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Evaluation of the Availability of Exchangeable Soil Bases Under Cotton in the Ouangolodougou Production Basin (North of Côte d'Ivoire)

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ABSTRACT: Ongoing soil degradation under cotton is a constant concern for farmers in cotton-growing basins. The aim of the study was to assess soil fertility under cotton in the Ouangolodougou production basin. To do this, soil sampling of the 0-15 cm horizon was carried out in the 15 sections that make up the Ouangolodougou production basin over four (4) successive cropping campaigns from 2017-2018 to 2019-2020. Chemical analyses of soil samples were carried out on the following parameters: exchangeable calcium (Ca^{2+}), exchangeable magnesium (Mg^{2+}), exchangeable potassium (K^+) and Ammonical Nirogen N-NH_4^+. Results indicate that the levels of N-NH_4^+ and exchangeable bases ($Ca^{2+,}$ $Mg^{2+,}$ K^+) are below the average threshold values over the 4 successive tracked campaigns. Also, results demonstrated a sectional basis effect of cotton cultivation on N-$NH_4^{+,}$ $Ca^{2+,}$ $Mg^{2+,}$ and K^+.

KEYWORDS: exchangeable basis, cotton, soil, fertility.

1 INTRODUCTION

In north Côte d'Ivoire, cotton plays a very important socio-economic role. It is a direct source of pecuniary income for 200,000 farmers (Aïwa, 2015). However, Ivorian cotton production is limited by a number of constraints. In recent years, yields have stagnated or even fallen, which could be explained by an upsurge in parasitism, despite extensive use of pesticides and chemical fertilisers (Hema, 2004). With strong demographic growth and the rapid expansion of cotton-growing areas, the fallow practice traditionally used to restore soil fertility is increasingly being abandoned in favour of continuous cropping (Le Guen, 2004, Sedogo, 2008; Gbakatchetche et al., 2010). Continuous cropping is followed by a rapid deterioration in soil fertility, resulting in a steady decline in crop yields (Traoré et al., 2007; Annabi et al., 2009; Koulibaly et al., 2010). Restoring the fertility of agricultural land and improving crop yields are two major challenges for farmers. It must be acknowledged, nonetheless, that little has changed in Côte d'Ivoire's cotton studies regarding fertilization.

Little information is available on the edaphic (physical, chemical and biological) characteristics of the various cotton production zones (Emmanuel *et al.*, 2018), particularly the Ouangolodougou region. Much work should be done on investigating mineral deficiencies a. In this context our study aimed to characterize the state of soil fertility in the Ouangolodougou region by assessing the availability of exchangeable bases.

2 MATERIALS AND METHODS

STUDY AREA

The work was carried out in the cotton-growing basin of the Tchologo administrative region (9° 35′ 00″ north, and 5° 11′ 00″ west), specifically in the Ouagadougou zone, which covers an area of 766 km^2 (Fig 1). The Ouangolodougou cotton-growing area is located in the savannah region of northern Côte d'Ivoire. The climate is of the Sudanese type, with two main seasons: a dry season from November to April, characterised by the harmattan and peaking in December and February, and a rainy season from May to October, with rainfall peaks in August and September. Average annual rainfall is between 1,000 mm and 1,200 mm. Ferralitic soils are found in this part of Côte d'Ivoire (Coulibaly *et al*. 2016). The soils of the lowlands belong to the hydromorphic soil class. However, apart from these two major classes, we encounter the following minor classes: crude mineral soils, soils that are not very advanced, tropical ferruginous soils, vertisols and brownified soils.

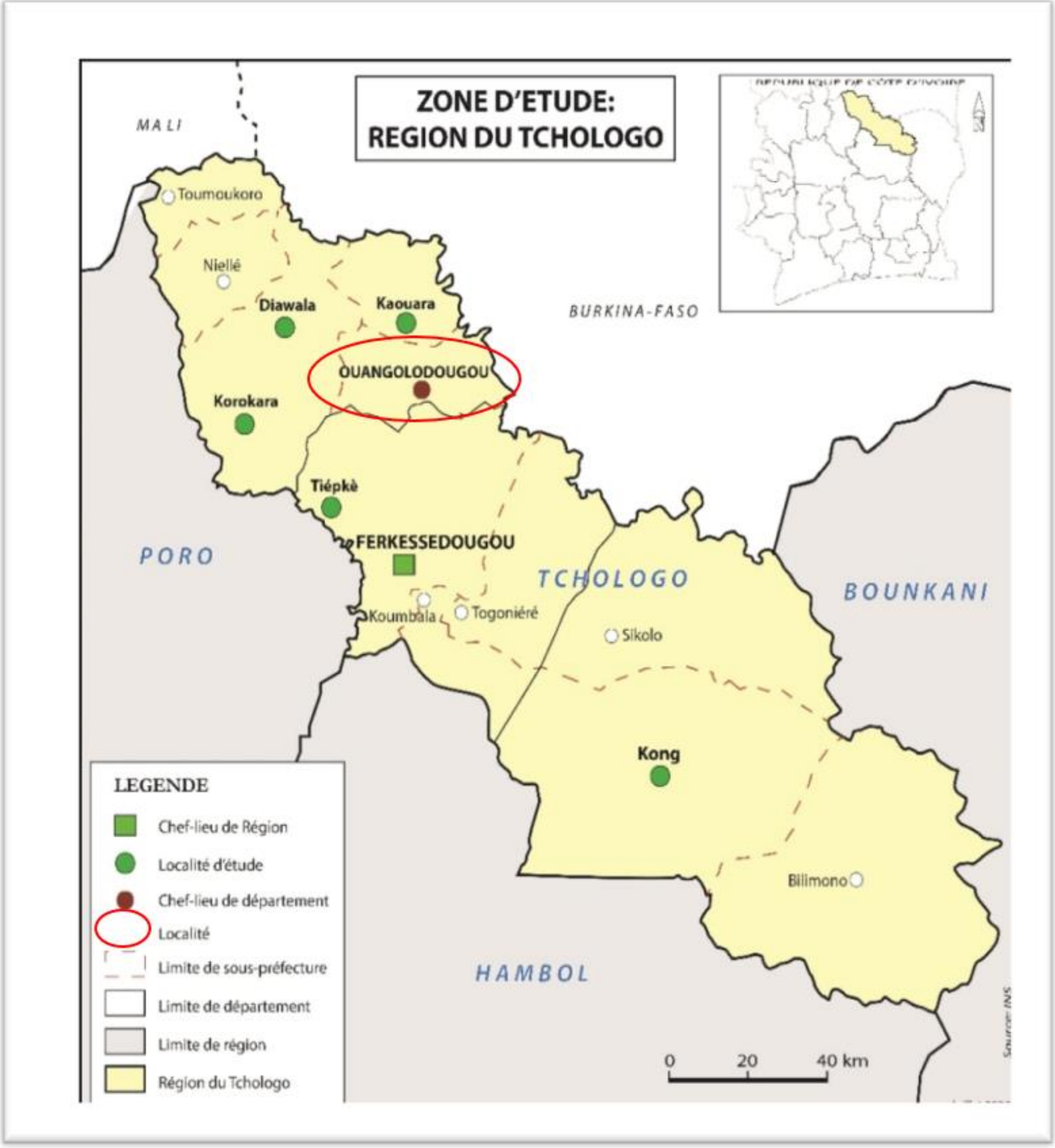


Fig. 1. Map of the Tchologo region, showing the department of Ouangolodougou

PLOTS SELECTION

A preliminary survey was carried out to select the plots. We choose plots where the farmers followed the technical itinerary recommended by the Company for the Exploitation of Cotton (SECO), the operator mandated by the Fonds Interprofessionnel for Agricultural Research and Advisory Services FIRCA to advise cotton growers throughout the Tchologo zone. Thirty (30) cotton plots, each with a surface area of 1 ha, were selected in Ouangolodougou. They are spread over the fifteen (15) sections of the department, with two (02) plots per section.

The plots were ploughed mechanically using ox-drawn teams to loosen the soil by turning over in strips. They were also fertilised with NPKSB fertiliser (15-15-15-6-1) at a rate of 200 kg/ha applied 15 days after seedling and urea at a rate of 50 kg/ha applied 45th day after emergence.

The trials were carried out on the same plots throughout the experiment.

COLLECTION OF SOIL SAMPLES

Soils were sampled over four (4) successive campaigns from 2017-2018 to 2019-2020 in order to determine the status of ammoniacal nitrogen N-NH_4^+ and exchangeable bases in the 15 sections. Samples were taken each time, just after the first rains in May. Sampling of each plot followed a Z-shaped itinerary. Each time, we took 20 elementary samples, which were mixed to form a composite sample that would be representative of the entire plot. The sampling depth was 15 cm, which corresponds to the useful depth exploited by the assimilating roots. The samples were taken using an auger. The soil samples were mixed in a plastic bucket as they were taken. At the end of sampling, the samples were thoroughly mixed in the container and approximately one kilogram of soil was retained for analysis. The composite samples were bagged, labelled, and stored in a cool and dry place away from direct sunlight and moisture. They were conveyed within the coming seven (7) days of sampling to the water-soil-plant laboratory of the Higher School of Agronomy (ESA) at the Institut National Polytechnique Félix Houphouët Boigny of Yamoussoukro (INPHB), for analysis.

LABORATORY ANALYSIS

Samples were air-dried, crushed and then sieved to 2 mm. The actual analyses were carried out on the fine soil (< 2mm). Exchangeable calcium (Ca^{2+}), exchangeable magnesium (Mg^{2+}) and exchangeable potassium (K^+) were determined using the ammonium acetate saturation method at pH 7. The $Ca^{2+,}$ $Mg^{2+,}$ and K^+ contents of the solution were determined by atomic absorption spectrometry (Pansus and Gautheyrou 2003).

The N-NH_4^+ content of the soil was determined using the Tie method (1995): 5 g of fine soil sieved to 2 mm was brought into contact with 25 ml of hydrogen peroxide (H_2O_2) at 50% quality technique. The obtained suspension was then placed in an oven at 60̊ C for 6 h, then diluted with KCl (1 M). The mixture was filtered and thereafter distilled using the Kjeldahl method (Scarf 1988).

STATISTICAL ANALYSIS

All the data obtained were subjected to an analysis of variance using IBM-SPSS statistical software, where comparisons of means were made at the 0.05 significance level using the Newman-Keul test. Moustache box plots were produced using R 3.14 software.

3 RESULTS

The results show that soil properties vary sectionwise (Tables 1, 2, 3 and 4). N-NH_4^+ levels varied significantly at the 0.05 threshold in the 15 sections over the four (4) monitoring campaigns from 2017 to 2019. Statistical analysis showed a variation in the N-NH_4^+ rate from 0.08 g/kg in the Torla section to 0.31 g/kg in the Soumailavogo section in 2017; from 0.16 g/kg in the Torla soils to 0.51 g/kg in the Benifesso soils in 2018, and from 0.13 g/kg in the Oumarvogo soils to 0.35 g/kg in the Ladjivogo soils in 2019. However, this rate did not vary significantly in 2020 ($p>0.05$). Ca^{2+} content varied significantly ($p < 0.05$) over the 4 years. It was significantly higher in the soils of Diarratchè **(**3.02 cmol/kg**)** in 2017, Koussanga (2.05 cmol/kg) in 2018, Ouangolo (1.49 cmol/kg) in 2019 and Nambigué (2.13 cmol/kg) in 2020. The results of the analysis of variance indicate that Mg^{2+} levels varied significantly ($p < 0.05$) from 2017 to 2020 except in 2018 ($p>0.05$). These levels varied from 0.34 cmol/kg in the Koussanga soils to 0.87 cmol/kg in the Gnanmandô soils in 2017; from 0.24 cmol/kg in the Gnanmandô section to 0.64 cmol/kg in the Ouangolo section in 2019 and from 0.42 cmol/kg in the Ladjivogo soils to 0.93 cmol/kg in the Koussanga soils in 2020. Potassium (K^+) levels in the various localities varied significantly ($p < 0.05$) from 2017 to 2019. The highest levels were found in the soils of Ouangolo (0.23 cmol/kg), Pleuhouo (0.44 cmol/kg) and Ouangolo (0.14 cmol/kg), in 2017, 2018 and 2019 respectively. However, in 2020 the different localities had statistically identical potassium levels. Statistical analyses showed an effect of the cotton-growing section on N-$NH_4^{+,}$ $Ca^{2+,}$ $Mg^{2+,}$ and K^+ levels. The levels obtained were below the average threshold value. This indicates that the soils under cotton in the various sections are devoid of nitrogen and exchangeable bases. Furthermore, within the same locality, N-$NH_4^{+,}$ $Ca^{2+,}$ $Mg^{2+,}$ and K^+ levels did not vary significantly at the 0.05 threshold over the 4 years (Fig 2).

Table 1. N-NH_4^+ and exchangeable base content of sub-cotton soils of the 15 sections during the 2017-2018 season

Section	N-NH_4^+ (g/kg)	Ca^{2+} (cmol/kg)	Mg^{2+}(cmol/kg)	K^+(cmol/kg)
Barrovogo	(0,13 ± 0,05) ab	(1,01 ± 0,65) ab	(0,46 ± 0,09) ab	(0,06 ± 0,01) ab
Benifesso	(0,14 ± 0,08) ab	(1,17 ± 0,79) abc	(0,58 ± 0,17) ab	(0,08 ± 0,03) abc
Dabavogo	(0,14 ± 0,09) ab	(1,82 ± 2,32) bc	(0,48 ± 0,17) ab	(0,08 ± 0,06) abc
Diarratchè	(0,30 ± 0,00) d	(3,02 ± 1,51) d	(0,68 ± 0,23) c	(0,15 ± 0,00) c
Gnanmandô	(0,24 ± 0,09) cd	(1,88 ± 0,98) bc	(0,87 ± 0,53) d	(0,05 ± 0,03) a
Koussanga	(0,13 ± 0,04) ab	(1,33 ± 1,01) abc	(0,34 ± 0,20) a	(0,05 ± 0,02) a
Ladjivogo	(0,18 ± 0,08) bc	(1,53 ± 0,85) abc	(0,57 ± 0,25) ab	(0,14 ± 0,05) bc
Nambigué	(0,26 ± 0,09) cd	(1,34 ± 0,67) abc	(0,48 ± 0,24) ab	(0,10 ± 0,05) abc
Nambolvogo	(0,21 ± 0,04) bc	(1,09 ± 0,40) abc	(0,37 ± 0,15) a	(0,06 ± 0,03) a
Niorornigue	(0,13 ± 0,03) ab	(1,32 ± 0,35) abc	(0,38 ± 0,04) a	(0,07 ± 0,06) abc
Ouangolo	(0,18 ± 0,07) bc	(2,27 ± 1,06) cd	(0,63 ± 0,13) bc	(0,23 ± 0,21) d
Oumarvogo	(0,21 ± 0,12) bc	(1,213 ± 0,46) abc	(0,57 ± 0,14) ab	(0,10 ± 0,03) abc
Pleuhouo	(0,18 ± 0,13) bc	(1,30 ± 0,88) abc	(0,47 ± 0,13) ab	(0,10 ± 0,04) abc
Soumailavogo	(0,31 ± 0,08) d	(2,29 ± 0,81) cd	(0,65 ± 0,17) bc	(0,10 ± 0,05) abc
Torla	(0,08 ± 0,03) a	(0,58 ± 0,20) a	(0,41 ± 0,12) ab	(0,07 ± 0,03) abc
Ddl	224	224	224	224
p	0,00**	0,00**	0,00**	0,00**
Signification	S	S	S	S
VSM	**[0,5; 0,65]**	**3,5**	**1,5**	**0,40**

Means with the same letter in the same column are not significantly different at the α <0.05 threshold, according to the Student-Newman-Keuls method; VSM = Mean Threshold Value.

Table 2. N-NH_4^+ and exchangeable base content of sub-cotton soils of the 15 sections during the 2018-2019 season

Section	N-NH_4^+ (g/kg)	Ca^{2+} (cmol/kg)	Mg^{2+}(cmol/kg)	K^+(cmol/kg)
Barrovogo	(0,19 ± 0,10) ab	(0,95 ± 0,57) a	(0,54 ± 0,19) a	(0,08 ± 0,05) a
Benifesso	(0,51 ± 0,82) b	(1,57 ± 1,46) abc	(0,58 ± 0,13) a	(0,14 ± 0,05) a
Dabavogo	(0,37 ± 0,18) ab	(1,48 ± 0,89) abc	(0,58 ± 0,26) a	(0,18 ± 0,07) a
Diarratchè	(0,21 ± 0,15) ab	(1,03 ± 0,57) a	(0,40 ± 0,13) a	(0,11 ± 0,04) a
Gnanmandô	(0,27 ± 0,13) ab	(1,72 ± 0,81) abc	(0,63 ± 0,12) a	(0,15 ± 0,12) a
Koussanga	(0,19 ± 0,13) ab	(2,05 ± 1,24) c	(0,73 ± 0,33) a	(0,16 ± 0,07) a
Ladjivogo	(0,27 ± 0,23) ab	(1,15 ± 1,48) ab	(0,50 ± 0,26) a	(0,10 ± 0,06) a
Nambigué	(0,36 ± 0,19) ab	(1,72 ± 0,87) abc	(0,59 ± 0,15) a	(0,17 ± 0,13) a
Nambolvogo	(0,19 ± 0,23) ab	(1,22 ± 1,10) abc	(0,39 ± 0,19) a	(0,12 ± 0,06) a
Niorornigue	(0,37 ± 0,12) ab	(1,03 ± 0,57) a	(0,45 ± 0,19) a	(0,18 ± 0,09) a
Ouangolo	(0,33 ± 0 ,14) ab	(1,10 ± 0,62) ab	(0,44 ± 0,09) a	(0,15 ± 0,11) a
Oumarvogo	(0,38 ± 0,20) ab	(1,93 ± 1,35) bc	(0,52 ± 0,22) a	(0,14 ± 0,08) a
Pleuhouo	(0,39 ± 0,23) ab	(1,52 ± 0,33) abc	(0,79 ± 1,24) a	(0,44 ± 0,64) b
Soumailavogo	(0,32 ± 0,12) ab	(0,90 ± 0,33) a	(0,36 ± 0,11) a	(0,11 ± 0,04) a
Torla	(0,16 ± 0,08) a	(1,32 ± 0,47) abc	(0,63 ± 0,14) a	(0,10 ± 0,08) a
Ddl	**224**	**224**	**224**	**224**
P	**0,02**	**0,02**	**0,07**	**0,00****
Signification	**S**	**S**	**NS**	**S**
VSM	**[0,5; 0,65]**	**3,5**	**1,5**	**0,40**

Means with the same letter in the same column are not significantly different at the α <0.05 threshold, according to the Student-Newman-Keuls method; VSM = Mean Threshold Value.

Table 3. $N\text{-}NH_4^+$ and exchangeable base content of sub-cotton soils of the 15 sections during the 2019-2020 season

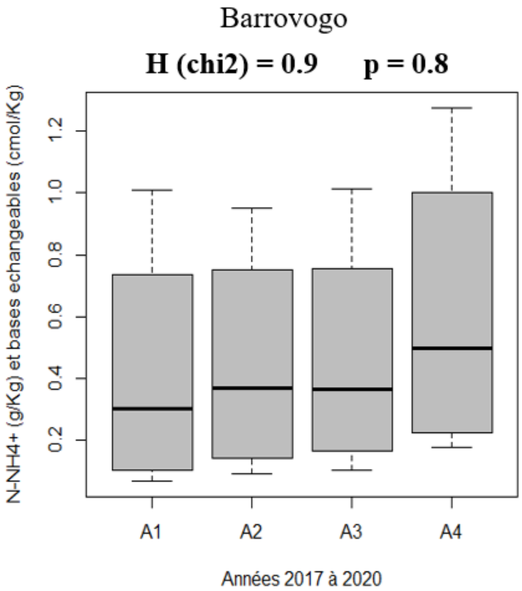
Section	$N\text{-}NH_4^+$ (g/kg)	Ca^{2+} (cmol/kg)	Mg^{2+}(cmol/kg)	K^+(cmol/kg)
Barrovogo	(0,22 ± 0,32) a	(1,01 ± 0,52) abcd	(0,50 ± 0,15) de	((0,10 ± 0,04) abc
Benifesso	(0,15 ± 0,07) a	(1,00 ± 0,57) abcd	(0,46 ± 0,15)	(0,07 ± 0,03) abc
Dabavogo	(0,21 ± 0,09) a	(0,88 ± 0,47) abc	(0,46 ± 0,19) cd cd	(0,07 ± 0,02) abc
Diarratchè	(0,15 ± 0,03) a	(0,89 ± 0,47) abc	(0,37 ± 0,14) abcd	(0,09 ± 0,02) abc
Gnanmandô	(0,16 ± 0,06) a	(1,02 ± 0,35) abcd	(0,24 ± 0,07) a	(0,07 ± 0,02) a
Koussanga	(0,16 ± 0,04) a	(0,90 ± 0,19) abc	(0,45 ± 0,11) cd	(0,09 ± 0,02) abc
Ladjivogo	(0,35 ± 0,23) b	(1,26 ± 0,51) bcd	(0,56 ± 0,23) de	(0,11 ± 0,05) bcd
Nambigué	(0,16 ± 0,04) a	(0,97 ± 0,45) abcd	(0,28 ± 0,13) abc	(0,08 ± 0,04) abc
Nambolvogo	(0,15 ± 0,03) a	(1,35 ± 0,70) cd	(0,40 ± 0,12) abcd	(0,08 ± 0,02) abc
Niorornigue	(0,19 ± 0,10) a	(0,72 ± 0,34) ab	(0,26 ± 0,14) ab	(0,06 ± 0,02) a
Ouangolo	(0,18 ± 0,07) a	(1,49 ± 0,53) d	(0,64 ± 0,24) e	(0,14 ± 0,07) d
Oumarvogo	(0,13 ± 0,03) a	(1,18 ± 0,54) abcd	(0,37 ± 0,16) abcd	(0,09 ± 0,03) abc
Pleuhouo	(0,15 ± 0,04) a	(0,88 ± 0,60) abc	(0,40 ± 0,09) abcd	(0,06 ± 0,02) a
Soumailavogo	(0,14 ± 0,09) a	(0,65 ± 0,25) a	(0,43 ± 0,19) bcd	(0,07 ± 0,02) ab
Torla	(0,21 ± 0,03) a	(0,98 ± 0,41) abcd	(0,45 ± 0,22) cd	(0,12 ± 0,02) cd
Ddl	**224**	**224**	**224**	**224**
P	**0,00****	**0,00****	**0,00****	**0,00****
Signification	**S**	**S**	**S**	**S**
VSM	**[0,5; 0,65]**	**3,5**	**1,5**	**0,40**

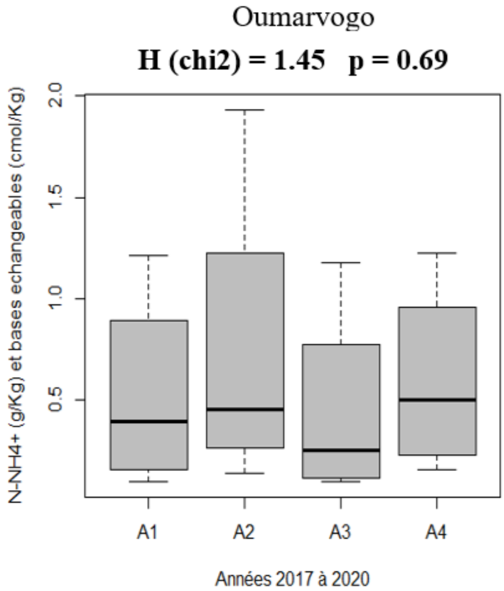
Means with the same letter in the same column are not significantly different at the α <0.05 threshold, according to the Student-Newman-Keuls method; VSM = Mean Threshold Value.

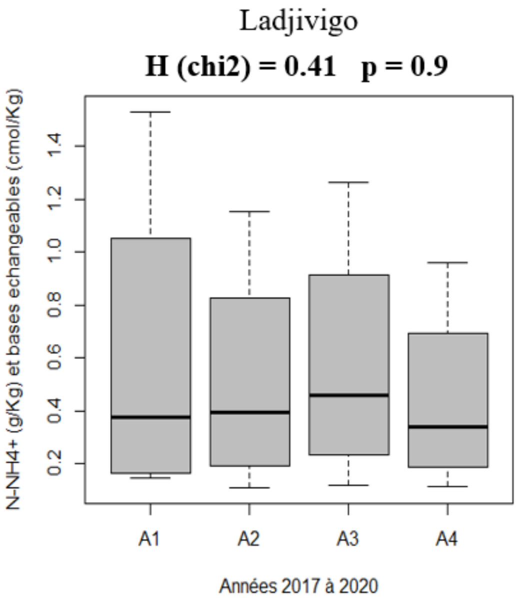
Table 4. $N\text{-}NH_4^+$ and exchangeable base content of sub-cotton soils of the 15 sections during the 2020-2021season

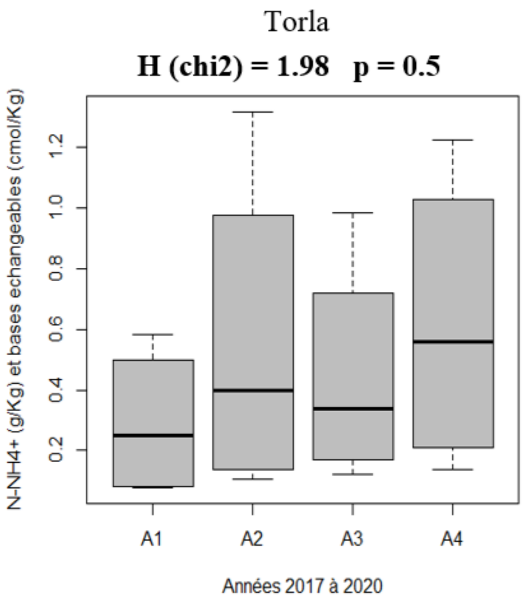
Section	$N\text{-}NH_4^+$ (g/kg)	Ca^{2+} (cmol/kg)	Mg^{2+}(cmol/kg)	K^+(cmol/kg)
Barrovogo	(0,267 ± 0,11) a	(1,27 ± 0,75) a	(0,72 ± 0,48) ab	(0,17 ± 0,22) a
Benifesso	(0,26 ± 0,05) a	(1,29 ± 0,99) a	(0,73 ± 0,34) ab	(0,08 ± 0,03) a
Dabavogo	(0,27 ± 0,07) a	(1,3 ± 1,15) a	(0,57 ± 0,43) ab	(0,09 ± 0,03) a
Diarratchè	(0,28 ± 0,07) a	(0,95 ± 0,29) a	(0,71 ± 0,33) ab	(0,07 ± 0,02) a
Gnanmandô	(0,31 ± 0,08) a	(0,93 ± 0,32) a	(0,63 ± 0,26) ab	(0,06 ± 0,02) a
Koussanga	(0,28 ± 0,04) a	(1,37 ± 0,55) a	(0,93 ± 0,22) b	(0,26 ± 0,35) a
Ladjivogo	(0,25 ± 0,10) a	(0,96 ± 0,50) a	(0,42 ± 0,21) a	(0,11 ± 0,06) a
Nambigué	(0,28 ± 0,01) a	(2,13 ± 0,86) b	(0,69 ± 0,11) ab	(0,12 ± 0,04) a
Nambolvogo	(0,22 ± 0,08) a	(1,35 ± 0,73) a	(0,69 ± 0,60) ab	(0,17 ± 0,25) a
Niorornigue	(0,24 ± 0,10) a	(1,34 ± 0,34) a	(0,86 ± 0,19) ab	(0,16 ± 0,25) a
Ouangolo	(0,29 ± 0,02) a	(1,58 ± 0,41) ab	(0,93 ± 0,31) b	(0,18 ± 0,22) a
Oumarvogo	(0,30 ± 0,16) a	(1,22 ± 0,63) a	(0,69 ± 0,60) ab	(0,15 ± 0,22) a
Pleuhouo	(0,34 ± 0,10) a	(1,59 ± 0,84) ab	(0,67 ± 0,36) ab	(0,26 ± 0,43) a
Soumailavogo	(0,24 ± 0,07) a	(1,14 ± 0,86) a	(0,67 ± 0,37) ab	(0,13 ± 0,08) a
Torla	(0,28 ± 0,04) a	(1,22 ± 0,69) a	(0,83 ± 0,34) ab	(0,13 ± 0,09) a
Ddl	**224**	**224**	**224**	**224**
P	**0,07**	**0,00**	**0,02**	**0,26**
Signification	**NS**	**S**	**S**	**NS**
VSM	**[0,5; 0,65]**	**3,5**	**1,5**	**0,40**

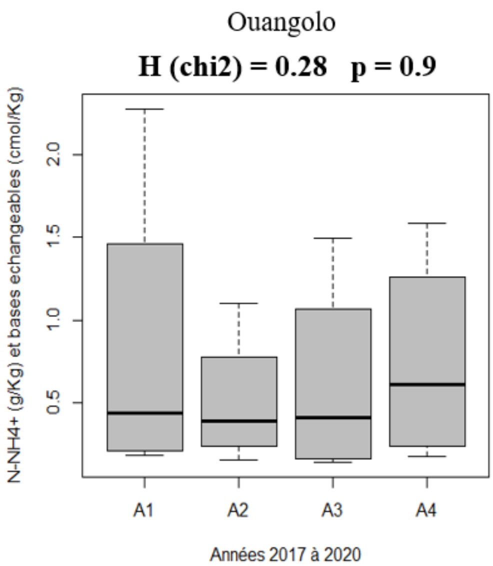
Means with the same letter in the same column are not significantly different at the α <0.05 threshold, according to the Student-Newman-Keuls method; VSM = Mean Threshold Value.

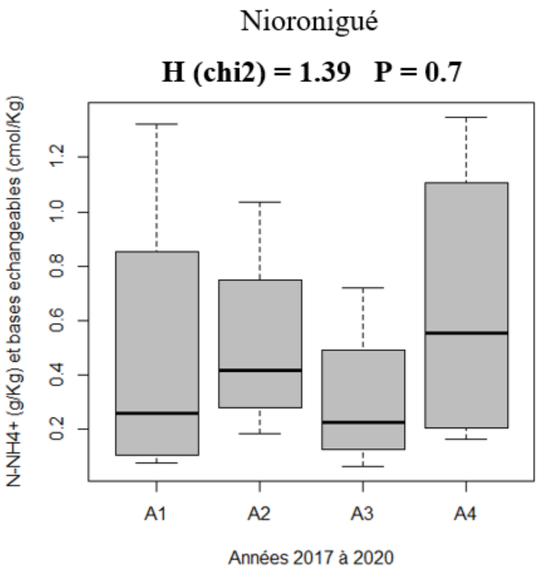

Barrovogo
H (chi2) = 0.9 p = 0.8
N-NH4+ (g/Kg) et bases echangeables (cmol/Kg)
A1
A2
A3
A4
Années 2017 à 2020

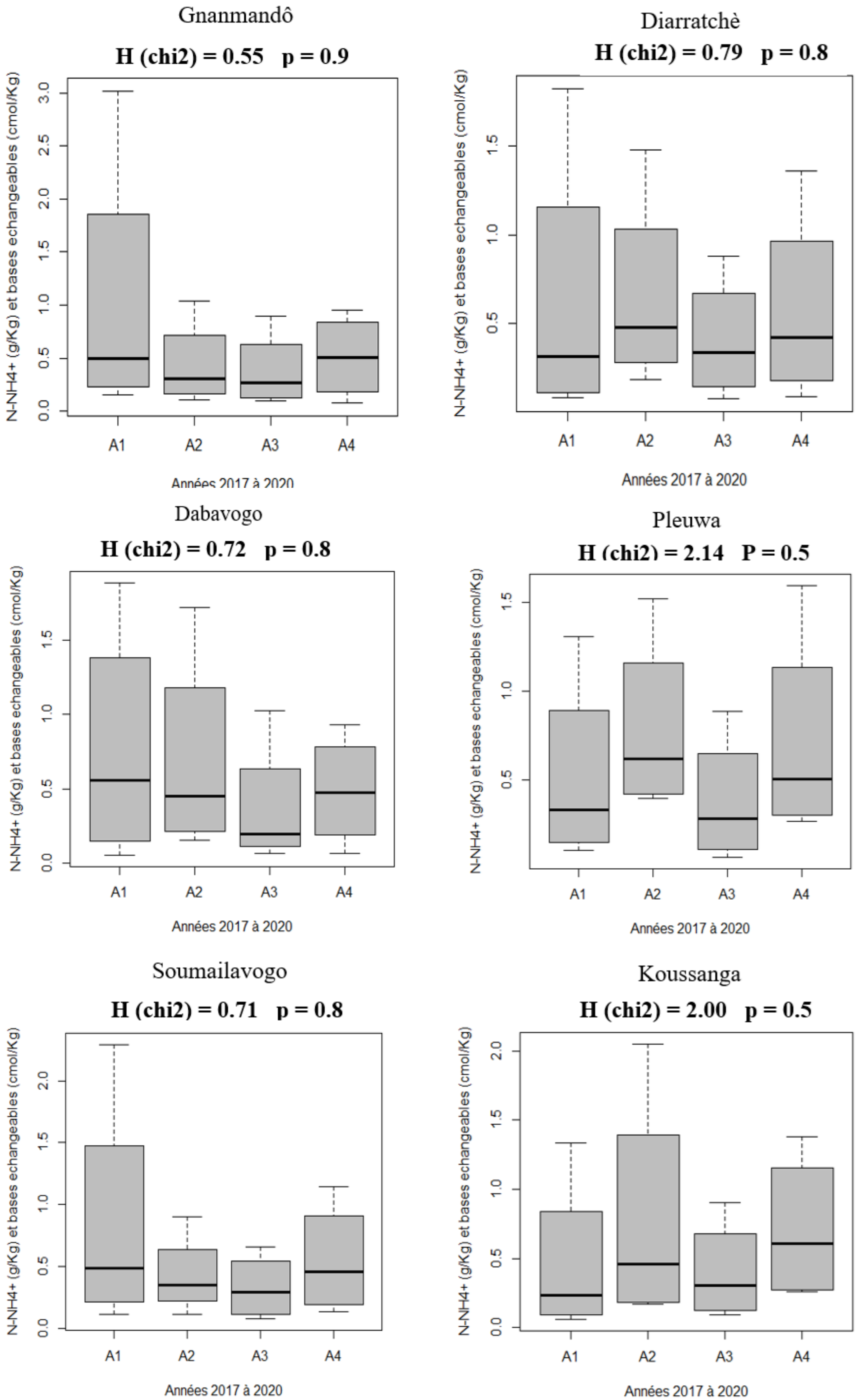

Oumarvogo
H (chi2) = 1.45 p = 0.69
N-NH4+ (g/Kg) et bases echangeables (cmol/Kg)
A1
A2
A3
A4
Années 2017 à 2020


Ladjivigo
H (chi2) = 0.41 p = 0.9
N-NH4+ (g/Kg) et bases echangeables (cmol/Kg)
A1
A2
A3
A4
Années 2017 à 2020


Torla
H (chi2) = 1.98 p = 0.5
N-NH4+ (g/Kg) et bases echangeables (cmol/Kg)
A1
A2
A3
A4
Années 2017 à 2020


Ouangolo
H (chi2) = 0.28 p = 0.9
N-NH4+ (g/Kg) et bases echangeables (cmol/Kg)
A1
A2
A3
A4
Années 2017 à 2020


Nioronigué
H (chi2) = 1.39 P = 0.7
N-NH4+ (g/Kg) et bases echangeables (cmol/Kg)
A1
A2
A3
A4
Années 2017 à 2020


Gnanmandô
H (chi2) = 0.55 p = 0.9
Diarratchè
H (chi2) = 0.79 p = 0.8
Dabavogo
H (chi2) = 0.72 p = 0.8
Pleuwa
H (chi2) = 2.14 P = 0.5
Soumailavogo
H (chi2) = 0.71 p = 0.8
Koussanga
H (chi2) = 2.00 p = 0.5
N-NH4+ (g/Kg) et bases echangeables (cmol/Kg)
A1
A2
A3
A4
Années 2017 à 2020

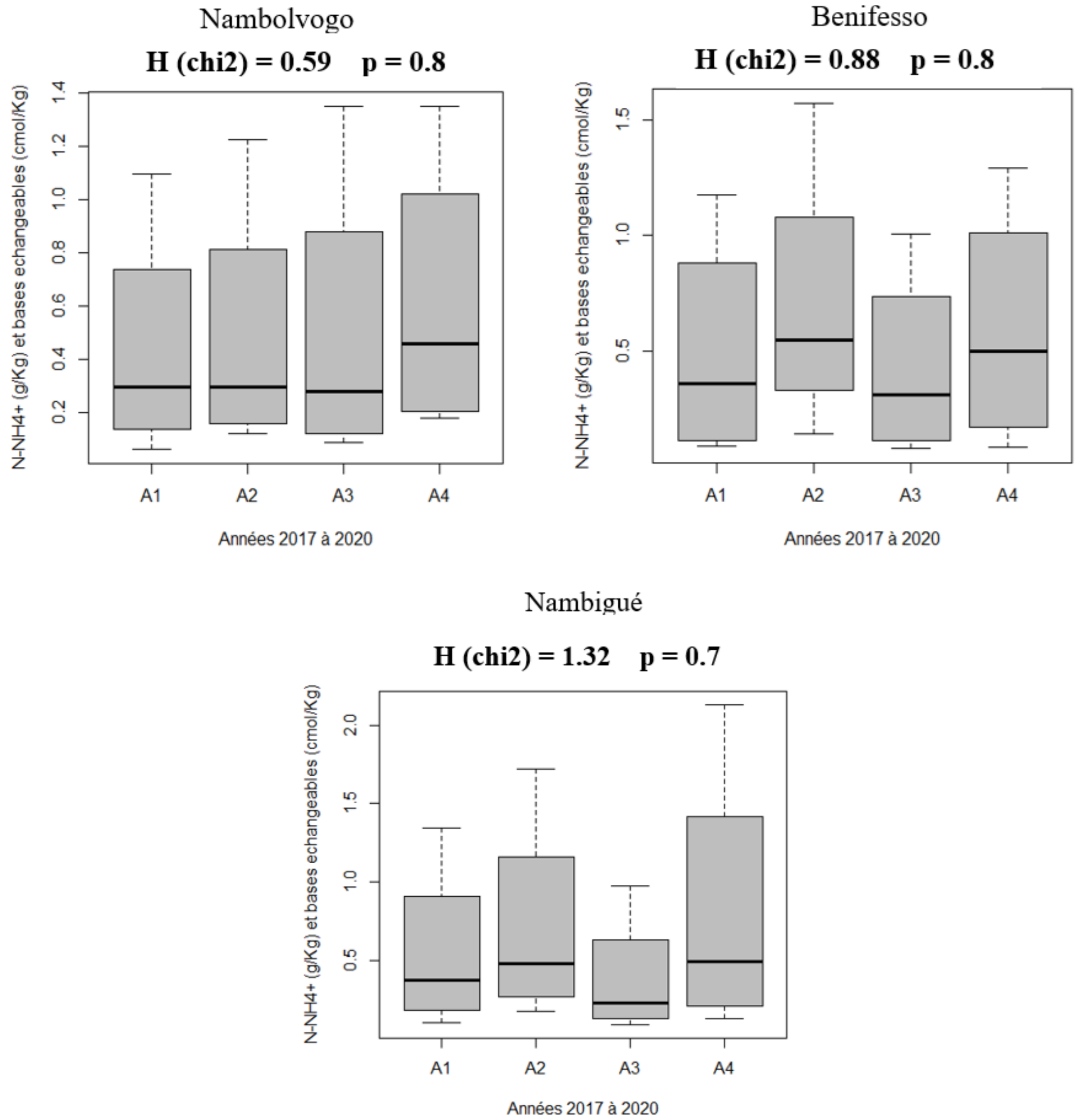


Fig. 2. Status of N-NH_4^+ and exchangeable bases in each section from 2017 to 2020

4 DISCUSSION

Nitrogen is the nutrient that guides the availability of other soil nutrients to plants. For this reason, it is referred to as the linchpin of cultivated soil fertility. It is present in the soil in several more or less stable forms, grouped into two: organic forms and mineral forms. Nitrogen is taken up by plants in the mineral forms NO_3^- (a form absorbed preferentially by the plant, but highly unstable and easily leached) and N-NH_4^+ (a form less directly absorbed by the plant, more stable than NO_3^- and transformed in the short and medium term by nitrifying bacteria in the soil into NO_3^- bioavailable to the plant). It is through the mineralisation process that organic nitrogen is transformed into mineral nitrogen that can be absorbed by plants. The estimation of N-NH_4^+ in the soil predicts the availability of other nutrients, enabling us to assess the chemical fertility of the soil. In view of the results recorded, the N-NH_4^+ content of the 15 sections from 2017 to 2020 is below the values corresponding to fertile soil, which is [0.5; 0.65] g/kg N-$NH_4^{+,}$ as emphasised by (Van der Pol F., 1992; Tie 1995). This shows an imbalance due to a lack of nitrogen in the soils under cotton in the 15 sections. These conditions of the soils under cotton in the 15 sections over these 4 successive years are largely attributable to the management methods of these soils (Kate et al., 2016). These low levels indicate that the soils under cotton in the 15 localities are poor. This nutrient poverty is evidence of soil overexploitation (Emmanuel et al., 2018). This overexploitation is the result of intensive cotton-growing, increased land pressure and an increase in the amount of land sown per farm, encouraged by the introduction of mechanisation (Valérie 2005). The use of ploughs can cause losses in mineral elements such as $Ca^{2+,}$ $Mg^{2+,}$ and $K^{+,}$ resulting in a reduction in exchangeable bases (Boyer, 1977), which could explain the exchangeable base levels below the threshold values obtained during these 4 years of study. These losses in mineral elements such as $Ca^{2+,}$ $Mg^{2+,}$ and K^+ can reach 50 to 60% after 15 years of mechanised cultivation, as pointed out by (Boyer, 1977). Deep ploughing breaks up the soil to a depth of 20-25 cm, which accelerates the leaching of nutrients and can sterilise the soil after only two or three cropping seasons (Charrière, 1984). These low levels of exchangeable bases in soils under cotton could be explained by the absence of fallow and the monoculture of cotton in the various sections (N'goran et al., 2015; Fagaye et al., 2015).

5 Conclusion

The aim of this study was to assess the availability of exchangeable bases and the N-NH_4^+ factor in the 15 cotton production sections in the Ouangolodougou department. The results showed that levels varied significantly over 4 successive years. Statistical analysis showed that the levels of N-NH_4^+ and exchangeable bases ($Ca^{2+,}$ $Mg^{2+,}$ K^+) were below threshold values. To improve the poor fertility of soils under cotton, chemical fertilisers must be used rationally, while respecting the fertiliser doses prescribed after soil analysis, and the soil must be enriched with organic amendments such as compost, bokashi and biochar.

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