ПРИЛОЗИ, Одделение за природно-математички и биотехнички науки, МАНУ, том **40**, бр. 2, стр. 145–150 (2019)
CONTRIBUTIONS, Section of Natural, Mathematical and Biotechnical Sciences, MASA, Vol. **40,** No. 2, pp. 145–150 (2019)

Received: October 9, 2018
Accepted: January 14, 2019

ISSN 1857–9027
e-ISSN 1857–9949
UDC: 631.413.4$97.7)
DOI: 10.20903/csnmbs.masa.2019.40.2.138

Original scientific paper

CONTENT OF EXCHANGEABLE CATIONS IN ALBIC LUVISOLS IN THE REPUBLIC OF MACEDONIA[#]

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On different locations of the country, 23 soil profiles of Albic Luvisols were excavated and morphologically described on the field. More than half of soil profiles (15) were under forest vegetation, 4 soil profiles were under grass and the other 4 on arable land. The survey showed that the cation exchange capacity (CEC) is higher in the humus accumulative horizon A, but lower in the eluvial horizon. Due to increasing amount of clay in a lower part of a soil profiles, a CEC increases in hor. Bt, BtC and C. The base saturation percentage ranges from 46.93 % to 60.83 %. From these data we can see that the soils are in advanced stage of acidification. In Albic Luvisols, the basic cations (Ca^{++}, Mg^{++}, K^+, Na^+) are more common in comparison to acid cations ($H^+ + Al^{+++}$). Exception is the eluvial horizon, where the content of acid cations higher compared to basic cations. Among the exchangeable basic cations, we can see that the content of Ca^{++} cation has the highest values, Mg^{++} is less represented, while K^+ and Na^+ cations have the lowest contents among the exchangeable cations.

Key words: albic luvisols; cation exchange capacity; exchangeable cations

INTRODUCTION

Albic Luvisols are of great importance for the agriculture and forestry in the Republic of Macedonia. Their importance, stems from their moderate production capability and the fact that they are formed and covers big areas in humid regions of the country. One part of these soils are cultivated with different agricultural varieties, while the other parts are under lawns and forest. The content of exchangeable cations is significant indicator for the soil formation conditions. Many processes and characteristics of soil depend of cation exchange capacity (CEC) and its content. The content of the exchangeable ions of Albic Luvisols in the Republic of Macedonia can be found in the previous work of [1–7].

Data regarding the content of the exchangeable cations on Albic Luvisols in the Republic of Macedonia formed under different vegetation can be find in our previous work [8].

MATERIAL AND METHODS

On different locations of the country, 23 soil profiles of Albic Luvisols were excavated and morphologically described on the field. More than half of soil profiles (15) were under forest vegetation, 4 soil profiles were under grass and the other 4 on arable land.

Field examinations have been performed according to accepted methods in Former Yugoslavia [9].

The laboratory analyses have been done according to the standard of adopted methods in Former Yugoslavia and the Republic of Macedonia, as follows:

- Mechanical composition of soil has been determined by the pipette method [10]; the dispersion of the particles has been done with 0.1M Na-pyrophosphate. The separation of the mechanical elements in fractions has been done by the international classification.

[#]Dedicated to academician Gjorgji Filipovski on the occasion of his 100th birthday

- pH (reaction) of the soil solution has been determined with glass electrode in water suspension and in MKCI suspension [11].
- Easy available forms of P_2O_5 and K_2O were determinate by Al method [12].
- The content of humus has been determinate at the base of total carbon by the method of Tjurin modified by Simakov [13].
- The total N has been determinate by Kjeldahl micromethod [11].
- Extraction with barium chloride three-ethanolamine in glass colons (Melich method) was used for quantification of acid exchangeable cations ($H^+ + Al^{+++}$). The extract is titrated with 0.04 M HCl in a presence of mixed indicator [11].
- Extraction with $BaCl_2$ [14] was used for quantification of the exchangeable cations (Ca^{++}, Mg^{++}, K^+, Na^+). The quantity of exchangeable cations was determined by use of atomic absorption spectrometry type "Varian".
- Cation exchange capacity (CEC), sum of basic exchangeable cations, and base saturation percentage (BS) as well as the percentage of particular cations saturation were calculated.

RESULTS AND DISCUSSION

A detailed overview of the mechanical composition and some chemical properties will be given, in order to give a correct interpretation of the results for CEC and a content of exchangeable cations of Albic Luvisols. An average results of 23 soil profiles are presented in Table 1 and 2.

Table 1. Mechanical composition of Albic Luvisol in the Republic of Macedonia (average values)

Horizon, Number of samples	Skeleton	in % of fine earth Coarse sand	Fine sand	Coarse+fine sand	Silt	Clay	Silt+ clay
	> 2 mm	0.2–2 mm	0.02–0.2 mm	0.02–2 mm	0.002–0.02 mm	< 0.002 mm	< 0.02 mm
A (23)	8.66	10.86	47.13	57.99	24.93	17.08	42.01
E (19)	14.93	11.75	45.62	57.36	26.46	16.18	42.64
Bt (23)	6.78	7.82	35.91	43.73	22.44	33.83	56.27
BtC (9)	5.4	7.62	33.26	40.88	22.27	36.86	59.12
C (15)	6.0	9.88	38.22	48.1	18.53	33.37	51.9

Table 2. Chemical properties of Albic Luvisol in the Republic of Macedonia (average values)

Horizon, Number of samples	Humus	Total	C/N	pH		Easy available mg/100g soil	
	%	N%		H_2O	NKCl	P_2O_5	K_2O
A (23)	5.88	0.27	11.84	5.67	4.70	6.56	28.48
E (19)	2.08	0.12	10.44	5.34	4.14	< 1	13.17
Bt (23)	0.92	0.07	8.01	5.62	4.29	< 1	17.69
BtC (9)	0.69	0.06	6.85	5.78	4.44	< 1	18.44
C (15)	0.46	0.04	6.79	5.92	4.58	< 1	17.59

CATION EXCHANGE CAPACITY

The cation exchange capacity depends on the total amount of clay, the nature of the clay minerals, the content of humus and the reaction of the solution used for its extraction [15]. The data for a cation exchange capacity in Albic Luvisols, are presented in Table 3. Out of the presented data, differences of cation exchange capacity can be detected, between soil horizons. These differences are due to various reasons, among which the most important are: greater accumulation of humus in the humus accumulative horizon, translocation of the clay from the humus accumulative and eluvial horizons to the argilic horizon Bt, stratification of the sediments and the inherited quantities of clay from the previous soil formation stadium.

Cation exchange capacity has its highest values in the humus accumulative horizon with average values of 19.51 cmol(+)kg^{-1} soil. Horizon E shows the lowest values of only 12. 20 cmol(+)kg^{-1} soil (low humus contents and intensive leaching of clay). In the argillic horizon (Bt) and the transitional horizon (BtC), cation exchange capacity increases with average values for hor. Bt of 16.02 cmol(+)kg^{-1} soil, and 16.93 cmol(+)kg^{-1} soil for hor. BtC. The increasing of cation exchange capacity in the lowest parts of the soil profile is due to a larger amounts of clay leached in that part of a soil profiles and probably a higher presence of smectite clay mineral. In the parent material (hor. C), the cation exchange capacity is decreasing and shows average values of 14.46 cmol(+)kg^{-1} soil. The average values of CEC for the Albic Luvisols in Republic of Macedonia reported by Filipovski, [7] are in the ranges of 16.02 for hor. A and 23.55 cmol(+)kg^{-1} soil for hor. Bt. Similar data for the CEC in Albic Luvisols are reported in the previous works of the researchers in the neighboring countries [16–21].

Table 3. Exchangeable cations of Albic Luvisol in the Republic of Macedonia (average values)

Horizon, Number of samples	Exchangeable cations in cmol (+)kg^{-1} soil						cmol (+)kg^{-1} soil	Exchangeable cations in % of CEC					
	Ca^{2+}	Mg^{2+}	K^+	Na^+	S	H^++Al^{3+}	CEC	BSP%	Ca^{2+}	Mg^{2+}	K^+	Na^+	H^++Al^{3+}
A (23)	7.26	2.18	0.47	0.22	10.13	9.38	19.51	54.05	38.83	11.50	2.53	1.21	45.95
E (19)	3.97	1.47	0.17	0.16	5.77	6.43	12.20	46.93	32.12	12.06	1.37	1.33	53.07
Bt(23)	5.69	2.28	0.20	0.25	8.43	7.59	16.02	53.64	36.25	14.44	1.26	1.64	46.36
BtC 9	7.01	2.26	0.18	0.19	9.64	7.29	16.93	58.26	42.24	13.75	1.11	1.16	41.75
C (15)	6.01	1.76	0.17	0.22	8.16	6.31	14.46	60.83	45.19	12.73	1.20	1.70	39.17

SUM OF EXCHANGEABLE BASE CATIONS AND BASE SATURATION PERCENTAGE

The sum of exchangeable base cations depends to the cation exchange capacity and to the base saturation percentage. Out of the data presented, it can be concluded that the sum of an exchangeable base is higher in hor.A, with average value of 10.13 cmol(+)kg^{-1} soil (bioaccumulation). The lowest average values of 5.77 cmol(+)kg^{-1} soil are found in the E horizon. This is due to the intense debasification in this horizon. In the lowest part of the soil profile, the content of basic cations is increasing as a result to the increased values of the cation exchange capacity (more clay) and retention of a part of a leached basic cations from hor. A and E. The average values of exchangeable basic cations for hor. Bt is 8.43 cmol(+)kg^{-1} soil and for the hor. BtC is 9.64 cmol(+)kg^{-1} soil. In the parent material (hor. C), the sum of an exchangeable base shows an average content of 8.16 cmol(+)kg^{-1} soil.

From a data of base saturation percentage we can see that the acidification is in advanced stage. The average value for the base saturation percentage for hor. A is 54.05 %. The lowest percentage of base saturation percentage is in hor. E with 46.93 %. The differences between these two horizons is mostly due to the bioaccumulation of a basic cations in hor. A. As a result to the retention of a leached base ions in the lower part of the soil profile, the values for a base saturation percentage are increasing in hor. Bt with average percentage of 53.64 % in BtC 58.26 % and 60.83 % in C.

This higher saturation with basic cations in the lower parts of the soil profile (horizons BtC and C), leeds to the conclusion that the basic cations are leached deep in the soil profile, underneath the argillic horizon Bt. This increase of the base saturation percentage in the deeper parts of the soil profile is referred by other authors as well [22, 20, 23].

According to Filipovski, [7] the base saturation percentage of cations in Albic Luvisols on the territory of Macedonia in hor. A in average yields 57.37 % while in hor. Bt up to 65.90 %. For comparison, here are cites data for base saturation percentage of cations from other authors in the neighborhood: Škorić, [24, 25] for E horizon reports 30 to 50% of base saturation, and for Bt horizon from 50 to 70 %, Ćirić, [26] from 40 to 70 %, Resulović, [27] 50–70 %, Penkov et al. [28] more than 65 %, Koroxenidis et al., [29] from 43 to 80 %.

THE CONTENT OF EXCHANGEABLE CATIONS

The quantity of a particular adsorbed exchangeable cations in Albic Luvisols depends to the character of the parent material, double layer of a soil profile and the character of the soil forming processes. With the processes of debasification and acidification of the hor. A and E, these horizons are losing the adsorbed basic cations, which are translocated and partially accumulated into hor. Bt, BtC and C. For the soil profiles under nature vegetative cover, actually it's very important the bioaccumulation of a base cations in hor. A. On arable land the content of adsorption cations in hor. Ap is changed due to the mixing during the cultivation of horizons with different content of the adsorbed cations. Out of the data presented in Table 3, we can see that the basic cations in Albic Luvisols, (Ca^{++}, Mg^{++}, K^{+}, Na^{+}) are slightly more present than the acid cations (H^{+} + Al^{+++}). Exception is the eluvial horizon, where acid cations are more present than the basic cations. Among the exchangeable base cations more common cations are Ca^{++}, then Mg^{++}, while K^{+} and Na^{+} are less represented. The exchangeable Ca^{++} cation is more common in the humus accumulative horizon which is result to its bioaccumulation. An average values of content of exchangeable cation Ca^{++} for hor. A is 7.26 cmol(+)kg^{-1} soil. We can see that in the eluvial horizon has the lowest value of this cation with only 3.97 cmol(+)kg^{-1} soil. The reduction on the content of humus and debasification in the eluvial horizon are the main reasons for this rapid declining of the Ca^{++} content. As a result to the larger clay content and retention of a part of the leached Ca^{++} cations from upper to the lower parts of the soil profile, the contents of this cation increases, hence the content of Ca^{++} in the argillic horizon is 5.69 cmol(+)kg^{-1} soil, in the transitional horizon averages 7.01 cmol(+)kg^{-1} and in a parent material the average contents is 6.01 cmol(+)kg^{-1} soil. In percent's, the average contents of exchangeable Ca^{++} in hor. A is 38. 83 %, in hor. E is 32.12 %, but in the lowest part of a soil profiles increases up to 36.25% in Bt, 42.24 % in BtC and 45.19 % in hor. C. The Mg^{++} has less contents among the basic cations in the adsorption complex of the Albic Luvisols. The content of an exchangeable Mg^{++} in horizon A is 2.18 cmol(+)kg^{-1} soil, or 11.50 % from a cation exchange capacity. The content in the eluvial horizon has the lowest values and in average is 1.47 cmol(+)kg^{-1} soil (12.06 % from CEC). In the lowest part of a soil profile, the exchangeable Mg^{++} is increasing. In Bt horizon, the content of Mg^{++} averages for about 2.28 cmol(+)kg^{-1} soil, or 14.44 % from the cation exchange capacity, while in a transitional BtC horizon 2.26 cmol(+)kg^{-1} or 13.75 % from CEC. In a parent material the content of the exchangeable Mg^{++} is 1.76 cmol(+)kg^{-1} soil or 12.73 % from the cation exchange capacity. Main reason for the lower contents of magnesium compared to the calcium cation in the adsorption complex is result to the fact that magnesium is less contents of this cation in the parent material. On the other side, its exchangeable force is lower, so this cations can be easily leached. In addition, this cation more easily enters the crystal lattice of the clay minerals mining that less quantities stayed available for adsorption. The exchangeable cations K^{+} and Na^{+} have the lowest content among the exchangeable cations. Potassium is the most common in a humus accumulative horizon, with average quantities of 0.47 cmol(+)kg^{-1} soil or 2.53% from CEC. Main reason for this is its bioaccumulation. The content of this cation decreases with increasing of the depth of a soil profiles. With regards to the adsorbed sodium, we cannot note any meaningfyll rules in its vertical distribution throughout the soil profile. The content of adsorbed sodium ranges from 1.16 % to 1.70 % of CEC. These values of adsorbed sodium can not cause any damages for the plant.

The acid cations (H^{+} + Al^{+++}) are more common in hor. A, which averages for 9.38 cmol(+)kg^{-1} soil. The E horizon content of acid cations is 6.43 cmol(+)kg^{-1} soil, Bt 7.59 cmol(+)kg^{-1} soil, BtC 7.29 cmol(+) kg^{-1} and in parent material the content of H^{+} + Al^{+++} cations in average is 6.31 cmol (+)kg^{-1} soil.

Expressed in percentage from the cation exchange capacity, the exchangeable acid cations (H^{+} + Al^{+++}) in hor. A yields 45.95%. In hor. E the acid cations contents has a highest values for about 53.07% from CEC, and have higher content than the basic cations. This is due to the intense debasification and acidification, and less intensive bioaccumulation of the basic cations.

In the lower part of the soil profiles, the values of an acid cations declines and are less common than the basic cations. In hor.Bt the content of acid cations is 46.36 %, in BtC 41.75 % while in hor. C they have the lowest values with only 39.17 % from CEC. The decline of the acid cations content in the lower parts of the soil profile is due to the weakening of the process of acidification and retention of the basic cations leached from the upper parts of the soil profile.

CONCLUSION

- The cation exchange capacity is highest in the humus accumulative horizon A (19.51

cmol(+)kg^{-1} soil. The lowest values has the eluvial horizon E (12.20 cmol(+)kg^{-1} soil. $^{-}$ As a result to the increasing of clay content in the lower parts of a soil profile, the cation exchange capacity increases in hor. Bt, BtC and C.

• The sum of the exchangeable base cations is highest in hor. A, while the lowest values are found in hor .E. In fact, the sum of an exchangeable base cations increases in the lowest part of a soil profiles (hor. Bt, BtC and C) as a result to the increasing of the cation exchange capacity and the retention of a part of a basic cations, leached from the upper parts.

• The base saturation percentage ranges from 46.93% to 60.83%. Out of the presented data, it can be concluded that the acidification is in advanced stage.

• In Albic Luvisols, the content of basic cations (Ca^{++}, Mg^{++}, K^{+}, Na^{+}) is more common than acid cations (H^{+} + Al^{+++}). Exception is the eluvial horizon, where acid cations are more common.

• Among the exchangeable base cations, Ca^{++} is the most common cation, then follows Mg^{++}, while K^{+} and Na^{+} are with lower content.

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СОСТАВ НА РАЗМЕНЛИВИТЕ КАТЈОНИ НА ЛЕСИВИРАНИТЕ ПОЧВИ ВО РЕПУБЛИКА МАКЕДОНИЈА

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На различити локации на територијата на Република Македонија се ископани и морфолошки проучени 23 основни педолошки профили на лесивирани почви, од кои 15 под шумска вегетација, четири под тревна вегетација и четири на обработливи површини. Резултатите од испитувањата покажаа дека капацитетот на атсорпција е највисок во хумусно акумулативниот хоризонт, а најнизок во елувијалниот хоризонт. Заради зголемување на содржината на глина во долниот дел на профилот, капацитетот на атсорпцијата се зголемува во хор. Bt, BtC и C. Степенот на заситеност со базични катјони се движи од 46.93 % до 60.83 %. Од овие податоци може да се види дека ацидификацијата е напредната. Во лесивираните почви, базичните катјони (Ca^{++}, Mg^{++}, K^{+}, Na^{+}) се малку позастапени од киселинските катјони (H^{+} + Al^{+++}). Исклучок е елувијалниот хоризонт во кој киселинските катјони се малку позастапени од базичните катјони. Од разменливите базични катјони Ca^{++} е најмногу застапен, потоа следува Mg^{++}, додека K^{+} и Na^{+} се многу малку застапени.

Клучни зборови: лесивирани почви; капацитет на атсорпција на катјони; разменливи катјони