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Crops residue trade-offs between livestock feed and soil amendment in no-till system in Moroccan dry area

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In the dry zone of Morocco, the production of biomass is irregular while the agricultural and animal production systems are matted. As a result, the crop residues use gives rise to tradeoffs which mainly translate into competition. This research aims to characterize the tradeoffs around cereal residues use between livestock feed and soil amendment in a no-till system. This study relied on a literature review, focus group discussions and experiment. Practices related to crop residues management were shaped by historical evolutions caused by two major shifts: Property rights and agricultural policies, and the frequency of droughts. The crop-livestock integration farming system in dry areas of Morocco is currently articulated around the role of residues as animal feed. Livestock is considered more profitable in general and more secure in case of drought. For this, the thatch has a very important value for livestock that compete with that on the soil amendment in a no-till system. It is obvious that the biophysical benefits of residues retention are tangible in term of improving yields, compared with no-till farming with residues removal. However, even reduced crop residues combined with limited soil disturbance would contribute to efficient water use and increased production.

Key words: Crop residues, tradeoff, livestock, no-till, Moroccan dry lands.

INTRODUCTION

Agriculture is a major pillar of the Moroccan economy and society. National production is strongly supported by rain-fed areas, where agricultural systems mainly include animal and grain production (Mrabet et al., 2011). In these dry areas, due to the scarcity of natural resources, small-scale farming systems face crucial compromise over the use of biomass crop residues (Magnan et al., 2010). For this reason, the introduction of conservation agriculture (CA) is experiencing great problems that retard its spread (Schwilch et al., 2015). In fact, in Morocco, crop residues provide 30 to 40% of feed (Magnan et al., 2012). This implies a compromise between critical feeding of livestock and soil improvement (Giller et al., 2009). In principle, the adoption of no-till but with removal of crop residues is against-productive (Ortiz et al., 2008).

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In fact, it is known that the adoption of CA depends on specific local variables (Knowler and Bradshaw, 2007). Similarly, compromises on crop residues are generally context specific because they depend on many factors involved and their interconnections (Erenstein, 2015). For example in Sahelian agro-pastoral systems, the most severe compromises have been highlighted at the village level rather than at the farm level (Andrieu et al., 2015).

However, the short-term competition between soil amendment and animal feed may become more long-term synergies if soil amendment improves the production of animal feed (Tittonell et al., 2015). It therefore appears that there is a lack of knowledge on these compromises and their factors in the rain areas of Morocco (Mrabet et al., 2012). To fill this gap, this research aims to characterize the severity of competitions around residues for Moroccan farmers, and the parameters for moving towards greater complementarities. The goal is to find a compromise between the need for a ground cover for successful direct sowing and proper use of crop residues for livestock feed.

MATERIALS AND METHODS

This work was conducted in Settat region in Central Morocco. The area is characterized by a semi-arid climate and calcimagnesium type of soil; with an altitude above sea level of 365 m, a latitude of 33°00′03 ″ North and a longitude of 7°36′59″ West.

Generally, Settat region is characterized by a warm temperate climate. The climate map of Köppen-Geiger (Climate Change & Infectious Diseases Group, 2019) classifies the climate of the region as Mediterranean climate with hot summer. The average temperature in Settat is 17.3°C with a maximum exceeding 40°C. The average annual rainfall is 372 mm.

The work was relied on a literature review (contextual and thematic), focus group discussions and experiment.

Focus group discussion

The discussion group as qualitative research targeting specific problems with common basic information for farmers was conducted in two parts: a participatory timeline exercise and a semi-open discussion on crop residues' management.

The main objective of these discussions was to capture and view trends related to climate patterns, land use and crop management practices and animal husbandry in last decades, in addition to stimulating discussions beyond these practices, particularly regarding the use of crop residues.

Experiment

Two trials were conducted to meet this goal:

(1) Test on the residues levels left after harvest, was conducted over two years (2014-2015 and 2015-2016);
(2) Test on the effects of residues on the following year's crops, was conducted in one year (2015-2016).

Four closed plots were used after crop harvesting. The quantities of residues per plot are estimated at the beginning (T0) and after each week (T1, T2, T3 and T4) of grazing by sheep (35 heads).

The trial was followed for two years to cover the rotation cycle (barley, vetch/oat mixture). The first year (2014-2015) was a good year; the rainfall was 395 mm, while the second (2015-2016) was dry with a rainfall of 193 mm.

The treatments adopted for the residue levels' test result from a combination of the cutting height of the crop during harvest and the intensity of stubble grazing. The first factor has two levels; cut high just below the ear and normal cut (10 to 20 cm from the ground). The second factor has three levels; no grazing, 50% of the residues grazed and 75% of the residues grazed. The combinations selected for the trial are:

P1: Harvest high, remove straw, no grazing
P2: Harvest normal, remove straw, no grazing
P3: Harvest normal; remove straw, 50% grazing
P4: Harvest normal, remove straw, 75% grazing

It should be noted that the logic behind these treatments is to have contrasting residue levels that are sufficiently distinct to be able to decide on the most optimal level to recommend for the present study area. Starting from this last hypothesis, it seems obvious that the first treatment (P1) will only be taken as an indication of an ideal situation, which in no case corresponds to the reality of the area. While the second treatment (P2) represents the control.

Two sets of data were developed:

(1) Crop residues before and after grazing
(2) Crop production for the following year.

Measurements are made on a 1 × 1 m² quadrate placed on the ground surface on representative areas. On each plot, 10 sites are selected for measurements. Measured parameters were biomass production for residues and fresh and dry mater and density for fodder crop.

The samples are cut and analyzed at the laboratory. The crude protein which is limiting parameter in arid regions was determined for stubble.

The data were analyzed and processed in Excel software and the analysis of variance (ANOVA) was done by SPSS software.

RESULTS

Land use and crops management

In the first half of the 20th century, Central Moroccan rain-fed area was located in transhumance corridors between Southern dry areas and Northern pasturelands (Célérier et al., 1924). More and more herders progressively settled and started to practice small-scale agriculture in rain-fed lands (Mehdi, 2010; El Koudrim, 2010; El Koudrim et al. 2020). Most of the farmers are descendent of experienced herders. They have inherited their land rights, the cultural value of livestock and a pastoralist perception of natural resources.

Until 30s, rangelands were used as collective pastures and for hunting. The French settlers instigated croplands expansion after clearing the most favorable areas occupied, until 50s. The expansion of rain-fed farms was

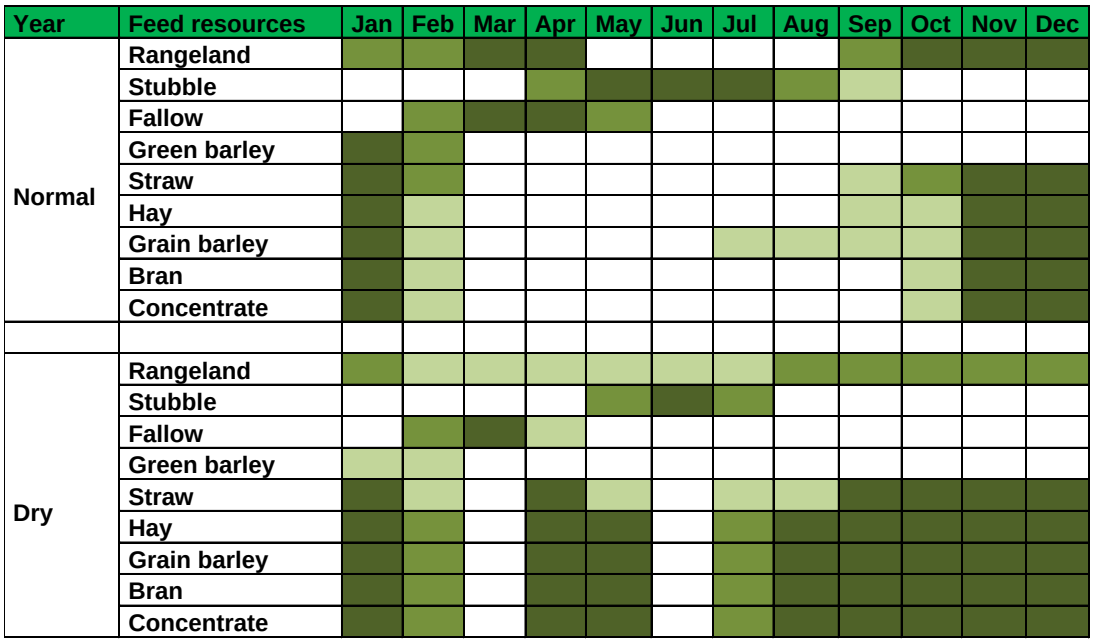

Figure 1. Typical forage calendar characteristic of the study area.

triggered in the years following independence (1956) by the national operation “mechanized clearing” (Clerc, 1961). Aiming to use mechanized tillage to offer arable lands to a growing rural population, this operation allowed the gradual conquest of rain-fed areas by agriculture. Clearing out and cultivating new lands were also a manner for families to claim rights on it (El Koudrim, 2014; El Koudrim et al., 2020).

The droughts of the 1980s and their dramatic consequences (food insecurity, destocking, migration) pushed farmers and political decision-makers to make changes in crop management.

Before the droughts, the precipitation abundance allowed a rotation with fallow every two years. Generally, cereals are alternated with weedy fallow or pulses. After the droughts in the 80s, two-year rotations became rare. Barley, more resistant to water shortage, became popular again, while bread wheat had been introduced through a national program in 1984 (Khrouz, 1992).

Livestock feeding and crop residues management

Until 1960, the main sources of animal feed were common pastures and crops residue. Stubble was free of access. Bran and fodder crops were introduced in semi-arid zone in the early 70s. Supplementation became common from 1990s.

Currently, in a normal year, livestock graze the stubble for 3 months after harvest in June. In a good year, stubble grazing can last longer, until the first rains. Supplementation begins in September-October. The rations contain a mixture of straw, hay, cereals, corn, bran and concentrate. Herds are sent as soon as possible in herbaceous fallow or pasture from January to February. Then they can graze forage residues after mowing until the grain harvest in June. Otherwise, rations are needed in dry years (Figure 1).

Crops residue production estimation by farmer

Straw production is characterized by high inter-annual variability (Figure 2). The yields of barley straw are well above the yields of wheat straw, even during dry years. Barley straw is also preferred for its nutritional value. This confirms the renewed interest of farmers for barley since the catastrophic droughts of the 80s. Similarly, durum wheat provides more straw than bread wheat in dry years and its quality is also preferred.

Likewise, yield of cereals stubble decreases substantially in dry years, from 1.2 (normal year) to 0.65 t/ha (Figure 3). The differences can be explained by the large spatial variability inherent to the stubble production and cutting height of straw.

On another side, farmers do not appreciate the amount of straw available in quantity, but in terms of grazing potential (Gauny, 2016). A farmer estimated that he has 90 days of grazing for his flock of 20 sheep in a normal year; 120 in a good year and only 25 days in a dry year.

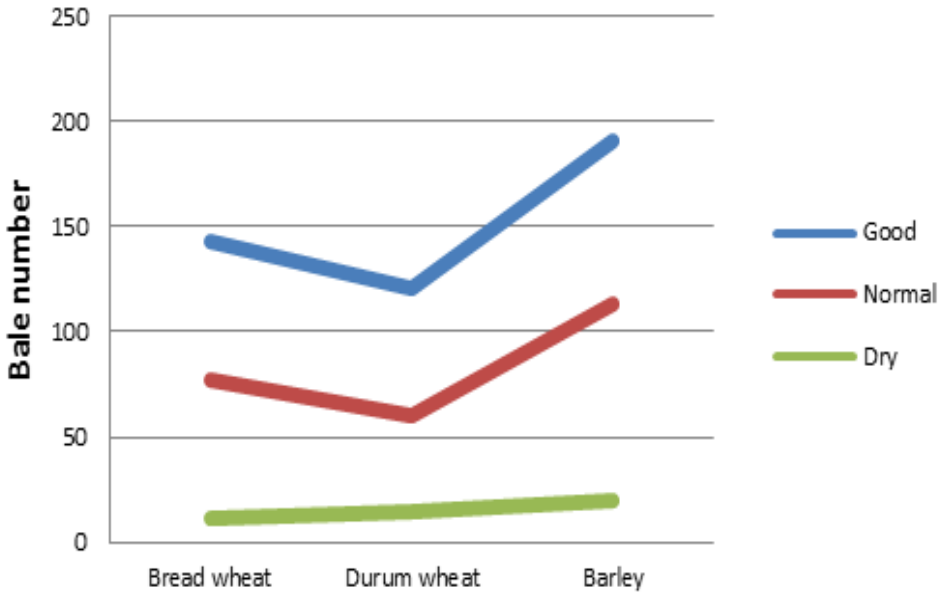

Figure 2. Average straw yield in normal, good and dry years.

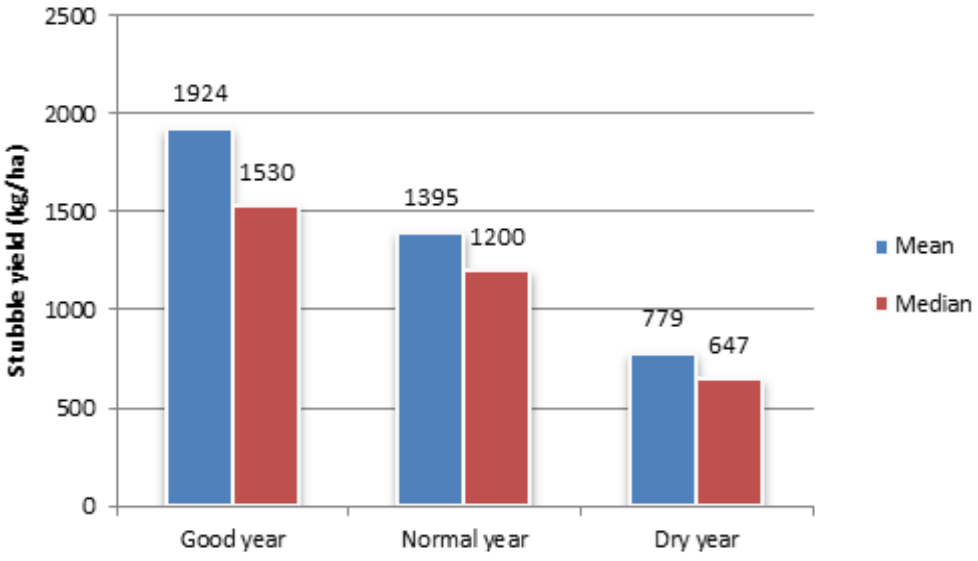

Figure 3. Mean and median cereals stubble yield in normal, good and dry years.

No farmer has indicated it can graze over a month during a dry year, but that does not mean that no more stubble.

Stubble production determination in station

In station, during the first year, the total amount of biomass remaining on the experimental plots after removing straw was relatively large (1.5 to 2.1 t/ha). It decreased by 2.1 to 1.2 t/ha for the third treatment (P3) during 2 weeks of grazing and by 1.5 to 1 t/ha during 4 weeks of grazing for the 4th treatment (P4). Stubble proportion remaining after pasture was 45% in P3 and 24% in P4 (Figure 4). The largest declines occurred in the first weeks for both treatments. This was due to the amount of residual grains in the stubble. Indeed, during

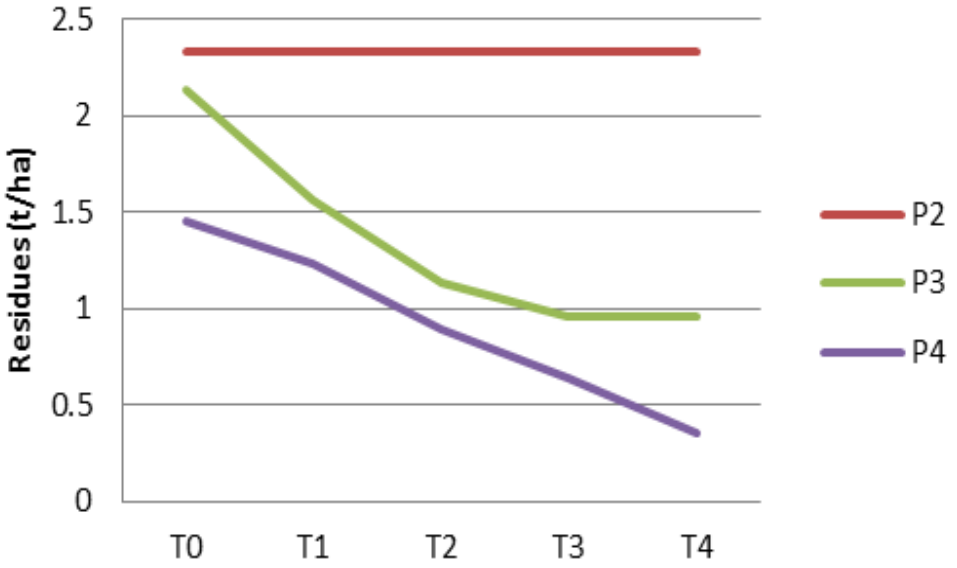

Figure 4. Residues management in the station in normal year.

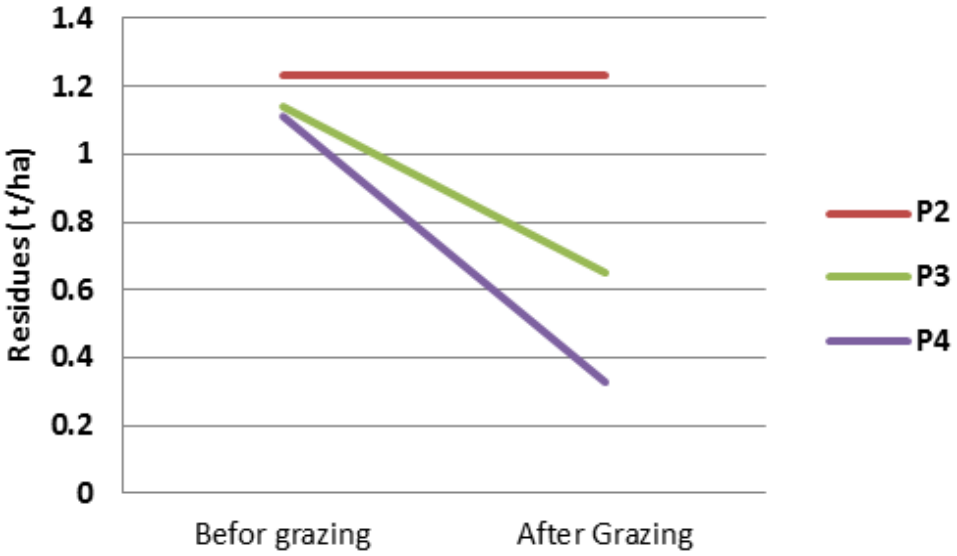

Figure 5. Residues management in the station in dry year.

the harvest, grains can be ejected from the stem and fall to the ground at the stubble. Therefore, stubble crop may include grain that makes it more nutritious and more appreciated by sheep.

During the following season, which was dry, the residue levels were significantly affected by adverse weather conditions. The total amount of residual biomass on land after removal of the straw was about 1.2 t/ha. For a week, stubble was reduced by 43% for P3 and 70% for P4 treatment (Figure 5).

During both seasons, the quality of stubble was affected by grazing. In fact, during the first year after a week of grazing, crude protein decreased from 5.6 to 3.7% and from 9.4 to 4.2%, respectively for P3 and P4. During the second week, the crude protein was reduced from 3.7 to 1.9% for P3 and remained stable for the plot P4.

For the second year (dry year), the same pattern was observed for both treatments. Thus, crude protein was reduced by 1.4% for P3 and 2.5% for P4 after grazing.

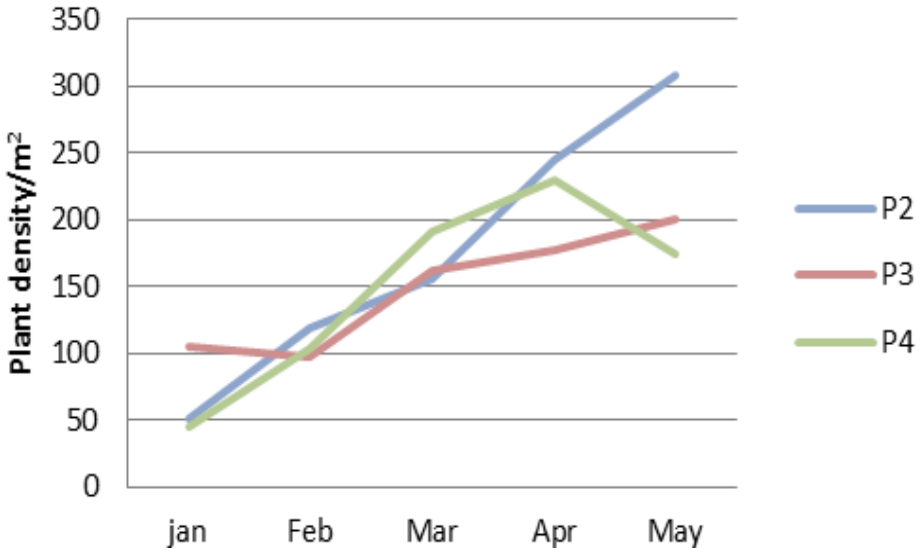

Figure 6. Evolution of forage mixture density in station.

Crop productivity in response to residue removal levels

Most of the experiments conducted on residue retention conclude that, overall, residue retention improves yields compared to conventional agriculture and no-till cultivation with elimination of residues (Mrabet, 2011; Verhulst et al., 2011; Mohammad et al., 2012). In the present study, both density and forage production of vetch/oat mixture were followed to compare between the different levels of residues (P2, P3 and P4).

The density of forage mixture increased continuously for the three plots until March and the beginning of April, and then it slowed down for P3 and fell for P4 (Figure 6). In contrast, the density of plants for plot P2 continued to increase until time to cut forage.

The analysis of variances (ANOVA) show that the influence of the quantity of residues on the herbaceous density is highly significant ($P<0.05$). In fact, the density varied significantly from P2 and other plots with high average density in P2 by the end of the trial.

By examining the production (fresh and dry matter), we found that the production of biomass P2 is larger than the two other plots. Statistical analysis of data for the three plots shows that the production of biomass (fresh and dry) was highly significant ($P <0.05$). Similarly, P2 and P3 have produced much more than P4 (Figure 7). Indeed, the fresh production of P2 exceeds that of P3 by 16% and that of P4 by 55%. At the same time, fresh production of P3 exceeds that of P4 by 47%.

Dry matter production follows the same trend and shows an excess of P2 by 27 and 57%, respectively compared to P3 and P4; similarly, P3 exceeds P4 by 41%.

DISCUSSION

In general, Moroccan dryland farmers have incorporated the risk of drought into their farming strategies. Since the catastrophic droughts of the 1980s, farmers have become accustomed to the recurrence of droughts and the temporal variability of precipitation. However, the main attitude of farmers to the risks of drought is not that of a proactive search for adaptive options but consists of a hoarding strategy to prepare for bad years. After a good harvest, straw and grain are stored and used either for animals or for trade when the need for money or food is critical. In fact, they often plan in terms of short-term horizons (Patt et al., 2008).

In theory, almost all of the benefits of the no-till system come from permanent soil cover and only a few from not tilling the soil (Mrabet et al., 2012; Ortiz et al., 2008). But in dry land in Morocco, stubble have a very important value for livestock feeding.

So, the question of proposing a conservation agriculture package without retaining crop residues is under debate, in Morocco and in international forums (Gauny, 2016). Given the importance of residues for animal feed in farming systems in semi-arid zones, it is questionable whether the slight improvement in yield recorded with maximum residue retention, compared to the system direct sowing with moderate retention, justifies the importance given to this practice.

The results of this study show that the total amount of biomass remaining on the experimental plots after removing straw ranged betwen 1.2 and 2 t/ha. This stubble is more nutritive than straw, thanks to green material and residual grains left after reaping (Magnan et al., 2012). This grain, up to 600 kg/ha according to Boulal

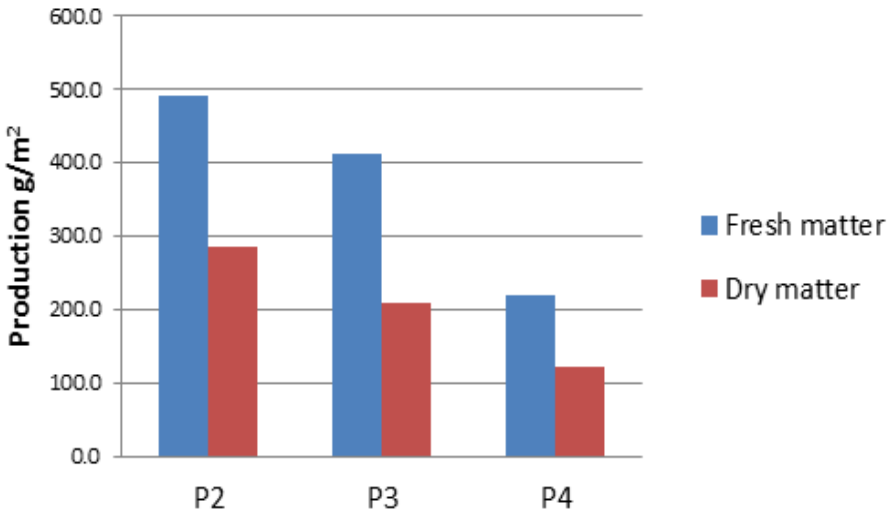

Figure 7. Forage production response to residue level.

(2001), adds considerable value and offers "free" nutritive feed during few weeks, in a normal year.

Similarly, the present work shows that the level of residue retention significantly influences the biomass production of the crop. So, the difference in production between plot 100% of residues retention and the other plots is very apparent. It is particularly important for the low residue level (25%). For the medium residue level (50%), the difference is relatively low with 16 and 27% difference respectively for fresh and dry biomass. Although these results exceed those found by Mrabet (2011) for a long-term experiment from 1994 to 2002 in conditions close to our region, they can agree on the same conclusion which states that conserving 100% of residues instead of 50% makes no dramatic difference in terms of production.

Experiments in other countries confirm our results. In fact, a 4-year experience in the Peshawar region (Pakistan) has shown that by retaining all the residues in two tillage treatments, the yield could be increased by 10% in conventional tillage and by 33% in non-tillage (Mohammad et al., 2012). Others results came out of a 13-years study about a maize-wheat system in Mexico (Verhulst et al., 2011). While no-till with any residues retention slightly exceeded the yield in conventional tillage, retaining residues were needed to significantly improve the grain yield.

So we believe that, in short terms, the residue left, however small, combined with limited disturbance of the soil surface would likely contribute to efficient water use and better production. Then, the large-scale adoption of the no-till system will reduce the pressure on crop residues by agro-pastoralists. This is a position defended by a number of researchers (Gauny, 2016), for whom the main problem remains the disturbance of the soil by tillage. Several studies have shown that no-till can potentially improve cereal and biomass yields (El Gharras et al., 2009; Schwilch et al., 2015; Boughlala, 2013). This improvement is significant in itself. It is not obtained at the price of an acute compromise, but on the contrary with a drop in production costs (Boughlala, 2013). The socio-economic cost of an additional 5% increase in yields, thanks to soil cover (Mrabet, 2011), is more problematic, unless the equilibrium of the farming system is modified, by intensification of the farming system for example, which requires a diversification of the diet of the livestock.

Opinions on an adequate percentage of retention, although difficult to determine and control, as explained earlier, are more unanimous. Retention of all residues adds little value to retention of 50% or less (Mrabet, 2011), but its cost to the farmer is much higher. At the end, the rate of residue retention should above all balance both the benefits in terms of agricultural production and the capacity or needs of farmers for animal feed.

The identification of the main limiting factors at the local level is a prerequisite for the decision to combine no-till and retention of residues, or to apply a single component. In flat areas, for exemple, the relatively low erosion rates can indeed be adapted to direct seeding without significant retention of residues (Schwilch et al., 2015). Another bottleneck in the association of these two practices is the risk of direct seeding clogging with residues (Mrabet and Wall, 2015).

Conclusion

The acute tradeoff for residues use encountered in

Moroccan drylands seems to privilege “step-wise adoption” (Pannell et al., 2014). Using no-till as an entry for conservation agriculture has already demonstrated promising results, that have to be confirmed over time. The retention of residues can constitute a second step, once this technology is tailored to the local peculiarities and needs. It is likely that retaining residues would not be beneficial to all farmers. Therefore, flexibility definitely is a success factor of conservation agriculture adoption. But ruling out a better management of residues would seem as a missed opportunity and could invalidate the benefits of no-till in the long-term.

In general, the livestock can be kept on the stubble to light stocking rate, in relation to the biomass available for a limited period. Likewise, the use of stubble by animals can recover crop losses which are in the form of spikes and grains left on the field.

So, the crop-livestock integration in dryland of Morocco can lead to a particular system of direct seeding with a moderate retention of residues, because stubble has a very important value for livestock in these environments. The residue, as small as, combined with limited disturbance to the soil surface, likely contribute to efficient water use and greater production.

These results are encouraging and should be considered as scientific evidence to adopt a no-till system that takes into consideration the importance of crop residues in livestock feed. The consideration of this evidence will improve the rate of adoption of direct seeding in arid areas of Morocco and elsewhere.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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