Journal of Materials and Environmental Sciences
ISSN : 2028-2508
CODEN : JMESCN

J. Mater. Environ. Sci., 2018, Volume 9, Issue 5, Page 1544-1550

https://doi.org/10.26872/jmes.2018.9.5.170

http://www.jmaterenvironsci.com

Evolution of carbon and nitrogen biomass of vertisol and fersiallitic soil after previous cultivation of wheat and sugar beet in the irrigated perimeter of the Doukkala in Morocco

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Received 13 Apr 2017,
Revised 26 Oct 2017,
Accepted 31 Oct 2017

Keywords

- ✓ Previous crop
- ✓ wheat,
- ✓ sugar beet,
- ✓ soil
- ✓ carbon biomass
- ✓ nitrogen biomass
- ✓ mineral nitrogen
- ✓ Doukkala irrigated perimeter

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Abstract

The restoration of crop residues on the ground has a predominant role in soil fertilization. Their decomposition allows an evolution of the carbon biomass and the nitrogen biomass of the soil. In this study, we investigated the impact of residues from previous wheat and sugar beet crops on the evolution of the microbial biomass and mineral nitrogen at the harvest and after the first fall rains on two types of soils. These are vertisol and fersiallitic soil of the Doukkala irrigated perimeter in Morocco. The effect of wheat and sugar beet residues on the change in microbial biomass and soil mineral nitrogen shows that: (i)Between harvest and end of summer, the size of the microbial biomass of The 0-20 cm soil layer decreases in both soil types. It decreases on average by 33% and 46% for vertisol and fersiallitic soil, respectively. ii)After the first fall rains, the carbon biomass of the two soil types increases. In vertisol, it increases by 55% for the previous wheat and 125% for the previous beet. In fersiallitic soil, it increases by 48% for the previous wheat and 105% for the previous sugar beet. (iii)The contribution of biomass nitrogen to total soil nitrogen between end of summer and first fall rains is of the order of 29.6 kg N/ha and 70.4 kg N/ha in the vertisol and 12.3 kg N/ha and 29.6 kg N/ha in the fersiallitic soil, respectively, after the previous crops of wheat and sugar beet. iv) A high mineralization of the organic matter in the 2 layers 0-20 cm and 20-40 cm combined after the first fall rains. For the previous sugar beet, the amount of mineral nitrogen released is 75 kg/ha and 41 kg/ha for vertisol and fersiallitic soil, respectively. This form of nitrogen is likely to be leached. For the pre-crop wheat, mineral nitrogen is immobilized by microorganisms in the soil and therefore the risk of pollution of the water table by nitrates is attenuated. All the results obtained show that the restitution of crop residues constitutes a source of organic matter which could be used as fertilizers of the degraded soils of Morocco.

1. Introduction

Burying crop residues is the main source of soil organic matter (MOS) and improves the chemical, physical and biological properties of the soil. This maintenance is possible by recycling the nutrients needed for plants[1]. According to Power and Legg[2], degraded lands of North Africa are a good example of the effect of exports outside plot of crop residues. Indeed, Ayanlaja *et a*l.[3] showed that the organic carbon content of the soil is proportional to the amount of residue added to the soil. According to Naman and Soudi[4] and Traoré *et al*.[5], better management of crop residues remains the main way to regulate the rate of MOS.

The return of crop residues on the ground requires the evaluation of their fertilizer value. This depends on the quantity and quality of the pre-cropping crop[6]. Moreover, the fertilizer value of an amendment product depends on both its nutrient composition and the rate of decomposition. Among these elements, carbon and nitrogen play a crucial role in soil fertility. The latter remains subject to seasonal fluctuations and makes it difficult to predict its quantities that will be available for the plant at any given time. In fact the biochemical reactions of the carbon and nitrogen cycle governed by microorganisms depend on the factors of the environment. Several studies have shown that the seasonal fluctuations of mineral nitrogen follow a constant annual cycle. Indeed, in Morocco, Soudi[7] showed that the production of mineral nitrogen in the soils of the Chaouia area is the result of an intense mineralization of the organic matter after the rewetting of the soil after the first fall rains followed by a significant leaching of the nitrates as soon as the rains become percolating.

The purpose of this study is to investigate the impact of residues from previous wheat and sugar beet crops on the evolution of microbial biomass and mineral nitrogen at harvest after the summer and after the firstfall rains fall of the vertisol and the fersiallitic soil of the Doukkala irrigated perimeter in Morocco.

2. Materials and methods

2.1. Characteristics of the study area

The irrigated perimeter of the Doukkala of size 102 300 ha corresponds to a vast plain located to the south of the city of El Jadida in the Atlantic coast (figure 1). Its area represents 10% of the nine irrigated perimeters in Morocco[8]. Its climate is of the semi-arid Mediterranean type, with mild winters and summers generally lime and dry, somewhat softened by the proximity of the Atlantic Ocean whose average annual temperature is 18.5 °C. The Doukkala irrigated perimeter is of strategic importance for national agricultural production, especially sugar beet (38%).

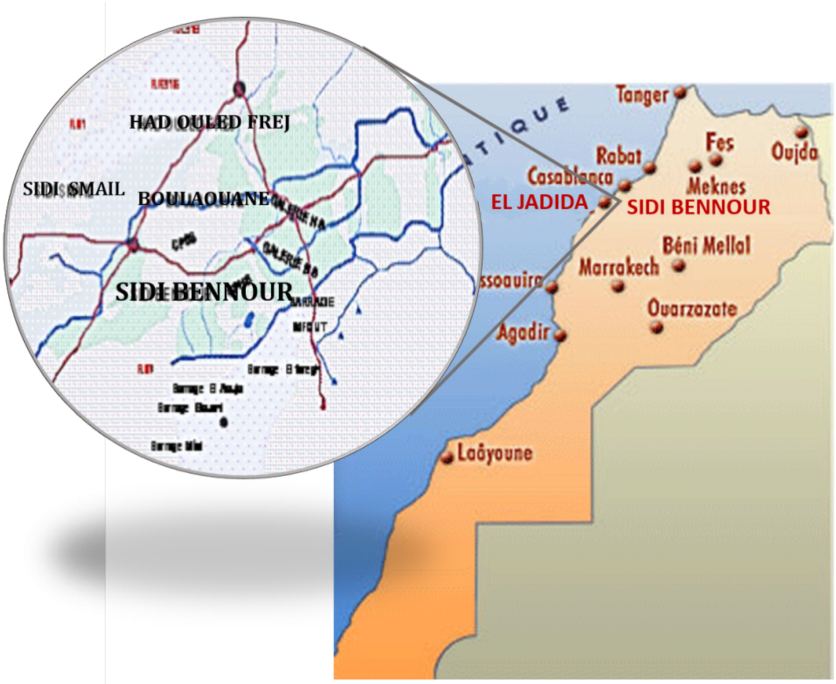

Figure 1: Geographical location of the study area

2.2. Physico-chemical characteristics of soils (vertisol and fersiallitic soil) and crop residues (sugar beet and wheat) The choice of vertisol and fersiallitic soil was based on two essential criteria: their representativeness in terms of area in the Doukkala irrigated perimeter since they represent, respectively 52% and 17% of the total soil[9] and the contrast in their physic-chemical properties. The two soil types were sampled at a depth of 80 cm divided into four horizons of 20 cm.

The choice of wheat and sugar beet residues analyzed in this study is based on the fact that these two plants are the most cultivated in the irrigated perimeter of the Doukkala. They occupy 50000 ha and 16000 ha, respectively[9].

The wheat and sugar beet residues were harvested separately on 20 squares of 1 m^2 each per plot. The average proportion of residues that was deduced has been applied to a surface area of one hectare.

The physic-chemical characterization of the soils was carried out in the Laboratory of Soil Biochemistry of the Hassan II Agronomic and Veterinary Institute of Rabat, Morocco and in the laboratory of microbiology of the Catholic Unive rsity of Louvain-La-Neuve in Belgium with the following methods: the granulometry of the soils, according to the international method, using the Robinson pipette. The pH was measured by the electrometric method with a land / water ratio of 1:2.5. The mineral nitrogen content of the soil was determined by the method of Keeney and Nelson[10]. The chemical elements of the crop residues (Mn, Ni, Pb, Zn, Al, Ba, Cd, Co, Cr, Cu, Fe) are extracted by the digestion method with concentrated hydrofluoric acid[11] and their contents were determined by atomic emission spectroscopy (Thermo Jarrell Ash, Iris Axial). Soil microbial biomass was measured by the so-called "fumigation-extraction" method[12]. The organic carbon and total nitrogen content of soils, their microbial biomass and crop residues were determined using the Walkley-Black and Kjeldhal methods[13].

2.3. Statistical analysis of data

Three replicates of soil and crop residue analysis were carried out. The statistical processing of the collected data is carried out using the SAS software. For the comparison of means, we used the LSD test with 5% as the probability threshold for the acceptability or rejection of the hypothesis of equality of means.

3. Results and Discussion

3.1. Physico-chemical characterization of vertisol and fersiallitic soil

The physico-chemical properties of the two soils studied are presented in table 1. Thus, clay, silt and sand levels vary between 16.3 and 43.6%, between 16.4 and 20.6% and between 35.7 and 67.2%, respectively. The organic carbon content was 4.98 g/kg sol and 7.89 g/kg sol, the total nitrogen content was 0.64 and 0.79 g/kg soil and the C/N ratios were 7.8 and 10 for fersiallitic soil and vertisol, respectively. Although the organic matter content in the vertisol is low (13.60 g/kg soil), it remains higher than that of the fersiallitic soil (8.58 g/kg of soil). These low levels are due mainly to the poor management of crop residues. The slightly alkaline pH of the two soils favors the development of certain microorganisms. The apparent density of vertisol and fersiallitic soil is 1.5 and 1.3, respectively.

Table 1: Physico-chemical characteristics of vertisol and fersiallitic soil

Type of soil	**Granulometry (%)**			**Organic matter (g/kg sol)**				**Water pH**	**Apparent density**
	Clay	Limon	Sand	C	N	C/N	OM		
Vertisol	43.6	20.6	35.7	7.89	0.79	10.0	13.60	7.9	1.5
Fersiallitic	16.3	16,4	67.2	4.98	0.64	7.8	8.58	7.7	1.3

OM : organic matter

3.2. Chemical and biochemical characterization of crop residues (sugar beet and wheat)

Our crop residues of sugar beet and wheat have a C/N ratio of 18.55 and 62.33, respectively. According to Bouajila *et al*.,[14], crop residues with a C/N ratio greater than 40 are deficient in nitrogen. Thereby, our wheat residues are able to immobilize part of the residual mineral nitrogen. This has the advantage insofar as mineral nitrogen, especially in nitric form, escapes leaching following the percolating winter rains. According to a study by Naman *et al*.,[15], wheat residues have higher levels of cellulose (42.80%), hemicellulose (24.70%) and lignin (6.42%) than those of sugar beet which are 19.35%, 23.48% and 3.31%, respectively. These three compounds decompose more or less slowly and provide varying amounts of stable organic carbon to the soil. This constitutes a more or less marked amending effect[16].

Sugar beet residues have a soluble fraction (53.85%) higher than that of wheat residues (26.07%)[15]. Moreover the mineralization intensity is positively correlated with the cellulose content and C/N ratio of the organic residues type[14]. Furthermore, organic residues rich in lignin are difficult to decompose due to the recalcitrance of these plant polymers[17].

The amount of fresh organic matter remaining on the soil surface after wheat crop (2.37 t/ha) is higher compared to the sugar beet crop (1.41 t/ha). Moreover, a large part of this organic matter is exported off plots, especially in the case of sugar beet leaves and collars used as livestock feed or as pasture fields in the case of wheat.

Table 2 shows the contents of the two crop residues in major elements. Among them, sugar beet yields the highest levels of N (22.91 kg/ha), Mg (11.80 kg/ha), Ca (15.87 kg/ha) and Na (37.07 kg/ha), while residues of wheat yielded the highest levels of phosphorus (4.36 kg/ha) and potassium (12.53 kg/ha).

Table 2: Major element inputs (kg/ha) of wheat and sugar beet residues

Previous crops	N	P_2O_5	K_2O	MgO	CaO	NaO
Wheat	16.13	4.36	12.53	3.63	5.46	2.59
Sugar beet	22.91	2.54	9.24	11.80	15.87	37.07

Except for Zn and Ni, sugar beet residues are richer in 9 trace elements than wheat residues. Among these elements, aluminum and iron have the highest levels (table 3).

Farmers in several agricultural regions in most agricultural regions of Morocco use crop residues as livestock feed. Therefore, the contents of major and minor elements brought to the soil remain insufficient for plants. As the restitution of crop residues to the soil has a double advantage (gradual and complete decomposition) on the input of mineral fertilizers. It would therefore be important to increase the level of production so as to have enough for soil amendment.

Table 3: Micronutrient inputs (g/ha) for wheat and sugar beet residues

Previous crops	Mn	Ni	Pb	Zn	Al	Ba	Cd	Co	Cr	Cu	Fe
Wheat	67	9.9	1.5	138	1120	59	0.2	1	17	5.9	770
Sugar beet	88	4.6	2.2	20	4880	65	0.34	1.5	11	6.4	2480

3.3. Evolution of C-biomass in vertisol and fersiallitic soil after the harvest of wheat and sugar beet at the end of summer in late summer and after the first fall rains

Microbial biomass is considered to be the transforming compartment of MOS. The latter is traversed by flows of energy and nutrients[18]. Its size is directly related to the amount of carbon existing in the soil necessary for the energy needs of micro-organisms (soil carbon more biodegradable and especially carbon from crop residues and inputs of organic matter).

Table 4 shows the C-biomass content on the 0-20 cm layer of vertisol and fersiallitic soil after the harvest of wheat and sugar beet at the end of summer and after the first fall rains.

After the harvest of wheat and sugar beet, the C-biomass content is higher in the vertisol than in the fersiallitic soil. It represents up to 2.22% of the total organic carbon.

Between harvest and end of summer periods, the C-biomass level declines by 33% in vertisol and 46% in fersiallitic soil. This is due to a drop in the soil humidity because of the heat of summer[19]. According to a study by Insam *et al.*,[20], this climatic factor plays many important roles such as biological activity, gas exchange, transfer and mobility of microorganisms and substrates. Therefore, a high temperature leads to the death of the microorganisms.

Table 4: C-Biomass amount after harvest of wheat and sugar beet at the end of summer and after first fall rains in the 0-20 cm layer in vertisol and soil fersiallitic.

Type of soil	Previous crops	After harvest (mg/kg soil)	The end of the summer (mg/kg soil)	After the first fall rains (mg/kg soil)
Vertisol	**Wheat**	175.40 ± 13	108.23 ± 11	167.75 ± 13
	Sugar beet	154.44 ± 16	112.48 ± 7	253.41± 23
Fersiallitic	**Wheat**	96.42 ± 15	51.74 ± 13	76.36 ± 10
	Sugar beet	102.41 ± 10	56.26 ± 8	115.46 ± 9

The decrease in C-biomass between vertisol and fersiallitic soil is due to the clay texture of vertisol[21,22]. According to several studies the fine clay fraction allows water reducing fluctuations and the clay-humic complex promotes the survival of soil microorganisms[22-24]. Moreover, the strong CEC of vertisol favors the absorption of mineral elements essential for microbial growth[25]. Even when exporting off-site sulla residues,

microorganisms were more active in the clay soil than in the sandy soil[14]. The rate of clay 36% would have created a favorable environment for microbial activity, due to the retention power of water and the protective effect of clay on microbial biomass[26,27].
Between late summer and the first fall rains, vertisol microbial C-biomass increased by 55% for the previous wheat and 125% for the previous sugar beet. In the fersiallitic soil, C-biomass increased by 48% for the previous wheat and 105% for the previous beet. Many authors have shown the strong relationship between soil re-moistening and increased microbial activity[28,29]. Brookes *et al*.,[30] found a net reactivation of soil biological activity and development of additional microorganisms between these two periods. The large increase in C-biomass for the previous beet in both types of soil is due to the high assimilability of beet residue sugars by the telluric microflora, usually composed of chemo-organotrophs whereas wheat residues contain mainlycellulose[15,31]. According to According to another study, there is a balance between the size of the C-biomass and the energy requirements of the microflora and the bioavailability of the organic matter[32].
The high C-biomass level in the soil after organic amendment is mainly due to the availability of carbon in the amendment. The increase in soil C biomass was obtained also when the waste was added[33]. Therefore, the soil microbial biomass depends on their carbon level and the nature of the amendment[34,35].

3.4. Evolution of N-biomass after the harvest of wheat and sugar beet at the end of the summer and after the first fall rains

Mostly, the variation of the nitrogen stock in the soil depends on its microbiological activity. Microorganisms can thus release (mineralization), or imprison nitrogen compound (organization)[36].
Table 5 shows the N-biomass content on the 0-20 cm layer of vertisol and fersiallitic soil at the end of summer and after the first fall rains for the previous two crops. The microbial N-biomass between these two periods increases in the vertisol by 122% for the previous wheat and 125% for the previous beet. In the fersiallitic soil, N-biomass increases by 47% for the previous wheat and 105% for the previous beet. This high soil N-biomass stimulation is due its re-moistening. This results in an induction of the soil biological activity and the development of additional microorganisms.
After the first fall rains, the amount of soil mineral nitrogen is 29.6 kgN/ha and 70.4 kgN/ha in vertisol and 12.3 kgN/ha and 29.6 kgN/ha in the fersiallitic soil, after the previous crops wheat and sugar beet, respectively. The N-biomass contribution in the release of nitrogen into the soil is therefore more important when the carbonaceous substrate is readily biodegradable and the soil is clayey.

Table 5: N-biomass content in the 0-20 cm layer of vertisol and fersiallitic soil at the end of the summer and after the first fall rains for the previous two crops wheat and sugar beet.

Type of soil	Previous crops	The end of the summer (mgN/kg)	After the first fall rains (mgN/kg)
Vertisol	Wheat	18.04 ± 1.3	27.92 ± 1.21
	Sugar beet	18.75 ± 0.78	42.23 ± 2.71
Fersiallitic	Wheat	8.62 ± 1.45	12.73 ± 1.02
	Sugar beet	9.38 ± 1.63	19.24 ± 2.85

3.5. Evolution of mineral nitrogen after the harvest of wheat and sugar beet at the end of the summer and after the first fall rains

Table 6 shows the evolution of the mineral nitrogen content released by the vertisol and the fersiallitic soil after the two previous crops of wheat and sugar beet between late summer and after the first rains.
For the previous sugar beet, the amount of mineral nitrogen released in the two types of soil is greater in the 0-20 and 20-40 cm layers than in the 40-60 and 60-80 cm ones.
For the previous wheat, the released mineral nitrogen content in the two types of soil decreases in the 0-20 cm and 20-40 cm layers and increases slightly in the 40-60 and 60-80 cm ones. This mineral nitrogen decrease at the surface is due to its immobilization by the biomass which sees its size increased. Such immobilization is important for crops with high C/N as is the case with wheat residues. Indeed, the biological immobilization of nitrogen is beneficial for the soil. Since nitrogen retained in soil in organic form is protected against leaching,

volatilization and denitrification losses[37]. The incorporation of 3 t/ha of wheat straw reduced losses of mineral nitrogen in the fall by 47 to 60%[38]. Moreover, the incorporation of this type of residue in soil has an ecological interest because it reduces pollution of groundwater by immobilization of the excess nitrates that can be drained from the root zone[38]. When sugar beet is planted after the burial of wheat residues, it receives only a small amount of mineral nitrogen between germination and 6 leaves[39]. To remedy this event called "hunger of nitrogen", a reincorporation of the wheat residues long before the implantation of the beet becomes essential. For many authors, it was necessary to wait four weeks after the incorporation of 1% wheat straw supplemented with 100 to 160 mg of N-mineral/kg of soil dry[40,41]. In many countries, the stability of immobilized nitrogen is the desired objective when high doses of nitrogen fertilizer are applied[42].

Table 6: Amount of released mineral nitrogen after first fall rains by vertisol and fersiallitic soil after the two previous crops wheat and sugar beet

Type of soil	Previous crops	Depth (cm)	End of summer (Ne) (mg/kg soil)	After the first fall rains (Np) (mg/kg soil)	Nitrogen released (Np-Ne) (mg/kg soil)
Vertisol	**Wheat**	0-20 20- 40-60 60-80	25.63 ± 4.34 23.30 ± 1.22 17.50 ± 2.80 18.86 ± 2.31	24.45 ± 2.11 20.22 ± 0.76 19.80 ± 3.72 20.08 ± 1.85	-1.18 -3.08 2.30 1.22
	Sugar beet	0-20 20-40 40-60 60-80	23.04 ± 2.30 27.29 ± 1.25 16.76 ± 1.22 15.38 ± 0.96	37.13 ± 1.42 38.28 ± 0.86 18.60 ± 0.53 16.48 ± 1.52	14.09 10.99 1.84 1.10
Fersiallitic	**Wheat**	0-20 20-40 40-60 60-80	15.93 ± 1.06 16.24 ± 4.32 10.07 ± 1.26 8.34 ± 1.63	13.14 ± 0.87 12.34 ± 226 11.54 ± 1.73 10.52 ± 3.28	-2.79 -3.90 1.47 2.18
	Sugar beet	0-20 20-40 40-60 60-80	17.04 ± 1.45 14.82 ± 3.24 12.36 ± 1.39 10.11 ± 0.58	27.48 ± 3.09 20.20 ± 2.11 12.74 ± 0.68 11.61 ± 2.26	10.44 5.38 0.38 1.50

Ne: nitrogen measured at the end of summer, Np: nitrogen measured after the first fall rains.

Conclusion

Changes in microbial biomass and mineral nitrogen after harvesting wheat and sugar beets in late summer and after the first fall rains vary according to the type of soil and the nature of the previous crop.

Between the harvest period of wheat or sugar beet and the summer release, the C-biomass size decreases much more in the fersiallitic soil than in the vertisol. This decrease is due to the effect of the strong summer heat.

After the first fall rains, the size of the microbial C-biomass increases for both soil types. The degree of increase depends on the type of previous culture.It increases with sugar beet more than with the previous wheat. This is due to a difference in the assimilability of the sugars of the two types of residues. Microbial biomass contributes to the transformation of organic matter and provides mineral nitrogen to the soil.

The mineral nitrogen content increases in the two soil types studied at harvest in end summer and after the first rains after the previous two crops of wheat and beet. For sugar beet, we observed a strong mineralization of the organic matter after the first rains on the two layers of soil 0-20 cm and 20-40 cm combined. The amount of mineral nitrogen released into the soil is 75 kg/ha for vertisol and 41 kg/ha for fersiallitic soil.

For both types of residues, the amount of mineral nitrogen in the 0-40 cm layer of both soil types is more than the nitrogen crop requirements at the sowing stage. This nitrogen is likely to be leached into soil. For the previous wheat crop, 9.5 to 21% of the mineral nitrogen of the 0-40 cm layer is immobilized by soil microorganisms. Therefore, the risk of pollution of the water table by nitrates is attenuated.

To mitigate the problem of leaching nitrates in soils of the Doukkala irrigated perimeter, many recommendations must be made to put in place a policy of reasoned fertilization of nitrogen. Among them, promote early planting and rationalize irrigation. Such aims could be obtained by sensitizing farmers in the region to the problem of nitrate pollution of the water table.

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