Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2015, 7(11):41-47

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Microbial biomass behaviour in Algerian steppe soils

Bourahla Lame[1], Dellal Abdelkader[2] and Boukhari Yahia[2]

[1]Laboratoire de Recherche sur les Systèmes Biologiques et la Géomatique (LRSBG).
Faculté des Sciences de la Nature et de la Vie- Université de Mascara- Algérie
[2]Laboratoire de Recherche d'Agro-Biotechnologie et de Nutrition en Zones Semi Arides.
Faculté des Sciences de la Nature et de la Vie- Université de Tiaret- Algérie

---

ABSTRACT

This study is to assess the spatial and seasonal soil microbial biomass variation in Algerian steppe soils using the fumigation extraction method. The microbial biomass carbon ranged from 78 mg.kg^{-1} dry soil to 245 mg.kg^{-1} dry soil with an average of 146 mg.kg^{-1} dry soil; forming an 1,5% of total soil organic carbon. The soil microbial biomass carbon dynamics depends on the seasonal climatic conditions; the highest values were recorded in spring and autumn, while the lowest values were noted in winter and summer. The summer desiccation has a much greater influence on the reduction of microbial biomass carbon than the winter freeze. The sampling date is a key factor to assess the critical threshold of microbial biomass in these ecosystems.

Keywords: Algeria, aridisol, fumigation, microbial biomass, climatic condition.

INTRODUCTION

The Algerian steppe soils are degrading and poor in organic matter, their improvement require firstly the quantification of the microbial biomass living in these soils **[1]**. The amount of soil organic matter is around 1.0%. However, they can drop quickly after the cultivation of these soils by inappropriate methods **[2]**; causing the degradation of the physico-chemical and biological fertility **[3]**. In Algerian steppe, an important number of scientific studies have been devoted to changes in the physical and chemical properties of the soil quality **[4][5]** and the vegetation dynamics **[6][7][8]**, on the contrary, regarding the microbiological quality and the role of soil microbial biomass, which is still relatively low. The microbial biomass is defined as the fraction of the living organic matter in the soil **[9]**, composed mostly by chimioorganotrophic organisms **[10]**; distributed in the form of micro-colonies within the soil aggregates, for the most part, in a state of dormancy **[11]**. Many studies have demonstrated the role of the microbial biomass in the soil biological functioning and soil behaviour **[12].** The soil microbial biomass is an index of soil evolution **[13]**, by its rapid turnover, the microbial biomass recycles and regenerates the biogenic elements and constitutes the principal element of the food chain in the soil **[14][15].** It influences the chemical fertility by evacuating their cytoplasmic contents during the death and lyses of the microbial cells **[16]**. Several factors influence the distribution and microbial activity in the soil; the accessibility and the availability of the carbonate substrate more biodegradable within the soil aggregates **[17][18]**. The soil microbial biomass quantity is related not only to the quantity of plant biomass, but also to the diversity and the floristic richness **[19][20].** Other soil parameters influence the level of the microbial biomass. It shows a low level in a saline condition [**21][22][23]** and is more important in the clay fraction than to other size fractions **[24]**. The climatic factors also influence the dynamics of the soil microbial biomass where the ratio between the precipitation and the evaporation affect the microbial biomass **[25]**. Some studies have demonstrated that the seasonal variation of the temperature and the moisture of soil affect the level of the microbial biomass **[26][27]**.

This investigation aims to quantifying the level of the microbial biomass for some different steppe soils and study the seasonal climatic variation on the evolution of this living organic fraction.

EXPERIMENTAL SECTION

2.1. The study area

The study area is part of the steppe zone of West Algeria, the climate extends from the cold arid to the hot one, with limited annual rainfall ranging between 400 and 100 mm; varies in time and in space. The minimum temperature ranged between + 1 ° C and + 3 ° C with lower local minima -3°C and the maximum temperature is limited between 34°C and 37°C. The extreme temperature range (M-m) remains substantially equal to 34.6°C **[28]**. These soils belong to the aridisols order **[29]**, and are shallow, skeletal with very marked limestone **[30]**.

2.2. Soil sampling

The soil samples were collected from the top horizon between the clumps of steppe vegetation during the month of January. It is a cold period who characterizes the winter rest of spontaneous steppe flora.

Table 1: Geographical location of samples

Sample number	Dominant vegetation	Coordinates	Altitude (m)
1	alfa (*Stipa tenacissima)*	34-30'-25" N 00-50'-58" E	998
2	alfa (*Stipa tenacissima)*	34-29'-10" N 00-46'-15" E	1025
3	alfa (*Stipa tenacissima)*	34-27'-37" N 00-39'-22" E	1088
4	alfa (*Stipa tenacissima)*	34-25'-56" N 00-32'-49" E	1082
5	armoise *(Artemesia herba alba)*	34-29'-32" N 00-21'-12"E	1009
6	armoise *(Artemesia herba alba)*	34-21'-23" N 00-19'-49" E	1005
7	armoise *(Artemesia herba alba)*	34-18'-12" N 00-17'-35"E	1010
8	sparte (*Lygeum spartum*)	34-13'-23" N 00-04'-02" E	1037
9	sparte (*Lygeum spartum*)	34-08'-44" N 00-04'-16" E	1000
10	sparte (*Lygeum spartum*)	33-58'-12" N 00-06'-34" E	1103
11	sparte (*Lygeum spartum*)	33-47'-29" N 00-02-51" E	1123
12	aristida *(Aristida pungens)*	33-24'-38" N 00-15'-26" O	1147
13	atriplexe *(Atriplexe numelarea)*	34-08'-50" N 00-04'-13" E	1000
14	atriplexe *(Atriplexe numelarea)*	34-04'-54" N 00-05'-03" E	987
15	salsola (*Salsola vermiculata*)	34-03'-53" N 00-05'-15" E	984
16	aristida *(Aristida pungens)*	33-19'-24" N 00-04'-23" E	1149
17	remt (*Artrophytum scoparium*)	33-12'-41" N 00-05'-07" E	1148
18	remt (*Artrophytum scoparium*)	33-09'-27" N 00-05'-32" E	1181
19	remt (*Artrophytum scoparium*)	32-59'-29" N 00-O6'-59" E	1178
20	remt (*Artrophytum scoparium*)	32-46'-48" N 00-28'-56" E	1186

Sampling was conducted on a north-south direction with an increasing aridity; this axis is also characterized by a strong floristic and pedologic variation **(Table 1)**. Physical and chemical properties of soils were determined by standard methods: soil texture by international Robinson pipette method, acidity by Potentiometric method, the soluble salts are extracted and analyzed from the saturated paste **[31]**, The cation exchange capacity (CEC) quantified using ammonium acetate **[32]**, the total limestone by the calcimeter Bernard method and Organic carbon content (C_{org}) was determined using the Anne method **[33]**.

The microbial biomass carbon was estimated from the fumigation extraction method; 25g of soil samples are fumigated by chloroform vapour for 24h at 25°C. The samples were extracted with 0.5M of K_2SO_4 with a soil/solution (1/5) by shaking for 1h at 200 $r.min^{-1}$, the carbon is determined by $K_2Cr_2O_7$**[34]**; The unfumigated soil samples were extracted similarly at the start of experiment. The microbial extractable carbon (E.C) is equal to the extra carbon extracted in the fumigated samples compared to the untreated control samples with chloroform.

Many studies have confirmed that, regardless the type of soil, the extractible carbon is a substantially constant proportion of the microbial biomass **[34][35][36]**.

The microbial biomass carbon is calculated by the following formula:

$$C_{biomasses} = 2.64(C_{fumigated} - C_{unfumigated})$$

2.3. Statistical analysis

In order to establish a relationship between the different physico-chemical parameters and to further evaluate the relationship between them, the principal component analysis and the hierarchical classification was used.

All the values in this study are the average of three measurements.

Table 2: Physicochemical characteristics of soils

N° sample	Soil texture (%)			$CaCO_3$ (%)	pH 1/2,5	CE $dS.m^{-1}$	CEC $mmol.100g^{-1}$	Soil extract($mmol.\ l^{-1}$)							C_{org} (%)	C_{bio} ($mg.kg^{-1}$)	C_{bio}/C_{org} (%)
	Sand	Silt	Clay					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	SO_4^{--}	HCO_3^{-}			
1	52,00	39,00	9,00	9,00	7,71	1,81	9,89	2,68	0,65	2,04	0,82	4,64	1,30	3,35	0,99	201,00	2,02
2	49,00	41,00	10,00	8,25	7,70	1,71	12,21	2,05	0,78	1,96	0,78	3,87	1,23	3,20	1,08	225,00	2,08
3	52,00	38,00	10,00	8,75	7,64	1,83	12,25	2,18	0,65	2,21	0,88	3,64	1,30	4,00	1,35	245,00	1,81
4	40,00	47,00	13,00	6,50	7,60	1,43	13,65	2,02	0,80	1,88	0,75	2,80	1,50	2,50	1,46	202,50	1,39
5	40,00	48,00	12,00	8,75	7,40	1,45	15,58	1,68	0,52	2,04	0,82	3,20	2,00	2,57	1,35	189,00	1,40
6	40,00	46,00	14,00	7,50	7,50	1,45	13,95	1,63	0,50	1,79	0,72	2,80	1,00	2,00	1,57	217,50	1,39
7	59,00	33,00	8,00	9,85	7,85	2,15	7,81	2,51	0,84	3,06	1,20	4,13	1,48	3,75	0,87	132,00	1,51
8	52,00	39,00	9,00	8,50	7,65	1,90	9,89	2,13	0,65	2,72	1,25	3,64	1,70	3,35	0,99	147,00	1,48
9	57,00	32,00	11,00	9,50	8,36	2,25	14,77	2,38	0,71	3,68	1,45	4,20	1,43	3,75	1,30	153,00	1,18
10	62,00	28,00	10,00	10,50	7,50	2,25	12,21	2,64	0,78	3,00	1,30	4,34	1,55	4,00	1,10	163,00	1,48
11	66,00	27,00	7,00	11,00	8,03	2,45	6,98	2,75	0,83	3,70	1,48	4,62	1,65	4,25	0,76	115,00	1,52
12	72,00	21,00	7,00	12,00	8,16	2,59	5,98	3,00	0,95	3,50	1,40	5,04	1,80	4,62	0,81	112,50	1,39
13	46,00	36,00	18,00	8,50	8,50	7,75	13,19	1,96	0,58	28,00	0,60	12,88	5,02	11,85	0,67	97,00	1,45
14	40,00	37,00	23,00	7,00	8,00	6,95	17,52	1,64	0,50	35,00	0,72	11,20	4,00	10,25	0,84	121,00	1,44
15	27,00	57,00	16,00	4,50	7,20	8,50	10,42	1,13	0,84	32,00	0,32	7,56	2,70	6,93	0,58	88,00	1,51
16	73,00	22,00	5,00	13,50	7,50	2,50	9,16	3,09	0,94	3,00	1,20	5,11	1,88	4,70	0,56	78,00	1,39
17	78,00	20,00	2,00	13,00	7,54	2,70	8,14	3,25	0,98	23,4	0,93	5,46	1,95	5,00	0,52	79,00	1,52
18	75,00	17,00	8,00	12,50	7,25	2,45	7,82	3,13	0,94	1,99	0,80	6,34	1,88	4,85	0,87	126,00	1,44
19	73,00	18,00	9,00	12,18	7,75	2,40	9,89	3,00	0,92	1,84	0,74	8,32	1,83	4,68	0,98	133,00	1,35
20	75,00	21,00	4,00	12,50	7,80	2,47	5,86	3,13	1,00	1,98	0,79	5,25	2,01	4,85	0,63	89,00	1,42

C_{org}: total soil organic carbon- C_{bio}: microbial biomass carbon- CEC: cation exchange capacity- CE: electrical conductivity

RESULTS AND DISCUSSION

3.1. The variation of the microbial biomass in the steppe soils

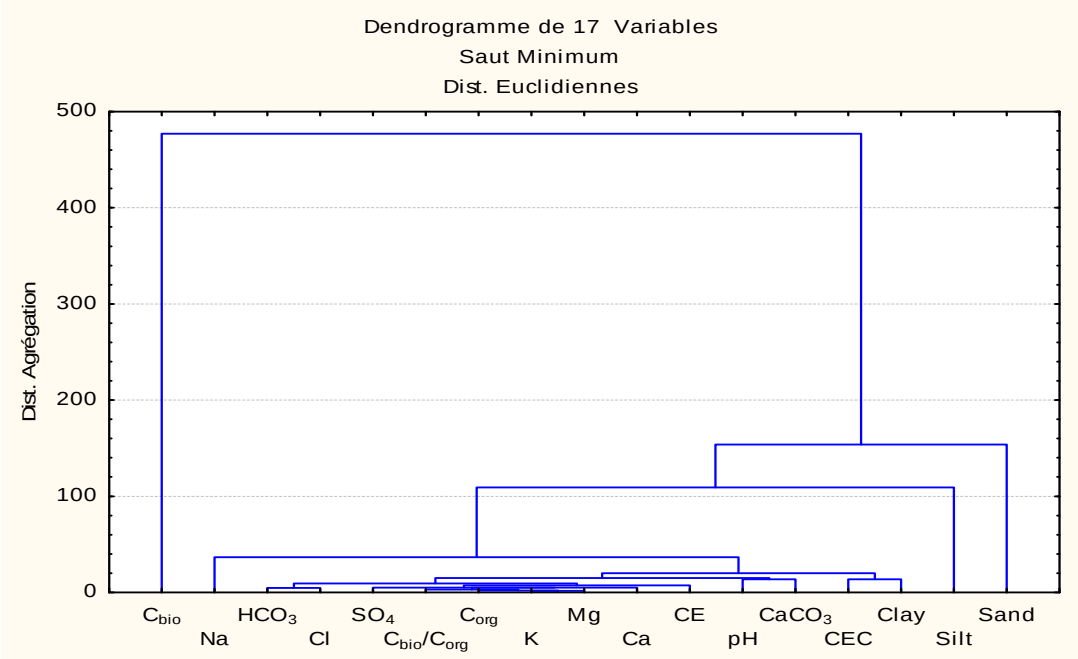
In all samples, the microbial biomass carbon ranged from 78 $mg.kg^{-1}$ dry soil to 245 $mg.kg^{-1}$ dry soil with an average of 146 $mg.kg^{-1}$ dry soil, the highest values are recorded in the alfa ecosystems with an average of 218 $mg.kg^{-1}$ dry soil (**Table 2**). In terms of the soil total organic carbon, this fraction ranges between 1,18% in the sparte ecosystems to 2,08% in the alfa ecosystems, with an average of 1,5%; these values are limited within the range of values found by Gil-Sotres and al**. [37]** but lower than found by other study [**38].**

The transition from alfa ecosystem to remt ecosystem correlates with the reduction of the microbial biomass carbon along the transect north-south of the realized sampling. It is important to note that, this transition also coincides with the reduction in plant biomass that passes from 35% of a recovery rate in alfa ecosystems to recovery rate not exceeding 15% in remt ecosystems with intermediate rate for sparte ecosystems ranged between 20 to 25%. This low level of microbial biomass carbon has been attributed to the unfavorable conditions characterizes this ecosystems.

The hierarchical classification of different parameters, using the dendrogram, shows that the level of the microbial biomass carbon forms a separate group towards the other soil parameters (**Figure 1**). It is a minimum level of microbial biomass that can host a taxonomic unit when habitat conditions became unfavourable. This fraction lives in dormancy and is undemanding in growth factors **[39]**.

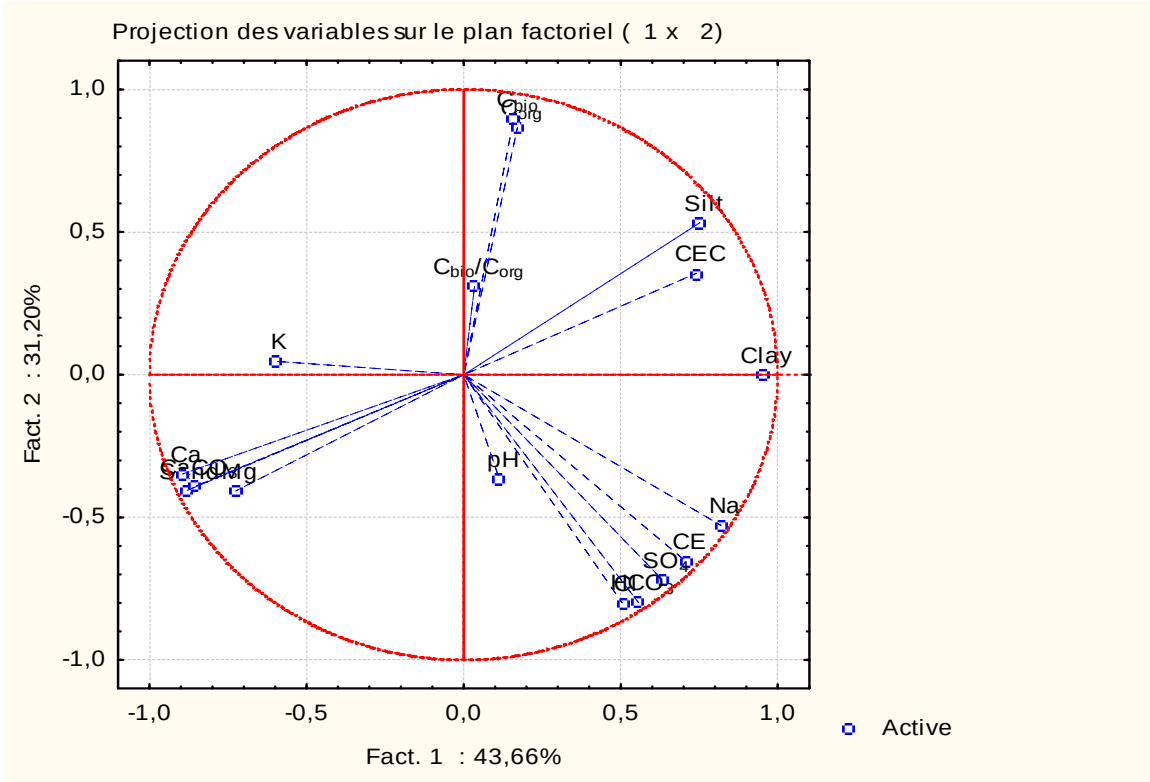
This value may be a threshold value, used like a biomarker of the degraded soil functioning **[3]**, and will be a potential indicator of the sustainability of the steppe ecosystems. Above this threshold, the balance is broken and the ecosystem 'soil' loses its properties influenced by the microbial biomass [**40]**. It should also be noted that the values of this threshold are very high in the alfa ecosystems than in the two other ecosystems. The comparative effect of different parameters is determined by the two axes of principal component analysis (**Figure 2**).

The two axes represent a total inertia of 74.86% with 43.66% and 31.20% of contribution respectively to the factors F1 and F2 ; showing diametric opposition between the microbial biomass carbon and soil parameters that promote the edaphic aridity; mainly sands, total limestone , CE, Ca and Mg. Our results are similar with these finding by other study **[21]**. The high salinity causes a significant decrease in microbial biomass carbon by increasing osmotic pressure and decreasing soil water availability **[41][42]**. The opposition of the textural parameters with the microbial biomass carbon reflects the weakness of the protection mechanism of this fraction by clays which dominated by the size with low specific surface area like palygorskite **[4]**.



C_{org}: total soil organic carbon- C_{bio}: microbial biomass carbon- CE: electrical conductivity
CEC: cation exchange capacity

Figure 1: Dendrogram classification of different parameters



C_{org}: total soil organic carbon- C_{bio}: microbial biomass carbon- CE: electrical conductivity
CEC: cation exchange capacity
Figure 2: Projection of the analyzed parameters in principal component analysis (PCA)

3.2. Seasonal variation of the soil microbial biomass

The monthly variation of the microbial biomass carbon was followed during the season 2013/2014 under three types of plant cover characterizing the Algerian steppe namely the alfa (*Stipa tenacissima*), the sparte (*Lygeum spartum*) and remt (*Artrophytum scoparium*).

This evolution is given in **Figure 3**, the month of August marks the minimum value of the microbial biomass carbon 126, 101 and 84 $mg.kg^{-1}$ dry soil respectively for the alfa, the sparte and the remt ecosystems, the month of November marks the maximum of microbial biomass carbon 260, 170 and 113 $mg.kg^{-1}$ dry soil respectively for the alfa, the sparte and the remt ecosystems, despite this increase, these values are insufficient to improve the fertility of these soils; the same result was found by other authors **[43][44][45].**

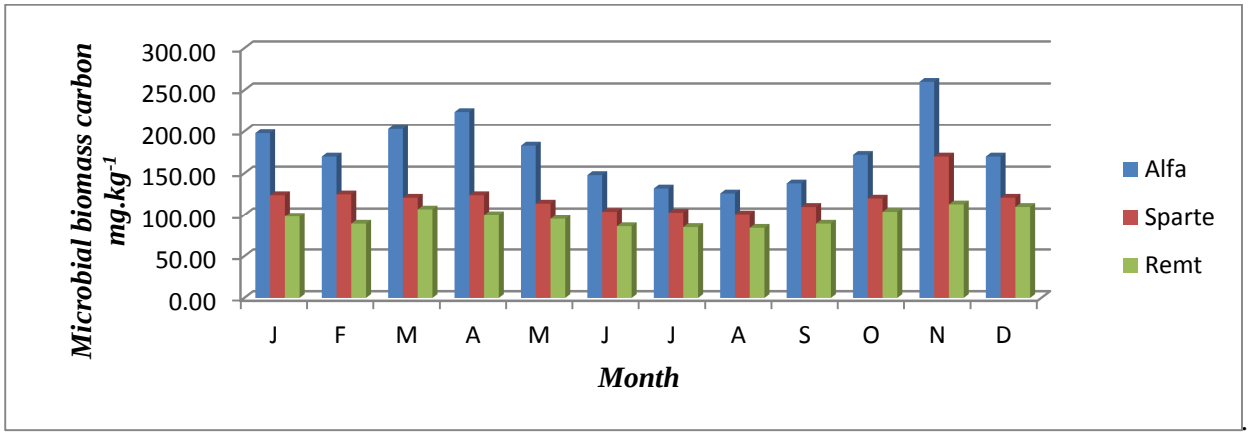


Figure 3: Monthly variation of microbial biomass carbon (season 2013/2014)

The seasonal variation of the microbial biomass is characterized by the presence of two peaks of high microbial biomass carbon level (spring and autumn) and two peaks of low microbial biomass carbon level (winter and summer). The same remarks were found by other authors **[44][45][46]**. In steppe conditions the autumn and spring are favourable to the regeneration of vegetation; affecting the level of microbial biomass by rhizodeposits quantity **(Table 3**).

Table 3: Average seasonal variation of microbial biomass carbon (*season* 2013/2014)

	alfa ecosystem		sparte ecosystem		remt ecosystem	
	C_{bio} ($mg.kg^{-1}$)	Reduction rate	C_{bio} ($mg.kg^{-1}$)	Reduction rate	C_{bio} ($mg.kg^{-1}$)	Reduction rate
Autumn	190,00	-5%	133,00	-7%	102,00	-3%
Winter	179,00		123,00		99,00	
Spring	203,00	-33%	155,00	-32%	100,00	-15%
Summer	135,00		105,00		85,00	

During the transition from autumn to winter, the reduction rates reached 5%, 7% and 3% respectively for the alfa, the sparte and the remt ecosystem; but the transition from spring to summer, the reduction rates reached 33%, 32% and 15% respectively for the alfa, the sparte and the remt ecosystem. This reduction is due to the partial sterilization phenomenon influenced by the winter cold and summer heat on the soil microbial biomass. It is higher in summer than in winter, which supposes that the drying affects much more the reduction of the microbial biomass than the low temperatures. Several studies demonstrated that the strong seasonal temperature difference changes the porosity by reducing the diameter of the pore spectrum than minimizing water availability by increasing the tension matrix and even rewetting of soil after prolonged desiccation does not make the level of the microbial biomass in its initial state [**47][48]**.

CONCLUSION

Through the climate and soil data, this study has demonstrated the fragility of these ecosystems and the difficult conditions of the biotope in where biological life exists. This study demonstrates, that when the soil conditions of the steppe ecosystems became unfavourable, this living organic fraction find a refuge in the soil micro aggregates and takes the lowest values. These values can be considered as a critical threshold to estimate the sustainability of these steppe ecosystems. Below these values the equilibrium is rapidly broken and the irreversibility threshold is quickly reached. The aridity of climate and the soil lowers the level of microbial biomass, a negative correlation was observed between this compartment and the parameters promoting edaphic aridity such as sand, limestone and salt. The seasonal variation of microbial biomass is also observed in this steppe ecosystems; the strong production levels of microbial biomass coincided with the resumption of the autumn and spring rain that are reflected by regeneration

of an ephemeral seasonal plant; but not sufficient to improve the fertility of these soils. However, the supply of organic material from the rhizodeposits can improve the level of the microbial biomass; this possibility can be realized by the long protection of the endemic existing vegetation and by a minimizing the extensive pastorals time. In these ecosystems, we can assume that the critical threshold of microbial biomass carbon is limited between 1 to 2% of the soil total organic carbon (equivalent 100 to 200 $mgC.kg^{-1}$ of dry sol). The multi-year study of the microbial biomass evolution will better analyse the cyclical behaviour of this living organic fraction and predict the high production phases. Eventually, the desiccation and the prolonged aridity have a stronger influence on the reduction of the microbial biomass than the low temperatures and we can retain the summer as the favourable date to evaluate the critical threshold of microbial biomass carbon in this arid region.

REFERENCES

[1] Pouget M.:Relation sol végétation dans la steppe sud algéroise. Ed.ORSTOM **1980**, 1-555
[2] Henni M., Mehdadi Z.: *Acta Botanica Gallica*. **2012**, 159 (2), 43-52.
[3] Lian J.; Zhao X.; Zuo X.: *J. Arid Land* **2013**, 1 (3), 71−79.
[4] Haltim A.: Sols des régions arides d'Algérie. Ed. OPU **1988**, 191-225.
[5] Tadj A.: These Magister Univ. Mascara **2010**, 1-57.
[6] Bessaih A.; Hellal B.; Ayad N.: *European Scientific Journal* **2014**, 10 (2), 357- 369.
[7] Nedjimi B.: J. *Saudi Soc. Agri. Sci*., **2012**, 11 (3), 43-49.
[8] Aidoud A.; Floch LE.; Houerou HN.: Sécheresse **2006**, 17, (3)22-27.
[9] Jenkinson DS.; Lad JN.: *Soil Biochemistry*. **1981**, 415-471.
[10] Ellis S.; Mellor A..: Soils and environment. Routledge, London-New York **1995**, 1-25.
[11] Foster RC.; Rovira AD.; Cok TW.:Ultrastructure of the root-soil interface. The American Phytopathological Society St Paul. M.N. **1983,** 2-7.
[12] Chen LD.; Zhang XY.: *Chinese Geographical Science* **2011**, 21(4), 392-402.
[13] Sparling GP.; Ross DJ..: Biochemical methods to estimate soil microbial biomass: current developpements and application, Int. Mulongoy K. et Merckx R. (eds.), Soil organic matter dynamics and sustainability of tropical agri. MT A/K. U. Wiley-Sayce-Co. **1993**.
[14] Glaciela K.; Odair A.; Mariangela H.: *Soil Biology & Biochemistry* **2010**, 42(3), 1-13.
[15] Hussain ST.; Siddique ST.; Saleem M.; Arshad M.; Khalid A.: *Advances in Agronomy* **2009**, 102(2), 157-198.
[16] Bending GD.; Mary KT; Francis R.; Marx MC.; Martin W.: *Soil Biology and Biochemistry* **2004**, 36(3), 1785-1792.
[17] Pavel R.; Doyle J.; Steinberger Y.: *Soil Biol. Biochem*. **2004**, 36(4), 549–554.
[18] Ullah R.; Lone MI.; Ullah KS.; Mehdi SM.; Qazi MA.: *The Journal of Animal & Plant Sciences* **2013**, 23(2), 493-499.
[19] Zak DR.; Holmes W.; White DC.; Peacock A.; Tilman D.: *Ecology* **2003**, 84(2), 2042-2050.
[20] Zhanfeng LA.; Guohua L.A.; Bojie F.; Xiao XZ.: *The Ecological Society of Japan* **2007**, 1(3)353-357.
[21] Ali-Haimoud A.; Amir H. ; Bounaga D.; Chami M. ; Djellali N.: *Physiologie végétale*. **1980**, 18(5), 19-32.
[22] Mallouhi N.; Jacquin F.: *Soil Biology & Biochemistry*. **1984**, 17(2), 23-27.
[23] Dellal A. ; Halitim A. : *Cahiers d'agricultures*. **1992**, 1(4), 335-340.
[24] Oulbachir K.; Dellal A.; Bekki A.: *European Journal of Scientific Research* **2009**, 36(8), 407-417.
[25] Insam H.: *Soil Biol. Biochem*. **1990**, 22(6), 525–532.
[26] Bergeron O. : Collec. *Mémoires et thèses électroniques Univ. Laval* **2007**, 32-45.
[27] Wardle DA.: *Biological Review* **1992**, 7(2), 321-358.
[28] Le Houérou HN.: Sécheresse **2006,** 17(3), 343-348.
[29] USDA.: A Basic system of soil classification for making and interpreting soil surveys Agriculture Handbook, Natural Resources Conservation Service, USDA **1999**, 1-436.
[30] Bourahla L.: These Magister Univ. Tiaret **1998**, 7-25.
[31] Rhoades, J.D.: Methods of Soil Analysis. Part2.Chemical and Microbiological Properties (2nd Ed.). Madison: American Society of Agronomy and Soil Science Society of America **1982**, 9-15.
[32] Anderson JM.; Ingram JSI.: Tropical Soil Biology and Fertility: A Handbook of Methods. Wallingford, Oxon, England: CAB International **1993**, 23-35.
[33] Baize D.: Guide des analyses courantes en pédologie. Ed. INRA **1988**, 7-45.
[34] Vance ED.; Brookes PC.; Jenkenson DS.: *Soil Biology and Biochemistry* **1987**,19(3), 703-707.
[35] Inubushi K.; Brookes PC. ; Jenkinson DS.: *Soil BioI. Biochem*. **1991**, 23(2), 737-741.
[36] Chaussod R.; Zuvia M.; Breuil MC.; Hetier JM.: *Cah. Orstom sér. Pédol*. **1992**, 27(1), 59-67.
[37] Gil-Sotres F.; Trasar-Cepeda MC.; Seoane S.: *Soil Biology and Biochemistry* **2005**, 37(5), 877-887.
[38] Nicolardot B. ; Chaussaud R. : *Revue Ecol. Biol. Sol*. **1986**, 23(6), 233-247.
[39] Nicolardot B. ; Chaussod R. ; Catroux G.: Association Française pour l'Etude du Sol. **2013**,2(5) 253-261.
[40] Bourahla L. ; Dellal A. : *Revue écologie et environnement*. **2006**, 2(4), 13-22.
[41] Syed AS.; Shah Z.: *Sarhad J. Agric*. **2011**, 2(5), 233-244.

[42] Tripathi S.; Kumari S.; Chakraborty A.; Gupta A.; Chakrabarti K.; Bandy, B.K.: *Biol. Fertil Soil* **2006**, 42(3), 273-277.
[43] Naâman F.; Denoel A.; Soudi B.; Chiang CN. : Séminaire 'Intensification agricole et qualité des sols et des eaux', Rabat, 2-3 Novembre **2000**.
[44] Bhuyan SI.; Tripathi OP.; and Khan Ml.: *The Journal of Agricultural Sciences* **2013**, 8(3), 142-152.
[45] Ibomcha Singh L. and Yadava PS.: *Tropical Ecology* **2006,** 47(4), 63-70.
[46] Tariq M.; Rehmat A.; Faqir H.; Kauser AM.; Ghulam RT.: *Pak. J. Bot*. **2007**, 39(2), 1751-761.
[47] Chaussod R.; Nicolardot B.; Catroux G. : *Science du sol* **1986,** 2(3), 201-211.
[48] Mathieu C.; Ruellan A. : Cah. ORSTOM, *ser. Pedol*. **1987**, 1(5), 3-25.