirms that the stocking rates assigned to the experimental stubble plots fit with this trade-off. The grazing ewes maintained their BW with both SR15 and SR30 and in the two cropping modes (Conv A and Cons A). Irrespective of the treatments, there was part of stubble biomass left on the ground. The response of the ewes to wheat stubble grazing was similar among the two cropping modes, i.e. Conv A and Cons A. Almost all dependent variables measured in this experiment were not affected by the cropping mode or the stocking rate. The impact of the presence of ewes on stubble plots on soil characteristics (e.g. compactness and organic matter level, etc.) and the economic evaluation of the cropping modes should be investigated in further studies.

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CHAPTER III. BIOMASS VARIATION AND EWES' RUMEN FERMENTATION AND BODY WEIGHT DYNAMIC ON WHEAT STUBBLE FROM CONVENTIONAL AND ZERO-TILLAGE CROPPING SYSTEM IN SEMI-ARID REGION

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Abstract

This experiment aimed to determine the effect of cropping system: Conventional and conservation agriculture on biomass variation, rumen fermentation and ewes body weight (BW) change of ewes grazing on wheat stubbles for 45 days. Thirty Barbarine breed ewes were divided into 6 homogeneous groups of 5 animals each.. Biomass and botanical composition of stubble plots were controlled every 15 days. The BW change was controlled every 10 days. Rumen fluid was collected during 3 consecutive days, three times a day (Just early before grazing, after 2 and 4 hours of the grazing) to determine rumen fermentation parameters i.e. rumen pH, ammonia nitrogen concentration and volatile fatty acid concentration and composition. Results showed that stubble biomass decreased significantly among period and was not affected by the cropping system. The variation of the botanical composition of biomass was similar among the two cropping systems. The BW was not affected by the cropping system. For both cropping systems, rumen pH decreased (P< 0.0001) with time. Total VFA concentration increased after 2 hours of grazing. Ammonia-N concentration in the rumen increased at 2h of grazing and conserved almost the same concentration at 4 h of grazing. The cropping system didn't affect rumen fermentation.

Key words: Ewe, wheat stubbles, biomass, body weight, rumen fermentation.

1. Introduction

The degradation of natural resources (i.e. water, soil and biodiversity loss), the increasing costs of agricultural inputs (e.g. energy, labor, pesticides, etc.) and climate change impacts, are fragilizing the ecosystems in the dry areas and threatening the sustainability of the production systems (MEA, 2005). An additional pressure is exerted by the growing food and water demands in the world (MEA, 2005). In these conditions, the necessity to develop sustainable agricultural practices is becoming a crucial concern to ensure the efficiency and the sustainability of agricultural systemsmainly those relying on livestock integration (MEA, 2005). Countries of the Mediterranean basin mainly those characterized by semi-arid or arid environmentsaresuffering from low quality soils and water shortage. This situation is the result of negative annual water balance, rainfall variability, deficit in organic matter,increased temperature andsoil erosion (Kassam, 1981, 1988, 1992).The use of agricultural mechanization in soil preparation and the loss of crop cover on soil surface increase the risks of erosions and soil degradation (Jat*et al*., 2012). In this context, intensive tillage presents a major cause of agricultural soil degradation, and therefore the decrease of the productive capacity, mainly in semi-arid regions of the Mediterranean basin (Kassam, 1981, 1988; Stewart *et al*., 2007). Consequently, conservation agriculture (CA) is seen as a promising alternative to conventional agriculture whereby minimum machinery intervention is displayed and soil fertility is improved with mulching. Also, it contributes to water saving through a decrease of evapotranspiration.Thereby, the production cost is expected to decrease and the natural resources are more protected (Uphoff*et al*., 2006; FAO, 2008; Pretty, 2008; Friedrich *et al*., 2009a; Kassam *et al*., 2009; FAO, 2010)

Conservation agriculture is based on three principals which are (i) a minimal soil disturbance (zero tillage), (ii) a permanent soil cover (mulch), and (iii) a crop rotation (Hobbs et al., 2007; Kassam *et al*., 2009).This "biological and ecosystems" paradigm represents a challenge in order to ensure the agricultural sustainability including pastures,arable and perennial crops, trees and livestock (Uphoff*et al*., 2006; FAO, 2008; Pretty, 2008;Friedrich *et al*., 2009a; Kassam*et al*., 2009; FAO, 2010). The southern river of the Mediterraneanbasin is home to more than 75% of smallholder farming system and livestock represents a main component in the farming systems (Sims *et al*., 2009). It's integration with crops is crucial for sustainability and efficiency of production systems (Van Keulen and Schiere, 2004).

However, crop-livestock integration seems to be incompatible with one of the principles of CA that is mulching through leaving a certain amount of crop residues on the soil surface. But, every so often the stubbles are fully consumed by livestock with quite no residues left on the soil to increase its organic matter content. Studies on trade-offs between mulching and stubble uptake by livestock should be emphasized to make possible the integration of crop and livestock under CA in the dry areas like Tunisia. Crop-livestock integration under CA requires good knowledge on the response of the animal to the optimization of grazing conditions (eg. Stocking rate, grazing duration etc.).Therefore, the main objective of this study was to investigate whether the cropping mode (Conv.A vs. CA) could influence the biomass dynamic of stubble, rumen fermentation parameters and the body weight of ewes grazing on wheat stubbles in a Tunisian semi-arid region.

2. Materials and Methods

2.1- Study location and plant material

This experiment was carried out in the experimental station (Bourabiaa) of the National Institute of Agricultural Research of Tunisia (INRAT). The climate is semi-arid with an average annual rainfall of about 350 mm. The trial was conducted from July 15th to August 28th, 2015 (45-day of experimental period); Animals grazed on stubbles of durum wheat cultivated according to ConvA (tillage-based) or to CA (zero-tillage-based conditions. Two plots, of 0.5 ha each, were respectively assigned to this experiment. The previous crop was common vetch (on CA since 3 years). Each plot was divided into 3 electrically fenced-subplots covering each 1665 m^2 and grazed at a stocking rate of 30 ewes/ha. In the 2 plots, durum wheat (Karim variety) was sowed in the 25thof November 2014 at a density of 160 kg/ha. Before sowing, the CA plot was treated by an herbicide (glyphosate 180 g of AI equivalent to 3L of commercial product/ha). The 2 plots were fertilized with ammonitrate (150 kg/ha) and DAP (100 kg/ha) and were weededwith2.4.d (2 applications). Wheat was harvested on the 12th of June 2014 at a cutting height of about 25 cm. The total grain yield was on average 1.3 and 1.5 T/ha, respectively for Conv-A and CA plots.

2.2. Animals and Experimental design

A total of 30 Barbarine ewes (Average age 5 years, initial average body weight 41 ± 2.2kg and average gestational age 2 months) were selected from the sheep flock of the experimental station of INRAT at Bourbiaa. They were divided into 6 groups of 5 ewes each and received an anthelmintic treatment (DALBEN) and were vaccinated against enterotoxaemia (COGLAVAX) Ewes were housed in collective boxes and were identified using different colors of painting. They had access to clean water 3 times a day. For each cropping mode, , there were three groups of ewes and each group was grazing a subplot of wheat stubbles. Along the experimental period, ewes were grazing twice a day, in the morning (from 5 h to 8 h) and in the afternoon (from 16 h to 18 h or from 17h to 19 h), with a total grazing duration of 5 hours per day.

2.3. Sampling and measurements

Stubble biomass and the removal of particular fractions were estimated using quadrats sampling technique (1 m^2, 5 quadrats per subplot placed to have representative samples) at the beginning of the experiment and at 15-day intervals. The cutting height of stubbles was of about 5 cm from the soil. Biomass samples were immediately weighed and transported to the laboratory of the National Institute of Agronomy of Tunisia (INAT) for DM determination. Proportions of heads, leaves, stems and other vegetation parts were estimated and samples were stored for chemical analysis. Animals were weighed early in the morning (5.00 am) before the start of grazing. Body weight of ewes was determined at 4 times after the start of the experiment (every 10 days) and the BW change (BWC) was calculated. To determine rumen fermentation parameters, samples of rumen fluid were taken by stomach tube during 3 successive days (August 8, 9 and 10, 2015), at three times (early before grazing and2 and 4 hours after). The pH of ruminal fluid was immediately determined using a digital pH meter and 18ml of filtered rumen liquid samples were mixed with 2 ml of conserving solution (1 g of mercuric chloride + 5 ml orthophosphoric acid, diluted to 100 ml with distilled water)and then conserved at -18 °C.

2.4. Chemical analysis

Biomass samples were oven-dried to a constant weight at 50°C ground to pass through a 1 mm screen then analyzed according to AOAC (1984) for ash and crude protein (CP) and according to Van Soest et al. (1991) for acid detergent fiber (ADF) content. Ruminal NH3-N was determined by the method of Conway (1962). Rumen VFA concentrations and molar proportions of individual VFA were analyzed by gas chromatography (Jouany, 1982).

2.5. Statistical analysis

Data generated from this experiment were subjected to analysis of variance according to GLM procedure of Statistical Analysis System software (SAS, 2002), using the repeated measurement procedure. The model included as independent variables cropping type (Conv-Aor CA), period and interactions. The animal was considered as co-variable.

$Y_{ijk} = \mu + A_i + P_j + (AP)_k + e_{ijk}$

Y is the dependent variable, µ is the overall mean, A_i is the effect of agricultural practices (Conv. A or CA; i= 1-2), $P_j$is the effect of period (j=1-5), $(AP)_k$ is the effect of the interaction between period and agriculture practices. For rumen fermentation parameters (pH, ammonia-N and VFA), the SNK test was used to compare treatment effects. The LSMEAN test was used to compare factors levels. When P-value is below 5 %, the treatment effect was considered significant.

3. Results

3.1. Stubble biomass variation and composition

The variation of biomass according to agricultural practices (Conv.A and CA) is presented in Tables 1 and 2. The cropping system (Conv-A and CA) didn’t affect the botanical composition of biomass. Biomass decreased (P<0.0001; Table 2) among sampling periods in both Conv-A and CA plots. From the beginning to the end of the experiment, the values ranged between 815 and 315kg DM/ha for Conv-A plots and between 931 and 380 kg DM/ha for CA.The decrease was much more pronounced at the second sampling time and higher for CA plots (-212 and -398 kg DM/ha, respectively for Conv-A and CA plots). Results in Table 1 reflect the similarity between the two cropping systems (Conv-A and CA) for biomass variation along the different sampling times. The proportion of weeds decreased considerably among sampling time (P=0.01, Table 2) for both Conv-A and CA cropping mode until their disappearance at the end of the experiment. Head proportions decreased among period (P=0.03, Table 2) and the decrease was much more pronounced in CA (-29.2 g/kgDM) than in Conv-A (-22.8 g/kg DM). This decrease was associated to an increase of stem proportions in stubbles biomass among sampling times (P<0.0001, Table 2). However, leaves proportions decreased (P<0.0001; Table 2) for the two cropping systems and the period.

3.2. Evolution of chemical composition of stubble

The variation of nutrient contents of stubble according to cropping system and period is presented in Tables 3 and 4. In both Conv-A and CA, ash content varied with the progress of the experiment period (P<0.0001; Table 4). Indeed, values ranged between 90 and 81 g/kgDM at the first sampling period and reached 73 and 74g/kgDM at the end of the experiment for Conv-A and CA, respectively. Crude protein content decreased among periods (P<0.0001; Table 4) irrespective to cropping system (-38.1 and -36.6%for Conv-A and CA, respectively). The decrease was much more pronounced in Conv-A than in CA. In opposite to CP variation, an increase of ADF content in biomass among sampling times (P<0.0001, Table 4) in both Conv-A and CA which was noted and estimated to 14.4 and 17.8 percentage units, respectively. Except in the second sampling time, DM (P=0.03; Table 3), CP (P<0.0001; Table 3) and ADF (P=0.04; Table 3) contents varied between the stubbles from Conv-A and CA-cropping. Agricultural practices affected (P=0.04; Table 4) ash contents of wheat stubbles.

3.3. Ewes' body weight variation

The BW and BWC are presented in Tables 5, 6, 7 and 8. Results showed that BWC varied among periods (P<0.0001; Table 8). In the first grazing period, there was a positive BWC of ewes assigned to Conv-A and CA plots (18.7 and 15.6 g/d respectively for Conv-A and CA; Table 5). During the second period, ewes grazing on CA-plots lost body weight (-44.7 g/d, Table 5). In the third grazing period and for the two cropping systems, there was a decrease of BW, which was more pronounced in Conv-A than in CA ewes (-132.7 and -59.3 g/d, respectively for Conv-A and CA; Table 7). In the last grazing period, ewes increased their body weight (+102.7 and 88 g/d, respectively for Conv-A and CA). For all the weighing times, the cropping mode didn't affect ewes' BW.

3.4. Rumen fermentation of Barbarine ewes

3.4.1. pH variation

Whatever the cropping mode, rumen pH decreased among sampling time (P<0.0001, Table 9). Before grazing (T0), pH values ranged between 6.91 and 6.96, respectively for Conv-A and CA ewes. After two hours of grazing on stubbles (T2), rumen pH decreased to 6.72 and 6.74, respectively for Conv-A and CA ewes. The lowest value of rumen pH (6.50) was obtained at 4 hours after the start of grazing (T4). The cropping mode had no effect (*P*> 0.05) on rumen pH.

3.4.2. Ammonia- N variation

Rumen NH_3-N concentrations varied (*P*=0.0003) among sampling times (Table 10). The lowest concentration was obtained before the beginning of grazing for the two cropping modes (55.7 and 63.4mg/l, respectively for Conv-A and CA). Then, NH_3-N values increased at 2h after the start of grazing (78 and 90 mg/l, respectively for CA and Conv-A). After 4 hours of fermentation, NH_3-N concentration decreased slightly and reached 88mg/l in Conv-A ewes and 78 mg/l in CA-ewes. Ammonia-N was not affected by the cropping mode for all the sampling times.

3.4.3. VFA concentrations variation

Mean daily values of rumen VFA of Barbarine ewes during pre- and post-feeding are presented in Table 11. For both cropping modes, total VFA (TVFA) concentrations increased after 2 hours of fermentation (*P*=0.03 and *P*=0.006, respectively for Conv-A and CA). TVFA concentrations averaged 55.9 and 52.6 mmol/l before morning feeding and reached 74.5 and 76.4 mmol/l at 2h after the beginning of grazing, respectively for Conv-A and CA. Results showed that cropping mode didn't affect TVFA concentrations. Molar proportions of VFA in ruminal fluid varied among sampling time for the two cropping modes (Conv-A and CA). In Conv-A, the proportion of C2 increased (*P*=0.01) from 69% at T0 to 71% at T4. However, no significant effect was observed in the proportion of C2 in CA-ewes. The molar proportion of C3 in rumen fluid varied in both Conv-A (*P*<0.0001) and CA (*P*<0.0002). Indeed, it increased from 16.7 and 17.3% to 18% and 18.7%, respectively for CA and Conv-A after 2 hours of fermentation and then decreased to reach 17% and 17.4% at T4. Molar proportion of C4 varied (*P*=0.02) among sampling time in CA ewes. It exhibited a decrease from 11% to 9.9%, respectively at T0 and T2 and then attended 10% after 4 hours of grazing. However, the rate of C4 was not affected by sampling time in Conv-A-ewes. The ratio C2/C3 varied in both Conv-A and CA-ewes. In Conv-A ewes, it decreased (*P*<0.0001) from 4 at T0 to 3.7 at T2. In CA-ewes, it also decreased (*P*=0.002) from 4.2 to 3.9, respectively before morning feeding and after 2h of grazing. After 4 hours of grazing, it increased and reached 4.1 and 4.2, respectively for Conv-A and CA. The cropping mode didn't affect molar proportions of VFA except for the proportion of C3 at T0 and T2 (*P*=0.01) and for C2/C3 ratio at T2 (*P*=0.01).

4. Discussion

4.1. Dynamic of stubble biomass and botanical composition

The yield of wheat stubble biomass was not affected by cropping mode (i.e. Conv-A and CA). The evolution of botanical composition of stubble varied between the different components of stubble. Stubble heads disappeared first, then leaves and finally stems. Similar findings have been reported by Ben Said *et al*. (2011) on their study on durum wheat under CA practice. They found that stubble heads and leaves disappeared within one month. When cropping durum wheat using conventional practices, Houmani (2002) showed that the proportion of grains in the stubble left on soil decreased more quickly than those of the proportions of leaves and stems so that at the last sampling period (48 days of grazing), the stubble biomass was composed of 90% of stems, 10% of leaves and 0% of grains. The decrease in head proportions suggests that stubble heads are highly palatable at th beginning of the grazing period and ewes used to select at first, the energy-rich parts of stubble (Brand *et al*., 1993; Treacher*et al*., 1996; Yiakoulaki and Papanastasis, 2005). In this context, Engels and Malan (1973) and Brand *et al*. (1993) claimed that the rapid disappearance of grains and leaves after a month of grazing is related to the grazing behavior of sheep. In the current experiment, ewes started to consume preferably heads, then leaves and finally stems. In connection with this, Treacher*et al*. (1996) reported in a similar experiment on ewes, that heads were selected first and disappeared during the period between 4 to 8 days of grazing for a stocking rate ranging between 20 to 60 sheep/ha and that stem uptake increased when most of the leaf had been removed from the soil. The same trend was found by Moujahed*et al*. (2015) in their study on barely. It is important to note that the variation in values and trends of stubble biomass mentioned in different studies is mainly due to several factors including cereal species, crop yields, technical itinerary and grazing practices (animals, stocking rates and grazing duration) (Treacher*et al*., 1996). However, in other studies, only grains were considered (Houmani, 2002 and Ben Said *et al*., 2011); which means that spines, sheath and envelop are associated with stems. Generally, we didn't found a significant effect between conventional and conservation agriculture. This suggest that sevral years on conservation agriculture are needed (i.e. several years) before observing concrete impacts of conservation agriculture on soil and crop.

4.2. Evolution of nutrients in wheat stubble

In the current experiment, ash level in wheat stubble was decreasing along sampling periods and was affected by the cropping mode. The same trend of variation was reported by Ben Said et al. (2011) under the context of CA and in semi-arid conditions. Values found by Ben Said *et al*. (2011) were higher than those found in the current experiment. Crude protein proportions in wheat stubbleat the beginning of the experiment were lower than those reported by Houmani (2002,) and Moujahed*et al*. (2015). In the current experiment, CP content in wheat stubble decreased among period whatever the cropping mode. Under CA system, Ben Said *et al*. (2011) mentioned that CP concentration decreased by -29.6% between July and August. Similar findings were reported by Moujahed*et al*. (2015) who found that for barley stubble grazed by ewes at a stocking rate of 30 animals/ha, CP concentration decreased by -18.9% between the first grazing period and after 14 days. The same trend was observed by Houmani (2002) on ewes grazing durum wheat stubble but the decrease of CP content was more pronounced (-53.8%). These findings could be explained by the decrease of grains in stubble with the progress of grazing period. The decrease of CP content was accompanied by an increase in ADF proportions in wheat stubble whatever the cropping mode. This is related to the variation of the botanical composition of biomass and to the kinetics of disappearance of different components. Indeed, heads or grains disappeared before, then leaves and finally stems, which explain the decrease of CP and the increase of ADF contents as reported by Moujahed*et al*. (2015). In this context, Avondo (2000) pointed out a negative correlation between the two nutrients. The two cropping modes didn't affect the chemical composition of wheat stubbles except for ash.

4.3. Body weight change

Along the first grazing period and for both cropping modes, ewes had maintained their body weight and have even gained some weight. This could have resulted from the higher quality of stubble at the beginning of the experiment, which was high in heads and grains, and consequently relative high in energy. Houmani (2002) clamed the same conclusion as he reported a positive body weight gain of ewes (112g/d) during the first grazing period. However, this was not in line with the results found by Moujahed*et al.* (2015) on lambs grazing barley stubbles. They observed a loss of the body weight of lambs grazing barley stubbles at a stocking rate of 30 animals/ha under the context of CA. The decrease of animals' BW in the third grazing period under the two cropping modes (i.e. Conv-A and CA) is probably related to the physiological state of ewes (pregnancy period), to the high temperature during the experimental period and to a lower nutritive value of wheat stubbles in that period. These results are not in line with those reported by Houmani (2002) who found that from 24 days of grazing until the end of the experiment (48 days of grazing), ewes lost weight as a consequence of decreased nutritional quality and digestibility of stubbles. Results of the current study suggest that stubble biomass in the experimental plots was not limiting mainly during the first half of the grazing period and was enough to sustain the body weight increase. This indicated that generally in this feeding system, body condition of animals was preserved and stubble could contribute to safeguard livestock even in absence of supplementation (Moujahed*et al.*, 2015). In this context, Masmoudi (2012) noted that there is a close relationship between livestock and the previous cover crop (before grazing), the stocking rate and the grazing period. He mentioned that the integration of livestock into a cropping system is possible when more than 78% of crop residue (mulch) was left on soil surface before grazing. In addition, Köller (2003) mentioned an average of mulch more than 30% must be left on soil.

4.4. Rumen fermentation parameters

Values of pH at all sampling times were in line within the range considered as appropriate (6.0 to 7.0) for fiber and protein digestion (Hoover, 1986; Van Soest, 1994). The minimum average value of pH in ruminal fluid was registered at 4 hours of grazing (pH = 6.50 in the two cropping modes). The decrease of rumen pH is explained by the increase of VFA concentrations in ruminal fluid after the beginning of grazing . This observation highlighted the negative correlation between pH and VFA proportions. Similar findings have been reported by Zeoula*et al.* (2006) and ValérioGerio et al. (2015) in studies conducted on sheep fed diets containing fibrous residues. These authors claimed that the decrease of ruminal fluid pH after 4h of fermentation was correlated to the increase of VFA production from the fermentation of dietary carbohydrates in the rumen. In agreement to our results, Bhatt *et al.* (2013) mentioned in a study conducted on lambs, that rumen pH was lowered at 4 h post feeding. Also, Sheikh *et al.* (2018) found in a study conducted on sheep fed Paddy straw based complete feed supplemented with probiotic mixture, that in all the treatment groups, the significant decrease in pH was observed at 4 h post-feeding, probably due to greater production of VFA and and lactic acid. The study of De Castro Budel*et al.* (2017) conducted on sheep mentioned that the lowest pH value (6.21) of rumen fluid was registered after 2 hours of fermentation. This was explained by the fermentative effect of food offered. Alves *et al.* (2012) affirmed that rumen pH is influenced by the nutritional factors in the diet (e.g. Fiber and carbohydrate contents), the rumination time and fermentation products (e.g. Volatile fatty acids). It's worthy to note that rumen pH begins decreasing to reach its lowest value at 4 hours postprandial (fermentation peak and the greatest VFA production); then it increases gradually until reaching again initial values (Wheaton *et al.*, 1970).

Ammonia-N increased at 2h of grazing and conserved almost the same level after 4 hours of grazing wheat stubbles produced with the two cropping modes. This result reflects the continuity of the fermentation activity simultaneously to animal grazing during 4 hours. Geron*et al*. (2015) found that the highest mean concentration of NH3-N in the rumen fluid (20.6 mg/dl) was obtained at 3h after the morning feeding. This concentration was higher that the value found in our experiment and it traduces the difference in N content and proteolysis pattern, which could have been associated with a pick of proteolytic deaminase activity at 3h-post feeding (Sheikh *et al*.,2018).
Total VFA concentration significantly increased after 2h of grazing and maintained almost the same level after 4 hours of fermentation. This reflects the progress of fermentation in parallel with animal grazing. Indeed, animals grazed slowly during 4 hours and the digestion was still occurring simultaneously with the arrival of the ingesta to the rumen. In this context, Galip (2006) confirmed in a study conducted on rams that whatever the diet (supplemented or not with *Saccharomyces cerevisiae* live yeast culture), total VFA concentrations significantly increased in rumen after feeding (at 2h and 4h). Also, Sheikh*et al*. (2018) mentioned that whatever the treatment, the highest concentration of total VFA was observed at 4 h post-feeding and explained this by a stimulated ruminal microbial growth and activity. The evolution of individual VFA proportions followed an acetic pattern, which could be explained by the abundance of leaves and stems comparatively with epics (grains). Indeed, the variation of molar proportions of VFA in ruminal fluid, although significant for C3, didn’t indicate major changes in fermentation trends. This trend of rumen fermentation may be characteristic for ruminants on stubble grazing, which would be equivalent to the common diets composed of hay or straw and concentrate. De Castro Budel*et al*. (2017) observed a peak of total VFA concentration at 04 h:25 min postprandial, in a study on sheep fed diets containing Brazil nut cake. The peak of total VFA is due to the increase in acetic acid concentration, which peaked after 4 hours of fermentation.
The decrease in C2:C3 ratio after two hours of fermentation is explained by the increase of C3. Higher C2:C3 value was observed at 4 h after feeding; this is related to the the decrease of C3 proportion of rumen content. Low C2/C3 ration may traduce an increase of the levels of C3 in the rumen and likely contribute to the production of glucose throughneoglucogensies(Parakkasi; 1990) and may stimulate fattening (Syapura*et al*., 2013).

Generally, rumen fermentation parameters were not affected by the cropping mode. This result suggests that the nutritional potential of the available stubble biomass was similar between the two cropping modes.

5. Conclusion

It was concluded that neither body weight nor fermentation pattern in ewes grazing on wheat stubbles were affected by the cropping mode, i.e. Conv-A and CA. In the first month of grazing, the heads and grains were predominant in stubbles biomass and consequently ewes maintained their body weight and had even gained some weight. In the following period, the decreased nutritive value of the remaining stubble biomass was associated with a loss of ewes’s BW, and therefore concentrate feed supply would be requested given the critical physiological state of ewes, meaning gestation. Since ewes performed similarly when grazing on Conv-A and CA-stubbles, cereals cropping under CA conditions would encourage farmers to adopt CA mainly because the production cost with CA would be decreased and soil fertility would be improved through mulching.Several successive years on CA are needed to conclude on an eventual specific effect of stubble on ewes.

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Table 1. Botanical composition of wheat stubble as affected by the cropping mode.

Period (d)	Botanic composition	Cropping mode		P-value	SEM
		Conv-A	**CA**		
	Total (kgDM/ha)	814.91	931.04	0.07	38.028
	Leaves (g/kgDM)	476.90	522.38	0.10	14.587
Day 0	Stems (g/kgDM)	469.12	420.36	0.07	14.719
	Epics (g/kgDM)	32.3	32.5	0.98	6.81
	Vegetation (g/kgDM)	21.7	24.8	0.77	7.90
	Total (kgDM/ha)	602.68	533.25	0.30	31.268
	Leaves (g/kgDM)	442.48	409.64	0.26	13.861
Day 15	Stems (g/kgDM)	512.84	544.93	0.27	13.389
	Epics (g/kgDM)	26.6	25.2	0.92	8.38
	Vegetation (g/kgDM)	18.1	20.3	0.85	5.50
	Total (kgDM/ha)	403.23	451.38	0.47	30.864
	Leaves (g/kgDM)	406.97	379.61	0.35	12.536
Day 30	Stems (g/kgDM)	565.22	599.76	0.23	12.290
	Epics (g/kgDM)	18.2	11.0	0.61	6.64
	Vegetation (g/kgDM)	9.6	9.6	0.99	5.34
	Total (kgDM/ha)	315.00	380.40	0.30	30.557
	Leaves (g/kgDM)	383.32	360.60	0.40	15.629
Day 45	Stems (g/kgDM)	607.16	636.06	0.28	15.438
	Epics (g/kgDM)	9.5	3.3	0.63	4.99
	Vegetation (g/kgDM)	0	0	1	0

SEM: Standard Error of the Mean

Table 2. Significance of the effects of the independent variable on the variation of stubble botanical composition

P-values	Period	Cropping mode	P*Ag
Total	<0.0001***	0.22	0.24
Leaves	<0.0001***	0.51	0.17
Stems	<0.0001***	0.40	0.10
Epics	0.03*	0.59	0.97
Vegetation	0.01*	0.81	0.99

Table 3. Chemical composition of stubble biomass as affected by cropping mode.

Period (d)	Chemical composition	Cropping mode		P-value	SEM
		Conv. A	CA		
	DM (g/kgRM)	866.67	866.67	1	2.842
	Ash (g/kgDM)	90.2a	80.9b	0.0006***	1.93
Day 0	CP (g/kgDM)	36.5	37.2	0.80	1.40
	ADF (g/kgDM)	442.83	431.45	0.25	2.979
	DM (g/kgRM)	883.33a	850 b	0.03*	12.811
	Ash (g/kgDM)	89.6 a	71.2 b	<0.0001***	2.97
Day 15	CP (g/kgDM)	38.0 a	29.1 b	0.004**	1.89
	ADF (g/kgDM)	476.29a	455.70b	0.04*	6.045
	DM (g/kgRM)	883.33	900	0.27	8.333
	Ash (g/kgDM)	66.6 a	82.4b	<0.0001**	2.54
Day 30	CP (g/kgDM)	32.7	29.8	0.33	1.56
	ADF (g/kgDM)	471.99	465.41	0.50	6.579
	DM (g/kgRM)	900	900	1	0
	Ash (g/kgDM)	72.9	74.5	0.54	1.40
Day 45	CP (g/kgDM)	22.6	23.6	0.74	1.34
	ADF (g/kgDM)	517.11	524.64	0.44	3.604

a,b: Means in the same line with different letters are significantly different; *P<0.05; **P<0.01; ***P<0.001; SEM: Standard Error of the Mean.

Table 4. Significance of the effects of the independent variable on the variation of stubble chemical composition

P-values	Period	Cropping mode	P*Ag
DM	0.004**	0.58	0.14
Ash	<0.0001***	0.04*	<0.0001***
CP	<0.0001***	0.09	<0.07
ADF	<0.0001***	0.12	0.24

Table 5. Body weight (Kg) of grazing ewes as affected by cropping mode.

Period (d)	Cropping mode		P-value	SEM
	Conv-A	CA		
Day 0	41.2	40.7	0.72	0.68
Day 10	41.4	40.9	0.71	0.64
Day 20	41.5	40.4	0.43	0.65
Day 30	40.2	39.8	0.80	0.71
Day 40	41.2	40.7	0.72	0.68

SEM: Standard Error of the Mean

Table 6. Significance of the effects of the independent variable on the variation of body weight.

P-values	Period	Cropping mode	P x C
Body weight	0.77	0.35	0.99

Table 7. Body weight change (g/d) of grazing ewes as affected by cropping mode.

Period (d)	Cropping mode		P-value	SEM
	Conv-A	CA		
P 0-10	18.7	15.6	0.94	25.33
P 10-20	11.3	-44.7	0.24	23.00
P 20-30	-132.7	-59.3	0.12	28.38
P 30-40	102.7	88.4	0.76	15.92

SEM: Standard Error of the Mean

Table 8. Significance of the effects of the independent variable on the variation of body weight change.

P-values	Period	Cropping mode	P x C
Body weight change	<0.0001***	1	0.28

Table 9.pH variation of grazing ewes as affected by cropping mode.

Time (h)	Cropping mode		P-value	SEM
	Conv-A	**CA**		
T0	6.91A	6.96A	0.35	0.036
T2	6.72B	6.74B	0.86	0.041
T4	6.50C	6.50C	0.95	0.039
P-value	<0.0001***	<0.0001***		
SEM	0.032	0.043		

A.B,C: Data in the same column with different letters differ significantly; SEM: Standard error of the mean; ***: P<0.001.

Table 10. Ammonia nitrogen (mg/l) variation of grazing ewes as affected by cropping mode.

Time (h)	Cropping mode		P-value	SEM
	Conv-A	**CA**		
T0	55.7B	63.4B	0.10	3.02
T2	89.8A	78.0A	0.09	2.49
T4	87.9 A	77.9A	0.68	6.14
P-value	0.0003***	0.04*		
SEM	3.98	2.73		

A.B: Data in the same column with different letters differ significantly; SEM: Standard error of the mean; *P<0.05; ***P<0.001.

Table 11.VFA variation of grazing ewes as affected by cropping mode.

Time (h)	VFA	Cropping mode		P-value	SEM
		Conv-A	**CA**		
T0	Total (mmol/l)	55.9 B	52.6B	0.60	3.39
	Aceticacid (mol%)	69.0 B	69.2	0.96	0.51
	Propionicacid (mol%)	17.3 Ba	16.7b B	0.01*	0.15
	Butyricacid (mol%)	15.4	11.0A	0.47	2.62
	C2/C3	4.0A	4.2A	0.07	0.04
T2	Total (mmol/l)	74.5A	76.4A	0.67	4.74
	Aceticacid (mol%)	69.5 B	69.8	0.17	0.37
	Propionicacid (mol%)	18.7Aa	18.0bA	0.01*	0.15
	Butyricacid (mol%)	9.7	9.9 B	0.73	0.16
	C2/C3	3.7Bb	3.9a B	0.01*	0.03
T4	Total (mmol/l)	77.7A	72.8A	0.63	4.46
	Aceticacid (mol%)	71.1A	71.0	0.65	0.32
	Propionicacid (mol%)	17.4 B	17.0 B	0.13	0.12
	Butyricacid (mol%)	9.8	10.0 B	0.89	0.18
	C2/C3	4.1A	4.2A	0.14	0.03
P-value	Total (mmol/l)	0.03*	0.006**		
	Aceticacid (mol%)	0.01*	0.18		
	Propionicacid (mol%)	<0.0001***	0.0002***		
	Butyricacid (mol%)	0.27	0.02*		
	C2/C3	<0.0001***	0.002**		
SEM	Total (mmol/l)	3.71	3.46		
	Aceticacid (mol%)	0.32	0.38		
	Propionicacid (mol%)	0.13	0.13		
	Butyricacid (mol%)	1.65	0.17		
	C2/C3	0.03	0.03		

a.b: Data in the same line with different letters differ significantly; A.B: Data in the same column with different letters differ significantly; SEM: Standard error of the mean; *P<0.05; **P<0.01; ***P<0.001.

CHAPTER IV. ON FARM PRACTICE OF THE 30/30 GRAZING MODEL

I. Introduction

Today, agriculture in the developing countries such as Tunisia is facing many problems such as the lack of productivity and climatic changes. Many regions in Tunisia are affected by erosion phenomena. That’s why the adoption of tillage system and the excessive use of machinery increase these problems. In order to preserve the soil and to decrease the process of soil degradation, farmers try to find an alternative to conventional system that reduces the environmental threat and enhances the productivity. In this context, conservation agriculture represents a suitable solution in developing regions especially in Tunisia. This new concept is based on three major principles:

(i) Maintenance of a permanent vegetative cover or mulch on the soil surface;

(ii) Minimal soil disturbance;

(iii) Diversified crop rotation.

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 principles 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, tradeoffs between the use of stubbles for 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. Unfortunately, the crop-livestock interaction in conservation agriculture has rarely been studied and little data are available in the literature to resolve this conflict.The objective of these experiments was optimizing crop residue management and livestock feeding under CA systems and stimulating adoption and dissemination of the 30/30 stubble grazing model.

II. Materials and Methods

1. Experimental area

1.1. On farm of Laaroussa (Gouvernorate of Siliana)

The trial was carried out in the farm Nawali (Region of Laaroussa, Governorate of Siliana; 112 km from Tunis, semi-arid: 250 mm of rainfall). During the experimental period, animals grazed on stubble of bread wheat cultivated according to CA conditions in a 1 ha plot using a stocking rate of 30 ewes/ha. Bread wheat from the Nawali farm was sowed in the 23rd of November 2014 at a density of 200 kg/ha. A treatment by herbicide (glyphosate 180 g of AI equivalent to 3L of commercial product/ha) was applied before sowing. The plot was fertilized using Ammonitrate (100 kg/ha) and DAP (110 kg/ha). Wheat was harvested on the 10th of June at a cutting height of about 15 cm. The registered grain yield was approximately 0.6T/ha.

1.2. On farm of Krib (Governorate of Siliana)

The trial was carried out in the farm of AdnenAbdrabba (Region of Krib, Governorate of Silina). During the experimental period, animals grazed on stubble of durum wheat cultivated according to Conservation agriculture for an area of 1 ha for a stocking rate of 30 ewes/ha. In the 2 plots, durum wheat from the variety El Hadba ESAK was sowed in the 8th of November 2017. A treatment by herbicide by Bazagran (2I/ha) was applied before sowing. The 2 plots were fertilized using Ammonitrate 33% (1 Qtx/ha) and Super 45 (45% phosphate; 1Qtx/ha). Wheat was harvested on the June 2018 at a cutting height of about 15 cm. The registered grain yield was of about 2.2 T/ha.

2. Animals

2.1. On farm of Laaroussa (Gouvernorate of Siliana)

A total of 30 Noire of Thibar ewes (initial average weight 43 kg when selected) were used in the farm Nawali for the experiment. They received an anthelmintic treatment and were vaccinated against enterotoxaemia. They were housed in collective boxes and marked on using color of painting to be easily identified. They had access to water 3 times a day.

2.2. On farm of Krib (Governorate of Siliana)

A total of 30 Noire de Thibar ewes (initial average weight … kg when selected) were used in the farm on Adnen (Region of Krib, governorate of Siliana) for the experiment. They received an anthelmintic treatment and were vaccinated against enterotoxaemia. They were housed in collective boxes and marked on using color of painting to be easily identified. They had access to water 3 times a day.

3. Experimental design, sampling and measurements
3.1. On farm of Laaroussa (Gouvernorate of Siliana)

During the experiment, ewes grazed twice a day (from 5 h to 8 h and from 16 h to 18 h or 17h to 19 h) with a total grazing duration of 5 hours per day. The experiment lasted from the 07-08-2015 to the 07-09-2015 with a total duration of about 30 days. The biomass of stubble and the removal of particular fractions were estimated using quadrats sampling technique (1 m^2, 15 quadrats in the plot placed to have representative samples) at the beginning of the trial and each 15 days after. Samples were immediately weighed and transported to the laboratory (INAT) for immediate DM determination The animals were weighed early in the morning (5h) before the start of grazing. . Body weight and Body weight change by period (BW and BWC respectively) were calculated.

3.2. On farm of Krib (Governorate of Siliana)

During the experiment, ewes grazed twice a day (from 5 h to 7 h and from 16 h to 19 h) with a total grazing duration of 5 hours per day. The experiment lasted from the 17-07-2018 to the 17-08-2018 with a total duration of about 30 days. The biomass of stubble and the removal of particular fractions were estimated using quadrats sampling technique (1 m^2, 15 quadrats in the plot placed to have representative samples) at the beginning of the trial and each 10 days after. The cutting height was at about 15 cm from the soil. Samples were immediately weighed and transported to the laboratory (INAT) for immediate DM determination. Proportions of heads, leaves, stems and other vegetation parts are evaluated and samples are stored for chemical analysis. In order to monitor ewes live weight variation, the animals were weighed early in the morning (5h) before the start of grazing. Body weight and Body weight change by period (BW and BWC respectively) were calculated.

4. Statistical analysis

The GLM procedure of SAS (2002) was used for variance analysis using the repeated measurement procedure. The following model was used:

$$Y_i = \mu + A_i + e_i$$

Where, Y is the dependent variable, μ is the overall mean, A_i is the effect of period (i=1-4), and e is the residual error. The LSMEAN test was used to compare treatment effects. The difference between the means of two treatments was considered significant when P-value is below 0.05.

5. Main results and Discussion

5.1. Biomass Dynamic

5.1.1. On farm of Laaroussa (Gouvernorate of Siliana)

Results relative to biomass dynamic under CA conditions are presented Figure 1 Biomass decreased significantly ($P<0.001$) among sampling periods. The values ranged between 1402.80 and 431.40 kg DM/ha between the first and the last sampling time. We noted that at the end of the experiment, the remaining biomass on soil represented about 30.75% of the initial amount. This result confirmed somewhat the model we found in trial 2014 in Bourbiaa station, also it is in line with the suggestion of Köller, (2003), who claimed that livestock could be fully integrated into conservation agriculture since more than 30% of the crop residues will be conserved on soil as mulch.

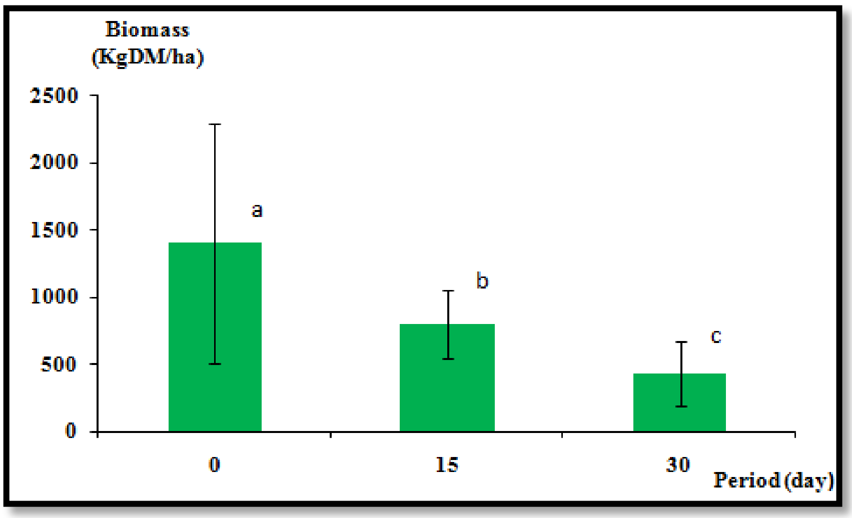


Figure 1: Biomass dynamic among period under CA conditions

a, b, c: Different letter indicate that the difference between the treatment effects are significantly different ($P<0.001$)

5.1.2. On farm of Krib (Governorate of Siliana)

Results relative to biomass dynamic in CA conditions are presented in Figure 2 Biomass decreased significantly (P<0.001) among sampling periods. Values ranged between 1084.6 and 498.61 Kg DM/ha respectively at the first sampling time and at the end of the experiment. The decrease was much more pronounced at the second sampling time (-222.85 kg DM/ha). Proportions of biomass components detailed in Figure 2 showed that proportions of heads decreased considerably but not significantly after 10 days of grazing (-3.5 g/KgDM) until their disappearance. This decrease could be due to the sorting exerted by sheep which preferred heads while grazing (Brand et al., 1993; Yiakoulaki and Papanastasis, 2005). Leaves proportions decreased significantly (p<0.01) at the fourth sampling time however stems proportions increased significantly (p=0.02) after 20 days of grazing. The other vegetation fractions did not statistically vary. In the current trial, ewes started to consume preferably heads which were selected first by ewes because they are higher in energy than the other parts of the stubble (Houmani, 2002). In connection with this, Treacher et al. (1996) reported in a similar experiment on ewes, that heads were selected first and removed in the first 4 to 8 days of grazing at stocking rates of 20-60 sheep/ha and that intake of stem increased when most of the leaf had been removed. Also, Ben Said et al. (2011) showed that proportions of biomass components (heads and leaves) removed relatively quickly (1 month) resulting in preponderance of the stems in the stubble.

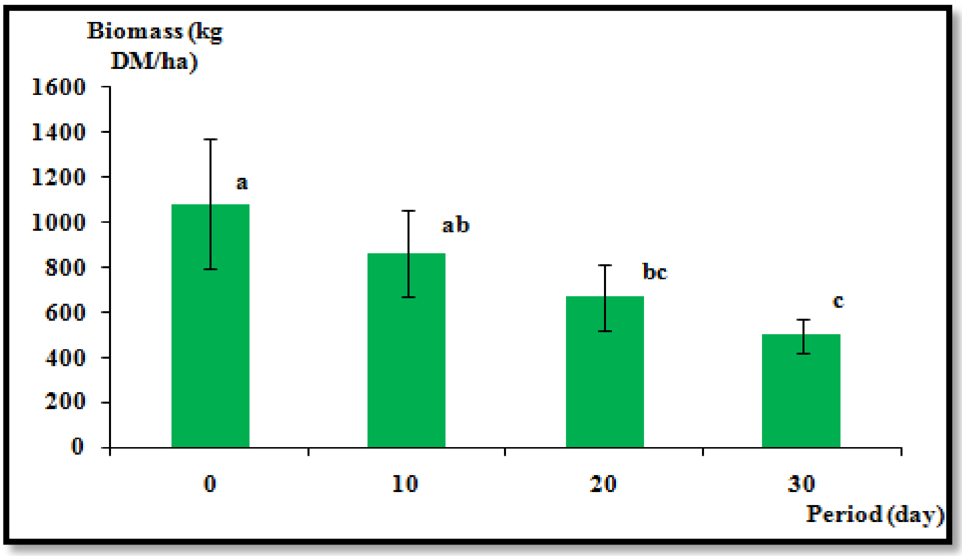


Figure 2: Biomass dynamic according to sampling period

a, b, c: Different letters mean different values according to sampling period(P<0.001)

5.2. Ewes' performances

5.2.1. On farm of Laaroussa (Gouvernorate of Siliana)

Body weight (BW) and Body weight change (BWC) results among period in CA conditions are presented in Figures 3a and 3b, respectively. Between the weighing times, BW increased and this increase was not significant between the start and the end of the experiment (45.41 and 48.79 kg respectively). Figure 3b showed that BWC decreased from the first period (121.02 g/day) to the second one which was equivalent to an average of 54.14 g/day. This high difference in BWC, between the first and the second period is associated with the richness of biomass in heads and epics at the beginning of the grazing period. The increase in body weight suggests that the biomass in the plot was not limiting. Also, the ewes were within the 4th and the 5th month of gestation, a period marked by a substantial increase of the fetal and placental weight.

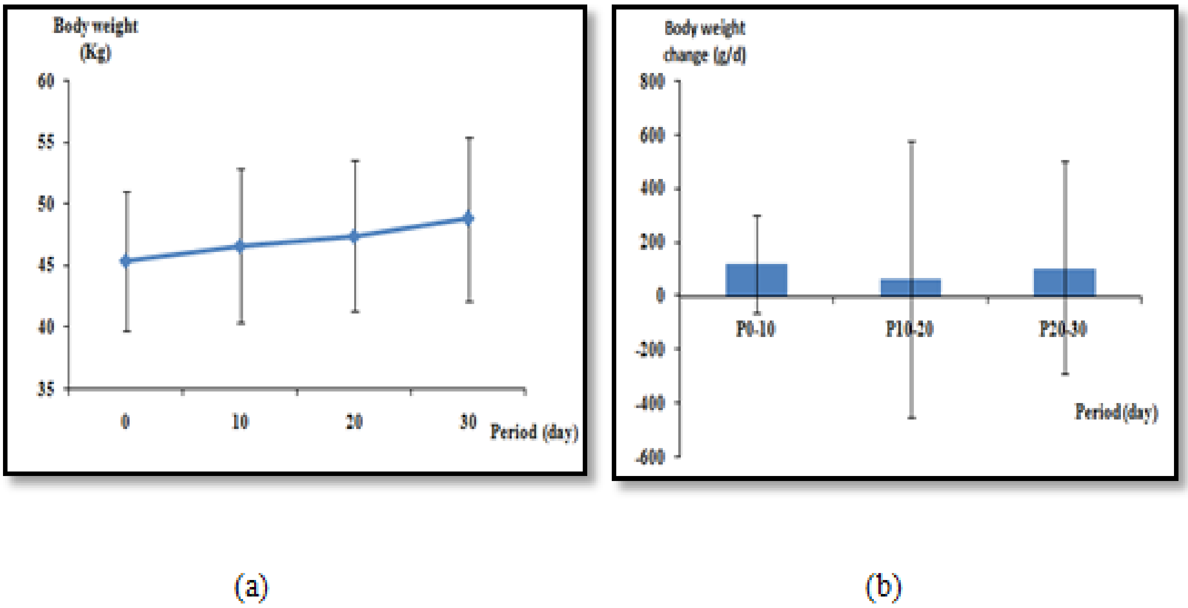
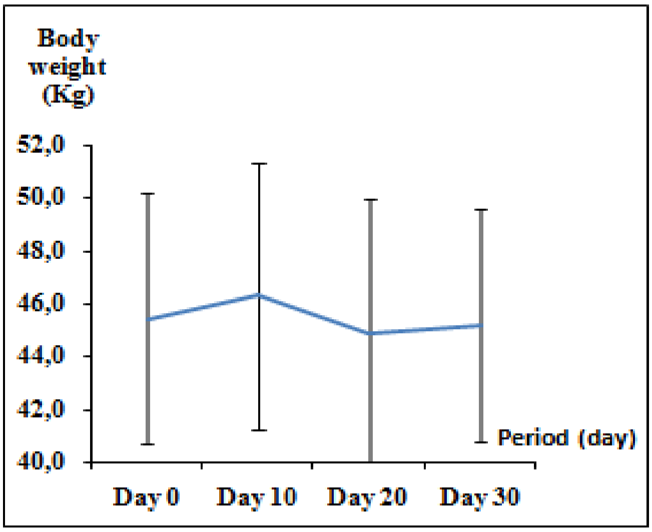


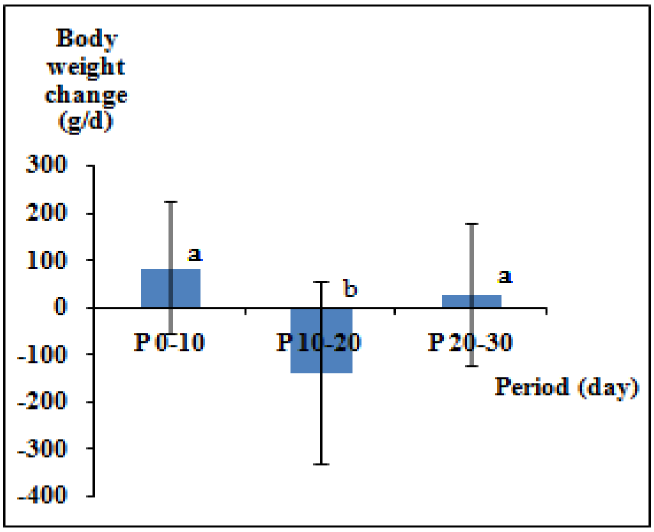
Figure 3: BW (a) and BWC (b) variation according to period on farm of Laaroussa

5.2.2. On farm of Krib (Governorate of Siliana)

Body weight and body weight change results according to period are presented Figures 4a and 4b. In the first grazing period, animals registered a positive DLWG (85g/d). In the second period, BWC decreased significantly ($p<0.0001$; -136.67) affecting the body weight which decreased but not significantly. Then, the live weight increased in the third period and it was maintained until the end of the experiment with a positive BWC registered on ewes (28.3g/d).

Figure 4b showed that in the first period in CA, animals registered the highest BWC (85 g/d). This can be explained by the higher quality of stubble at the beginning of the experiment which is rich of heads, presenting a high source of energy. The last finding could claim that biomass in the plot was not limiting and enough to sustain live weight increase. Results presented in Table 9 (Appendix 2) and Figure 6 indicated that generally in this feeding system, body condition of animals was preserved and stubble could contribute to safeguard livestock even in absence of supplementation (Moujahed et al., 2015).





(a) **(b)**

Figure 4: BW (a) and BWC (b) variation according to period on farm of Krib

a, b: Different letters mean different values according to sampling period

IV. Prediction of residual biomass (%DM) according to grazing duration

A grazing management tool was developed on farm trials of Laaroussa and Krib in the governorate of Siliana (Tunisia) (Figure 5 and 6 respectively).We developed linear mathematical relationships between the residual biomass and grazing duration under CA conditions relative to the stocking rate of 30 ewes/ha for a duration of 30 days. The model in the two trials exhibited high determination coefficients (0.844 and 0.796 respectively in Laaroussa and Krib farm) and allowed to predict the residual biomass after any grazing duration. This represents a precious tool for stubble gazing management since it is possible de decide about the duration of grazing according to the biomass needed for soil and plant requests and for mulch effect in conservation agriculture conditions.

- In Laaroussa farm, for 30 days, the residual biomass is in order of 30.31% (Figure 5)
- In Krib farm, for 30 days, the residual biomass is in order of 43.12% (Figure 6)

In this trend, Köller (2003) claimed that livestock could be fully integrated into conservation agriculture, when more than 30% of the residues from the previous crop are 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.

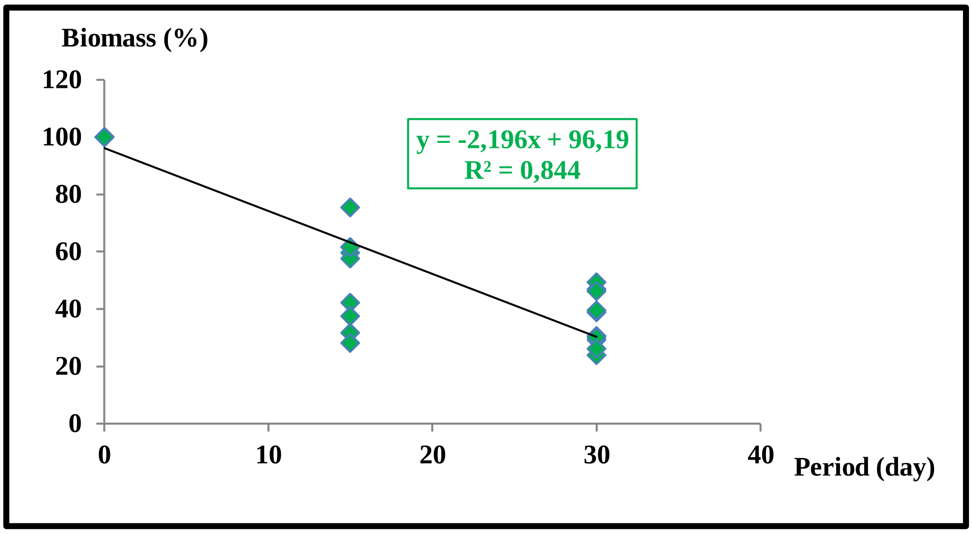


Figure 5: Relation between biomass and grazing period in CA conditions on Laaroussa farm (governorate of Siliana)

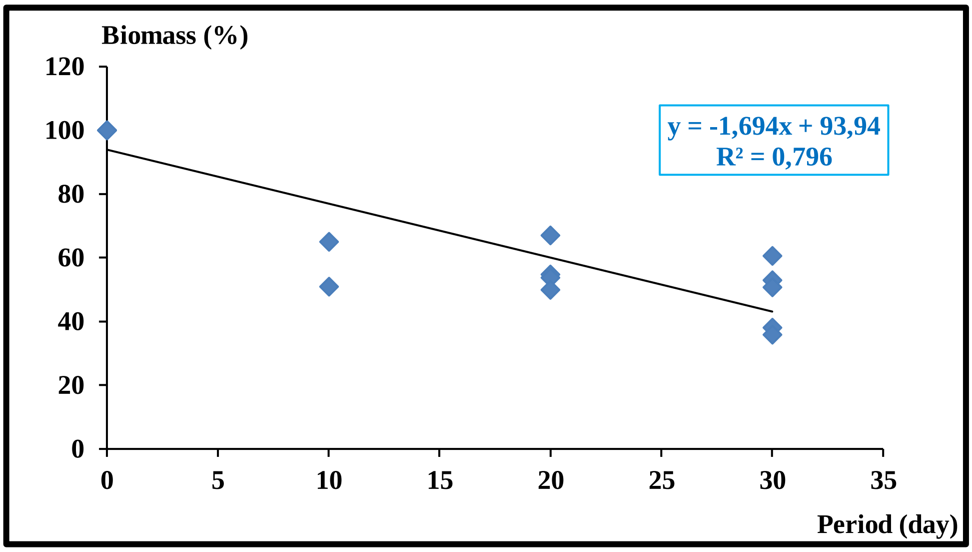


Figure 6: Relation between biomass and grazing period in CA conditions on Krib farm (governorate of Siliana)

V. Conclusion

The present chapter had as objectives to optimize crop residue management and livestock feeding under CA systems and to stimulate adoption and dissemination of the 30/30 stubble grazing model. It was concluded that in Krib and Laaroussa farm conditions, it should be mentioned that biomass seemed not limiting until the end of the experiment and more than 30% of crop residues was preserved on soil. At the same time ewes were accomplishing their end gestation stage normally, with increasing live weight.

Also, the current measurements should be extended on agronomic and soil evaluation results to understand the impact and the significance of integration in the studied agricultural system. Finally, it is important to note that the process of conservation agriculture needs several years to realize the real impact on soil and crop and that the strategies that we can propose should be repeated several years on the same filed to see eventual progresses and incomes.

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CHAPTER V. Optimization du pâturage des chaumes par les ovins dans des conditions de l'Agriculture de Conservation: Simulation à l'aide du modèle de pâturage 30/30

optimization of stubble grazing by sheep under conservation agriculture conditions: Simulation using 30/30 grazing model

30/30 إختبارنموذجالرعي :تحسينرعيالأغناملمحصودالقمحفيظلالزراعةالحافظة

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Résumé

La présente étude visait à tester le modèle de pâturage 30/30 dans les conditions réelles sur terrain dans le contexte de l'agriculture de conservation (AC). Les essaisontétémenés dans trois gouvernorats du nord-ouesttunisiens (Beja, Siliana et Jendouba). Au total, 12 agriculteursétaientconcernés, dont 10 agriculteurs à Siliana, 1 agriculteur à Jendouba et 1 agriculteur à Béjà. Durant la périodeexpérimentale, des brebisayant des taux de charge animaledifférentsontpâturé des chaumes de blé et d'avoinecultivéesselon les conditions de l'AC dans différentes zones. Deux races ovinesontététestées: Queue Fine de l'Ouest et Noir de Thibar. Les taux de charge animalevariaient entre 7 et 50 animaux / ha et la durée du pâturage de 26 à 63 jours. L'estimation de la biomasse a étéévaluée au début et à la fin de chaqueessai. La note d'état corporel a étédéterminée le matin sur des animaux à jeun. La variation de la biomasse a étéajustéeselon un modèle de pâturage 30/30 correspondant à une charge animale de 30 brebis / ha pour une durée de pâturage de 30 jours. Les résultatsontmontré que la biomassediminuaitconsidérablement entre les périodesd'échantillonnage. Le modèle de pâturage 30/30 a révéléunebiomasserésiduellemoyenne de 54,8%. A partir de cesrésultats, nous observonsqu'ilest possible de développer un modèlelinéaireprédisant la variation de la biomasseenfonction de chaqueespècevégétale au pâturage. Ce modèlepeutêtreutilisécommeoutil de gestion des chaumes, mais il a besoind'une compilation d'un plus grand nombre de mesures pour améliorersaprécision. La variation de la note d'état corporel de la régionlombaireindiquait que les animauxmaintenaientleur condition corporelle et enregistraientunelégère augmentation d'environ 0,3 points. Il a éteconclu que le modèlesimulé 30/30 semblerépondre au exigence de l'AC, qui est de maintenirune proportion de biomasse suffisante sur le sol commechaume. Cependant, d'autresessaissontnécessaires pour développer un outilstatistiqueprédictif pour la gestion des chaumes.

Mots clés: Agriculture de conservation, brebis, modèle de pâturage 30/30

Abstract

The current study aimed to experiment with the 30/30 grazing model by sheep under the real conditions in the field within the conservation agriculture (CA) context. The trials were carried out in three Tunisian North-Western governorates (Beja, Siliana and Jendouba). A total of 12 farmers were concerned, including 10 farmers in Siliana, 1 farmer in Jendouba and 1 farmer in Beja. During the experimental period, animals with different stocking rates, were allowed to graze stubbles of wheat and oat cultivated according to CA conditions in different areas. Two sheep breeds were used in these trials: Queue Fine de l'Ouestand Noir de Thibar. Stocking rates ranged between 7 to 50 animals/ha and grazing duration from 26 to 63 days.In all trials, the evaluation of stubble biomass and the removal of particular fractions were assessed at the beginning and the end of each trial. The body condition score was determined in the morning on fasted animals. Biomass variation was fitted according to a 30/30 model of grazing corresponding to a stocking rate of 30 ewes/ha for a grazing duration of 30 days. Results showed that biomass decreased significantly among sampling periods. The 30/30 grazing model reveled average residual biomass left above the soil of 54.8%. From these results, we observe that it's possible to develop a linear model predicting biomass variation according to each plant species grazing. This model can be used as a tool for stubble management, but it needs a compilation of a higher number of measurements to improve its precision. The variation of lumbar region score mentioned that animals maintained their body condition score and registered a slight increase of about 0.3 points. It was concluded that the simulated 30/30 model seems to respond to the CA condition, which is to maintain a sufficient biomass proportion on the soil as mulch. However, more field measurements are needed to develop a predictive statistical tool for stubble management.

Key words: Conservation agriculture, Ewes, 30/30 grazing model

التّلخيص

تهدف هذه الدراسة إلى اختبار نموذج الرعي 30/30 في نطاق الزراعة الحافظة .أجريت التجارب في ثلاث ولايات من الشمال الغربي التونسي باجة ،سليانة وجندوبة على مجموعة 12 مزارعا ، من بينهم 10 في ولاية سليانة، مزارع في ولاية جندوبة ومزارع في ولاية باجة.
خلال فترة التجربة ، قامت النعاج برعي محاصد القمح و الشوفان المزروعة في ظل الزراعة الحافظة.
تم اختبار سلالتين من الأغنام: Noire de Thibar et Queue Fine de l'Ouest وتراوحت مدة الرعي من 26 إلى 63ً يوما تمت دراسة تطور الكتلة النباتيّة في بداية ونهاية كل تجربة .تم تحديد ترقيم الحالة الجسدية في الصباح على الحيوانات الصائمة.
تم تعديل التباين في الكتلة النباتية وفق لنموذج الرعي 30/30 (30نعجة /هكتار لفترة رعي مدتها 30 يوما).
أظهرت النتائج أن الكتلة النباتيةانخفضت بشكل كبير بين فترات أخذ العينات.
أظهر نموذج الرعي 30/30 ّ أن معدل الكتلة النباتية المتبقية54.8%.
من خلال هذه النتائج نلاحظ أنّه من الممكن تطوير نموذج خطّي يحدد تطور الكتلة النباتية وفقا لكل نوع نباتي .
يمكن استخدام هذا النموذج كأداة تحدّد تغيّر الكتلة النباتيّة وفقا لمدّة الرّعي لكن يحتاج إلى تجميع المزيد من القياسات لتحسين دقّته.
يشير التّغيير في ترقيم الحالة الجسدية إلى أن الحيوانات حافظت على حالة أجسامها وسجلت زيادة طفيفة بنحو0.3 نقطة .
تم استنتاج أن نموذج 30/30 يبدوأنّه يلبي متطلبات ّ الزراعة الحافظة ، وهو الحفاظ على نسبة كافية من الكتلة النباتيّة على التربة .ومع ذلك ، هناك حاجة لمزيد من التجارب لتطوير هذا النموذج

الكلمات المفاتيح: الزراعة الحافظة، الأغنام ، نموذج الرعي 30/30

INTRODUCTION

Since two decades, a set of agricultural techniques have been disseminated throughout the world to restore the soil organic matter to a primordial place in production methods. These techniques are combined under the name of Conservation Agriculture (CA). These practices are based on three fundamentals: (i) Reducing tillage (or even eliminating it), (ii) permanent soil cover with plants or plant residues and (iii) crop rotation (Dugué 2015). Minimal soil tillage allows organic matter to be preserved on the surface to constitute protective mulch. Long and diversified crop rotations limit the development of diseases, pests and weeds, which proliferate in monoculture and make it possible to reduce or even eliminate the use of phytosanitary products (Kassam 2009). Crop residues enrich the soil with carbon and fix nitrogen. They also enhance the stability of the CA system thanks to their capacity to improve soil properties and to promote an increase biodiversity in the agro-ecosystem. Livestock represents an essential component in the farming system especially in arid and semi-arid regions suffering from climatic change, erosions, increase of population density and low productivity. However, the integration crop-livestock seems to be incompatible to maintain a "minimum" or a "suitable" soil cover and represent a conflict between the use of organic matter to feed the animals or to cover the soil (Guesmi and al 2019). This conflict needs to be resolved, especially in arid and semi-arid regions, characterized by the low biomass production. Unfortunately, the crop-livestock interaction in conservation agriculture was rarely studied and few data are available in the literature (Guesmi and al 2020; Moujahed and al 2015).

Moujahedand al (2019) reported that ewes grazing wheat stubble with a stocking rate of 30 animal per ha during 30 days (30/30 model) kept about 400 kg of biomass per ha, representing about 40% of the initial biomass. This model seems to provide a resolution to the conflict between CA requirements and animal needs, according to an integrated approach. However, it needs to experiment on the field.

In the present work, we tried to simulate the 30/30 model using database constituted from measurements of the dynamics of the stubble biomass resulting from CA conditions, grazed by sheep in regions from the North-West of Tunisia. The obtained measurements on real conditions are adjusted or extrapolated to the 30/30 model to verify the hypothesis of obtaining satisfactory residual biomass. In parallel, the study aimed also to stimulate the adoption and the dissemination of the 30/30 stubble grazing model within farmers adopting CA.

MATERIALS AND METHODS

1. Experimental area

Measurements were carried out in three governorates located in the North-Western region of Tunisia (Beja, Siliana and Jendouba). A total of 12 farmers (Table 1) were concerned, including 10 farmers from Siliana (Annual rain: 462 mm), 1 farmer from Jendouba (Annual rain: 763 mm) and 1 farmer from Beja (Annual rain: 580 mm). The measurement periods were situated between 10/07/2019 and 12/09//2019.

2. Grazed plant species, animals and grazing conditions

During the experimental periods, ewes grazed wheat and oat stubbles cultivated under CA conditions in different areas and according to different stocking rates as practised by farmers (Table 1).

Two sheep breeds have been used in these trials: “Queue Fine de l’Ouest: QFO”in Chwarnia and Fernena regions and “Noir de Thibar: NT”, in Beja and Laaroussa regions (Table 1). The stocking rates ranged between 7 to 50 animals/ha and the grazing duration varied from 26 to 63 days (Table 1).

Table 1. Regions, Animals and experiment conditions of the grazing trials

Farmers	Governorates	Delegations	Plant species	Superficies	Breed sheep	Number of ewes	Stocking rate/ha	Grazing duration
1	Jendouba	Fernana	Wheat	2ha	QFO	15	7	35 jours
2	Siliana	Chwarnia	Oat	4ha	QFO	30	7	59 jours
3	Siliana	Chwarnia	Oat	1ha	QFO	25	25	60 jours
4	Siliana	Chwarnia	Oat	5ha	QFO	50	10	59 jours
5	Beja	Beja	Oat	8ha	NT	58	7	26 jours
6	Siliana	Chwarnia	Oat	1ha	QFO	50	50	60 jours
7	Siliana	Chwarnia	Oat	0.5 ha	QFO	25	50	59 jours
8	Siliana	Chwarnia	Wheat	1ha	QFO	15	15	63 jours
9	Siliana	Chwarnia	Wheat	2ha	QFO	30	15	63 jours
10	Siliana	Laaroussa	Wheat	4ha	NT	250	62	37 jours
11	Siliana	Chwarnia	Wheat	3ha	QFO	50	16	60 jours
12	Siliana	Chwarnia	Wheat	1ha	QFO	25	25	63 jours

QFO: Queue Fine de l’Ouest; NT: Noire de Thibar

3. Measurements and sampling

For all the grazing plots,stubble biomass was measured before and at the end of the grazing period. Measurements of stubble biomass were performed using quadrats sampling technique (1 m^2, about 5 quadrats per plot) placed randomly to have representative samples. The cutting height of biomass was at about 5 cm from the soil. Samples were immediately weighed and transported to the laboratory (INAT) for DM determination. In each farm, ten ewes were randomly marked and followed for body score conditions (BCS) at the begging and the end of the experiment. It was assessed in the morning using the method described by Russel and al (1969) by palpation of the lumbar region of fasted animals and based on the average of two estimates.

4. Calculation and statistical analysis

Results relative to biomass were adjusted using an extrapolation process to be aligned to the 30/30 model. Two successive extrapolations were performed (duration and biomass respectively). Real and Corrected Residual Biomass (RRB and CRB respectively) were expressed in Kg DM and in % of Initial Biomass (IB). Calculations were performed using Excel (2007 version) Software.

To compare plant species, biomass and BCS parameters variations were analyzed using analysis of variance according to GLM procedure, and Statistical Analysis System software (SAS, 2002). The model included plant species and experimental error. The LSMEAN test was used to compare treatment effects. The difference between the means of each two treatments was considered significant when P value is below 0.05.
Linear regression equation was established to predict biomass variation according to the grazing duration using Excel (2007 version) Software.

RESULTS AND DISCUSSION

1. Biomass variation according to farmers

Results relative to biomass dynamic under CA conditions in farms are presented in Table 2. Generally, biomass decreased among sampling periods. Values relative to initial biomass ranged between 540 and 3268 Kg DM/ha. At the end of the measurement periods, real residual biomass (RRB) ranged between 205.2 and 1578 Kg DM/ha, while corrected residual biomass according to the 30/30 model (CRB) varied between 351.7 (65.1%) and 1643.8 kg DM/kg (76.9%). The obtained CRB results are largely higher than the proportions proposed by Köller (2003), who reported that livestock could be fully integrated into conservation agriculture when more than 30% of the residues from the previous crop are left on the ground as mulch. Moreover, Jarecki and Lal (2003) mentioned that conservation agriculture required 30% of the soil surface is covered with previous crop residues. In the same context, Moujahed et al (2019) mentioned that under conservation agricultural conditions and after a 30 days of grazing in Tunisian area, the found biomass corresponded to 43.12% (400Kg DM/ha). Finally, in the current study, it could be claimed that whether expressed as percentage or quantity, the 30/30 grazing model could satisfy the CA requirements.

Table 2. Biomass variation on farms

Farmers	IB (KgDM/ha)	RRB(KgDM/ha)	RRB (%)	CRB (30/30) (KgDM /ha)	CRB (%)
1	(1350 ± 376.5)*	1130 ± 324.6	83.7%	543.3 ±253.8	40.2%
2	540 ± 166.9	453.6 ±140.8	84%	351.7 ±127.9	65.1%
3	2138.4 ± 448.4	1314 ± 427.3	61.4%	1643.8 ±354.5	76.9%
4	612 ± 172.6	507.6 ±144.8	82.9%	452.7 ±136.8	74%
5	1734± 534.1	1578 ± 450.5	91%	962.6 ±179.1	55.5%
6	1346.4 ± 491.7	572.4 ± 494.2	42.5%	1114.2 ±476.4	82.8%
7	1144.8 ± 282.2	205.2 ± 101.5	17.9%	858.1 ±170.4	75%
8	1364.4 ± 340.9	1004.4 ± 283.9	73.6%	1021.5 ±285.6	74.9%
9	1299.6 ± 444.8	759.6 ± 243	58.4%	785.3 ±251.7	60.4%
10	3268.8 ± 848.2	716.4 ± 150.3	21.9%	2267.4 ±538.2	69.4%
11	1932 ± 410.6	1470 ± 316.1	76%	1498.9 ±304.3	77.6%
12	1728 ± 626.6	432 ± 149	25%	987.4 ±345.4	57.1%

*IB: Initial Biomass ; RRB : Real Residual Biomass; CRB Corrected Residual Biomass according to the 30/30 model; ( ) * means ± standard deviation*

The prediction of CRB for SR30 according to grazing period is presented in Figure 1. According to this linear model, after 30 days of grazing, the residual biomass is about 54.8% of the initial biomass (0.9 tones/ha). These predicted values are close to the averages presented in table 1 even with the low observed R^2. Such models could be developed and used as tools for stubble grazing in the CA conditions. Similar linear model with high R^2 (0.79) was developed by Moujahed et al (2019) in the experimental station and CA conditions. The low Observed R^2 in the current study may be related to field conditions and to the variability of plant species, initial biomass, animal breeds and regions. Improving the precision of the tool require a higher number of on-farm measurements.

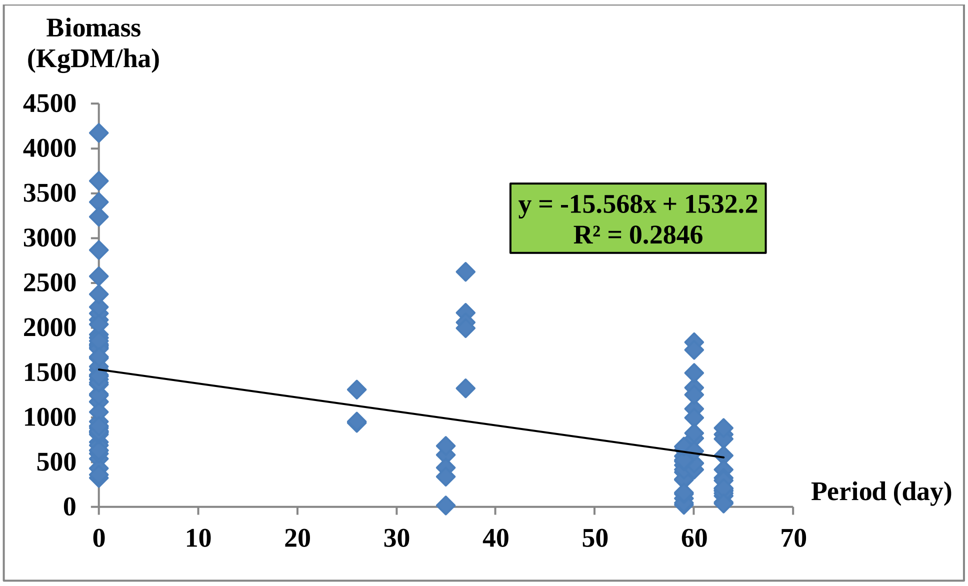

Figure 1. Theglobal model of prediction of residual biomass (KgDM/ha)

2. Biomass variation according to plant species

Results relative to biomass dynamic under CA conditions of plant species are presented in Table 3. For both species, biomass decreased among sampling periods. Values relative to IBM ranged between 1218.2 and 1816 Kg DM/ha respectively for Oat and wheat with a significant plant species effect ($p<0.005$). At the end of the measurement periods, RRB ranged between 714.2 and 879.4 Kg DM/ha respectively for wheat and oat. While CRB (30/30) varied between 892.5 and 1161.5 kg DM/ha respectively for Oat and Wheat. Residual biomass expressed as % of the IB ranged between 63.9 and 73.3% respectively for wheat and oat. The prediction of CRB according to grazing period for each vegetal species is presented in Figures 2 and 3. According to these linear models, after 30 days of grazing with a SR30, the residual biomass is about 66.2% of the IB (1202.1 kg DM/ha) for wheat stubble and about 75.5% of the IB (920.2 Kg DM/ha) for oats stubble.Determination coefficients are relatively low (R^2=0.38 and 0.28 respectively for Wheat and Oat stubbles). This difference in prediction precision may be due to variation sources affecting the experiment conditions. After 30 days of grazing with a stocking rate of 30 ewes/ha, we found average residual biomass of about 70.8% under CA. The equations of Figures 2 and 3 could provide recommendations to farmers expressed as simple days of grazing duration. In the same vein, Köller (2003) reported that livestock could be fully integrated into conservation agriculture when more than 30% of the residues from the previous crop are left on the ground as mulch. However, 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. To be optimized, this particular purpose needs more interactions between animal, soil and crop scientists, since few recommendations are available in the literature, on how much biomass should be left on the soil surface in the context of conservation agriculture.

Table 3. Prediction of plan species residual biomass (KgDM/ha)

Plant species	IB (Kg DM/ha)	RRB (Kg DM/ha)	RRB (%)	CRB KgDM/ha	CRB (%)
Wheat	1816±875.2[a]	714.2±554.6	39.3%	1161.5±666.2	63.9%
Oat	1218.2±671.3[b]	879.4±385.1	72.2%	892.5±518.1	73.3%
p	0.005**	0.2		0.09	
SEM	110.9	64.1		81.07	

*IB: Initial Biomass; RRB: Residual Real Biomass; CRB: Corrected Residual Biomassaccording to the 30/30 model;[a,b] Means in the same column, with different letters are statistically different; **:P<0.01. SEM: Standard Error of the Mean.*

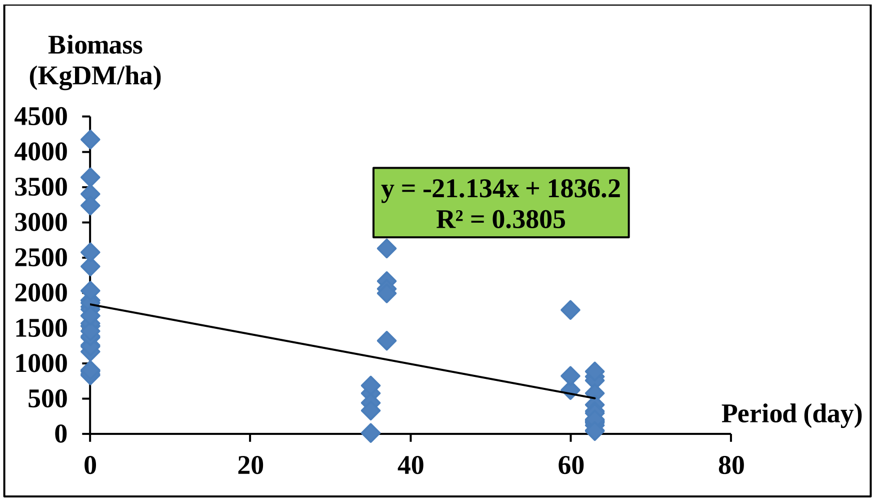

Figure 2. Prediction of wheat stubble residual biomass

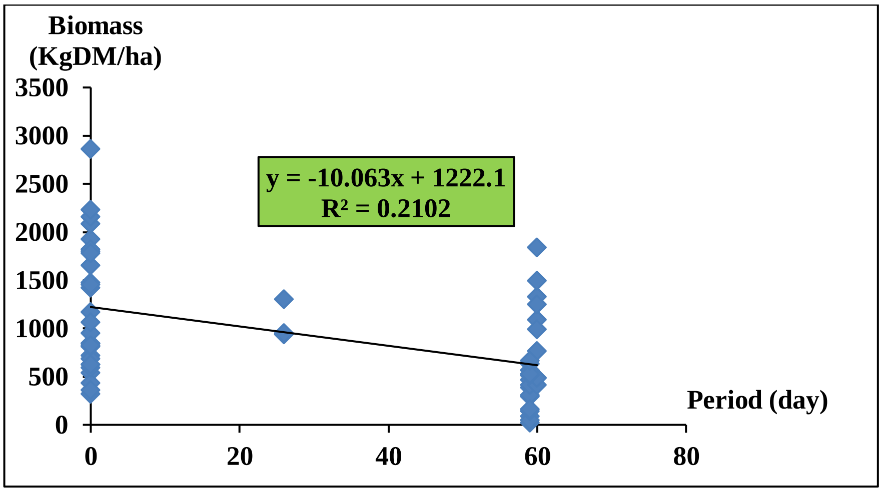

Figure 3. Prediction of Oat stubble residual biomass

3. Body condition score variation

Variation of BCS values in each farm are presented in Table 4. Values of BCSi varied between 1,7 to 3,4 (averaged 2,7). At the end of the experiment, body condition score increased averagely by about 0.3 points and ranged between 1,9 to 3,6 (averaged 3). When expressed by plant species (Table 5), final BCS ranged between 2,9 (Oat) to 3,1 (Wheat) also, lumbar region score registered a slight increase of about 0.3 point between the start and the end of the experiment (2.7 and 3 respectively). BCS values showed that ewes started the experiment with an average lumbar score about (BCSi=2.7) which was lower than that reported by Atti et Bocquier (1999) on Barbarine sheep breed but higher than the score found in the studies of Ben khlil et al (2017) and Guesmi et al (2019) in the same sheep breed. The low score of the lumbar region in this study can be explained by the bad initial state of animals and the pregnant state of ewes during the summer when the vegetation was limited and no supplementation was practiced by farmers. In the Tunisian conditions, animals are frequently underfed at this physiological stage (Khaldi 1983). Similarly, Atti and Abdenebbi (1995) and Meredef and Madani (2015) mentioned that the body condition score varied according to the physiological state of animals. In our experiment, at the end of the experiment, body condition score increased (averaged 3). This observation may indicate that animal requirements are relatively satisfied even during pregnancy. This result is in agreement with the recommendations of Everett-Hincks and Dodds (2008) who indicate that the body condition score should not vary during pregnancy and should be around 3.

Table 4. BCS variation according to farmers

Farmers	Grazingperiod (Day)	BCSi	BCSf
1	35	2.9	3.6
2	59	3.4	3.5
3	60	2.6	2.8
4	59	2.8	2.9
5	26	2.4	2.7
6	60	1.9	2.4
7	59	2.8	3
8	63	2.4	3
9	63	2.9	3.2
10	37	3	3.4
11	60	3.1	3.4
12	63	1.7	1.9

BCSi: Initial Body Condition Score; BCSf: Final Body Condition Score

Table 5. BCS variation according to plant species

Plant species	BSCi	BSCf
Wheat	2.7±0.53	3.1±0.61
Oat	2.6±0.49	2.9±0.36
P	0.95	0.50
SEM	0.14	0.14

BCSi: Initial Body Condition Score; BCSf: Final Body Condition Score. SEM: Standard error of the mean.

CONCLUSIONS

It was concluded that on-field measurements fitted according to the 30/30- grazing model, are in agreement with the objectives of CA to keep sufficient amounts of biomass on the soil at the end of the grazing period. Moreover, in the experiment conditions, animals generally conserved their body condition score. In the socio-technical conditions of the experiment, it was not possible to respect exactly these norms. Consequently, to stimulate the adoption and the dissemination of the 30/30 stubble grazing model within farmers adopting CA and to develop stubble management tools such as predictive equations, more field measurements are needed to be carried out and compiled.

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CHAPTER VI. GENERAL DISCUSSION

I. Introduction

Nowadays, the farming system is threatening by different climatic constraints such as drought, water scarcity, erosion, soil degradation and the loss of biodiversity. The increase of soil preparation using machineries and the lack of crop cover on soil surface increase the erosion and the degradation of the soil (Jat et al., 2014).

The adoption of conservation agriculture represents an alternative to the conventional system. Indeed, the direct seeding with no or minimum soil disturbance and the crop rotations as well as the vegetation cover left on soil enhance the soil health, increase the productivity, improve the sustainability of agriculture by decreasing the risks of erosions and reduce costs (Pathak et al., 2012).

In the south of the Mediterranean basin, livestock is present in almost all production systems and the integration crop-livestock not only it diversifies the incomes of farms, but also it enhances the crop yield and improves the recycling of nutrients. However, there is a paradox between the use of crop residues as animal feed or as a mulch to cover the soil. In this case, this conflict must be resolved especially in regions suffering from low crop yields.

The two trials of this study mentioned that livestock could be integrated into conservation agriculture and this integration presents several benefits. Also, biomass in plots was sufficient and satisfied all nutrient requirements of animals whose conserved their body weights. To be integrated, the prediction of crop residues left on soil and necessary for feeding animals presents a solution to this conflict and ensures the integration of crop and livestock into conservation agriculture system.

II. Prediction of residual biomass (% DM) according to grazing duration

On the basis of results of 2014 and 2015 in station trials of Bourbiaa in Tunisia under conventional and conservation agriculture, relative to the stocking rate of 30 ewes/ha. A linear mathematical relationship was developed between the residual biomass and grazing duration for both in Conv.A (Figure 1) and CA (Figure 2) conditions.

This represents a precious tool for stubble gazing management since it is possible de decide about the duration of grazing according to the biomass needed for soil and plant requests and for mulch effect in conservation agriculture conditions. In connection with this, we proposed a model of grazing consisting in a stocking rate of 30ewes/ha for a duration of 30 days. The tow model exhibited high determination coefficients (0.74 and 0.71 respectively for Conv-A and CA) and allowed to predict the residual biomass after any grazing duration.

This model was tested on farm trial in the region of Siliana (Tunisia) with Noire de Thibar ewes, grazing on durum wheat stubble produced in CA conditions. After 30 days of grazing in station trial, we found a residual biomass of about 47.63 % under CA which is higher than the value found by calculation on farm trial using the model of figure 3 (34.92%).

These equations could provide recommendations to farmers expressed as simple days of grazing duration (i.e.: to preserve 50% of biomass, a grazing period of about 22 days is recommended, Figure 3). The accuracy of these equations could be improved when integrating results and data from different years and experiments.

To be optimized, this particular purpose needs more interactions between animal, soil and crop scientists, since few recommendations are available in the literature, on how much biomass should be left on soil surface. In this trend, Köller (2003) claimed that livestock could be fully integrated into conservation agriculture, when more than 30% of the residues from the previous crop are 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 (Annual Report Project ICARDA, 2016)

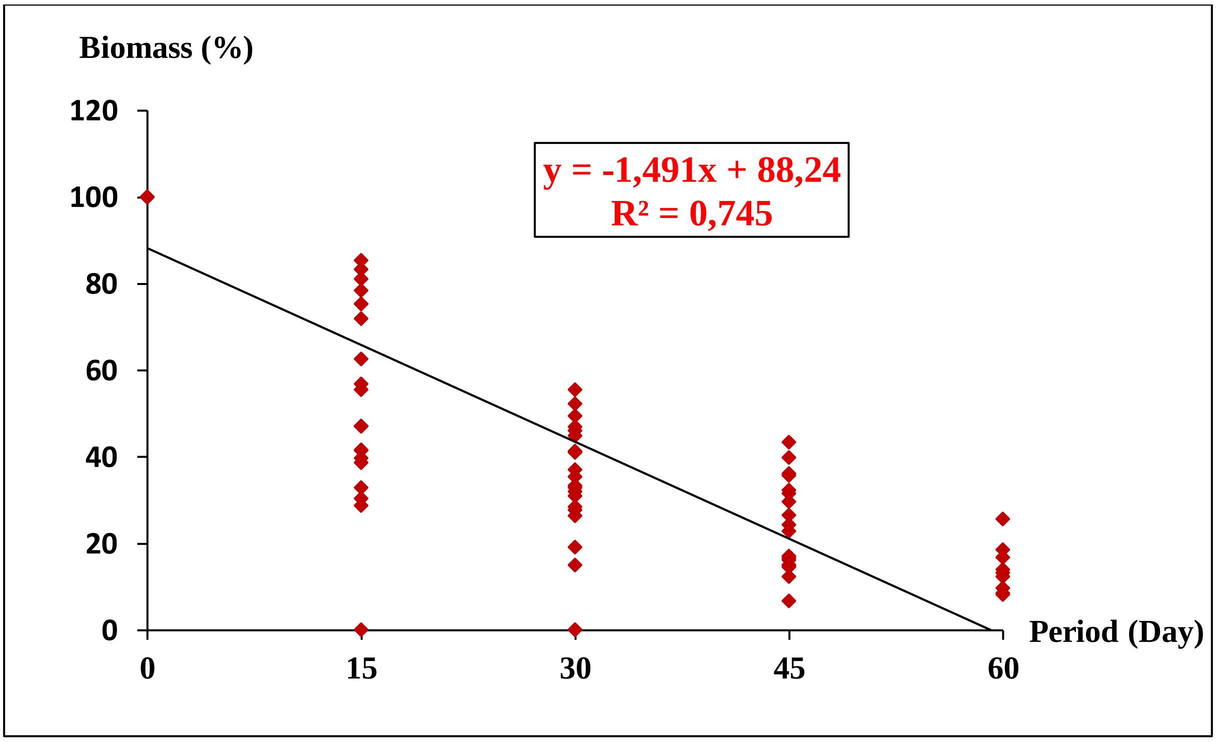

Figure 1: Relation between biomass and grazing period in Conv.A conditions in experimental station of Bourbiaa (Tunisia)

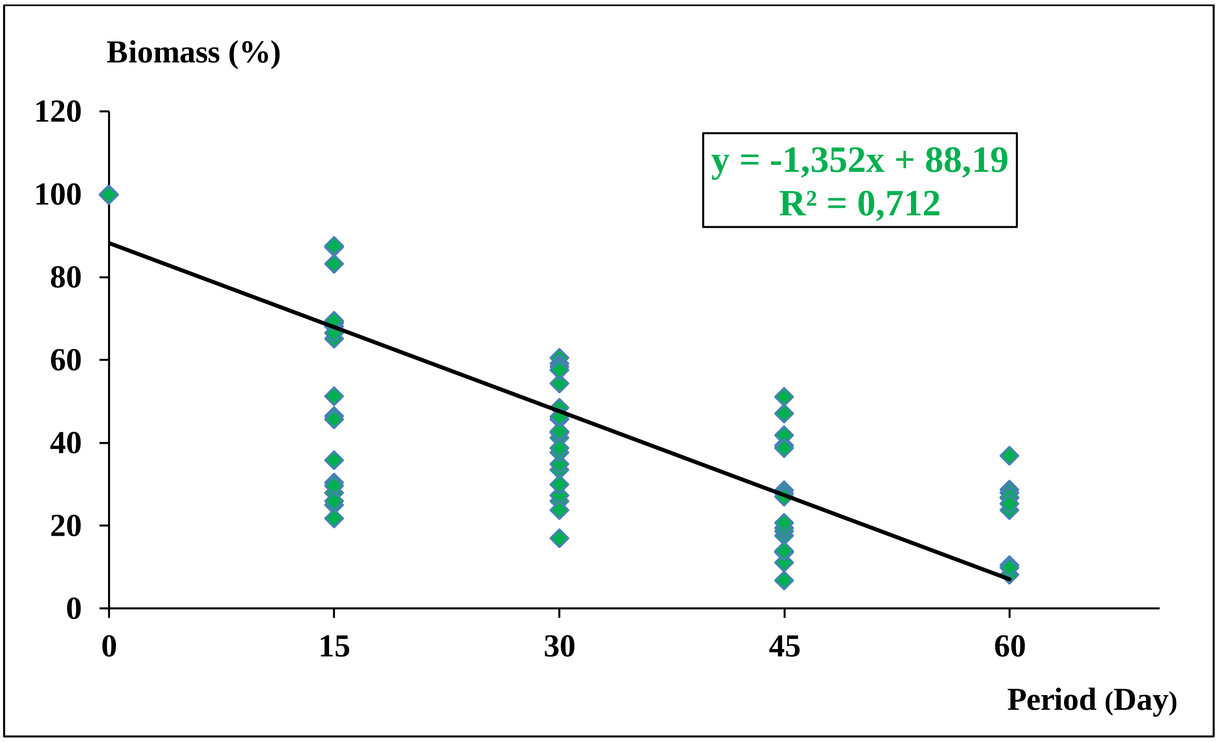

Figure 2: Relation between biomass and grazing period in CA conditions in experimental station of Bourbiaa (Tunisia)

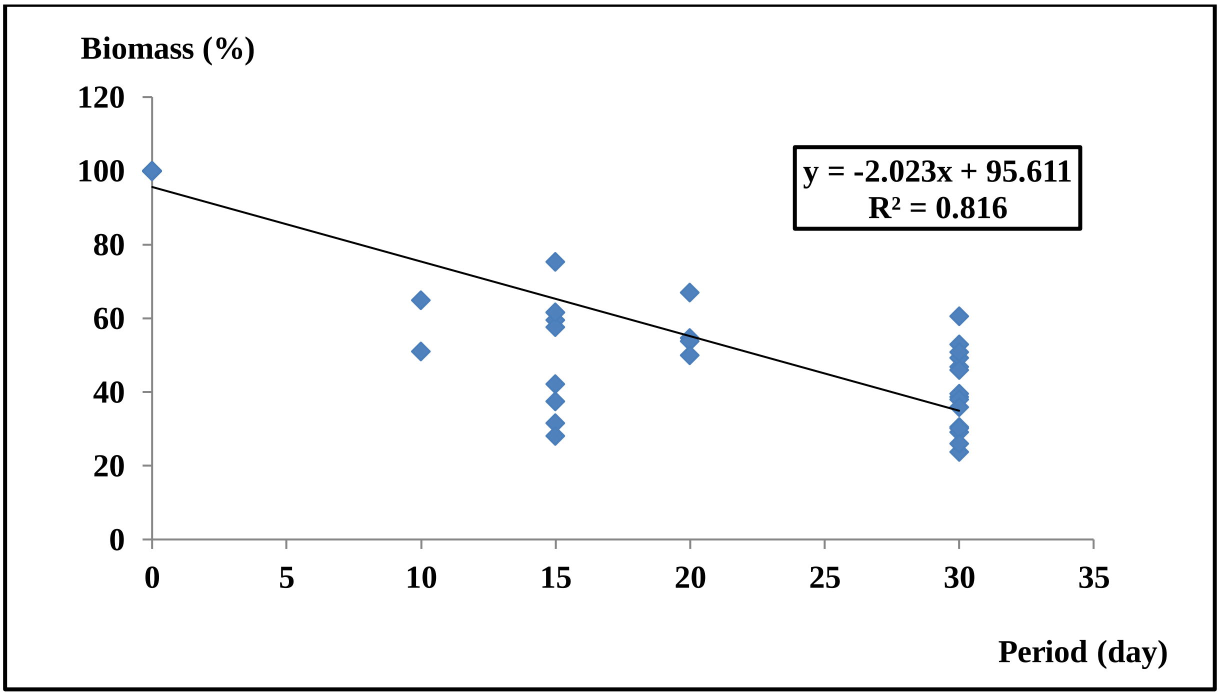

Figure 3: Relation between biomass and grazing period under CA conditions on Farm trial of Siliana: Farm of Krib and Farm of Laaroussa (Tunisia)

III. Prediction of grazing duration according to the number of grazing ewes

A grazing management tool wad developed on-farm trials of M'Sila in Algeria (Figure. 4). This grazing tool capitalizes on the data from 17 wheat and barley stubble grazing trials under conservation agriculture relating the number of grazing days to the flock size ensuring that the residual biomass is at least 0.6 T/ha. Empirical data from other environments and personal communications support that, under semi-arid conditions, such level of residual biomass could serve as mulch for CA and, in the conditions of Algeria, can account for the fraction which can be blown by the summer winds. The tool also shows the average body condition score of the flock at the end of the grazing period. The significance of monitoring body condition score in this model increases when the grazing period exceeds 20 days and could serve as a warning signal to readjust the diet by introduction of supplementary feed (Annual Report Project ICARDA, 2016)

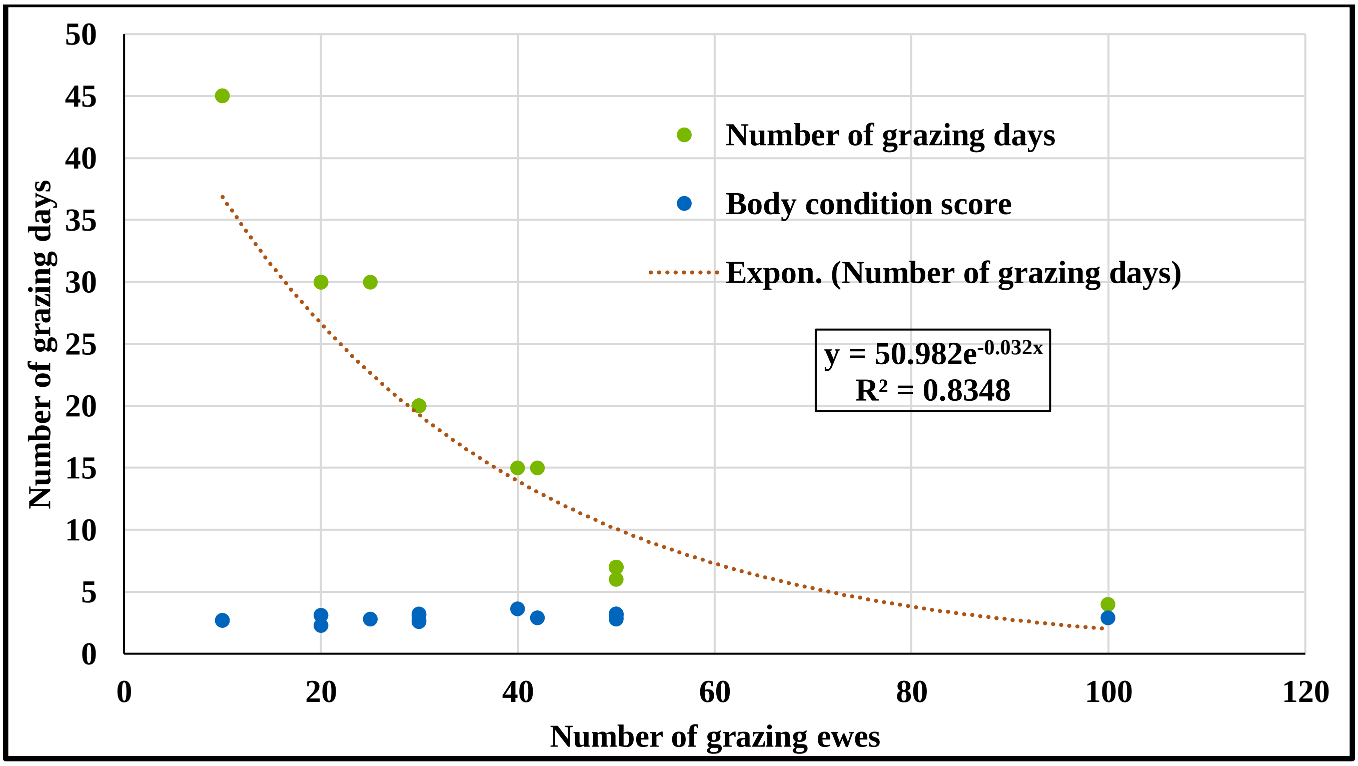

Figure 4: Stubble grazing tool under conservation agriculture on farm of M'Sila (Algeria)

IV. Conclusion

The arid and semi arid regions have a challenge task of ensuring food security for the population by enhancing the sustainability of agriculture. The climate change and the degradation of soils threaten the production system.

The conservation agriculture with its principals presents a solution against the conventional system. The integration of crop-livestock into conservation agriculture is possible while preserving soil cover and animal feeding. In this system, animals maintained their body weights and biomass is not limiting and satisfies all nutrient requirements of animals.

To ensure this integration, the development of simulation models for prediction of residual biomass presents a precious management tool to estimate the grazing duration, the stocking rate and the cover crop left on soil.

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CONCLUSIONS AND PERSPECTIVES

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The integration crop-livestock under CA system ensures the sustainability of agriculture. Indeed, the permanent soil cover enhances the soil quality, maintains the soil fertility, and eliminates the risks of erosion. Also, animals enhance the soil quality by giving organic matter. Furthermore, residues improve animals' performances especially in arid and semi arid regions suffering from climatic change and where livestock represents a main component in the farming system. Indeed, several studies mentioned that biomass satisfies all nutritional needs of animals and that livestock can be fully integrated into conservation agricultural system.

This study allowed us to draw the following conclusions:

- The grazing ewes maintained their body weight with both SR15 and SR30 and in the two cropping modes (Conv-A and CA).
- Whatever treatment, there was part of stubble biomass left on the ground.
- Ewes' response to wheat stubble grazing was similar among the two cropping modes, i.e. Conv-A and CA.
- Almost all dependent variables measured in this experiment were not affected by the cropping mode and the stocking rate.
- livestock could be integrated into Conservation agriculture
- The grazing ewes conserved their body weights in the two cropping modes (Conv.A and CA) and whatever the agricultural practices
- Biomass was sufficient and satisfies all nutritional requirements of animals

The current study allows us to predict the residual biomass according to grazing duration under conventional and conservation agriculture, relative to the stocking rate of 30 ewes/ha using a mathematical relationship between the residual biomass and grazing duration for both in Conv.A and CA systems, in experimental station and on farm trial. This prediction represents a precious tool for stubble gazing management since it is possible to decide about the duration of grazing according to the biomass needed for soil and plant requests and for mulch effect in conservation agriculture conditions. Results mentioned that:

- The tow models tested in the two farms of Silianaexhibited high determination coefficients (0.74 and 0.71 respectively),
- Also, thesetow models allowed to predict the residual biomass after any grazing duration,
- After 30 days of grazing in station trial, we found a residual biomass of about 47% under CA which is higher than the value found by calculation on farm trial,
- These equations could provide recommendations to farmers expressed as simple days of grazing duration (i.e.: to preserve 50% of biomass, a grazing period of about 19 days is recommended.
- The accuracy of these equations could be improved when integrating results and data from different years and experiments.

- These trials mentioned a synergy between crop and livestock and not a conflict. As a consequence, there was not a paradox between the two components.

To be optimized, this particular purpose needs more interactions between animal, soil and crop scientists, since few recommendations are available in literature, about how much biomass should be left on soil surface.

Considering the results of this study, we proposed these perspectives:

- These results must be considered and connected with agronomic and soil evaluation results in further studies in order to further understand the impact and the significance of the integration in the agricultural system,
- To connect the current findings with animal nutritional requirements, it’s recommended to plan an experiment on intake and digestibility of stubble comparatively in Conv.A and CA conditions,
- It is important to note that the process of conservation agriculture needs several years to evaluate the real impact on soil and cropsand the proposed model (30/30) should be practiced on the field, several successive years.