Soil fertility assessment in Tibetan villages in relation to the human Kashin-Beck disease

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Abstract
This research on the Tibetan Plateau near Lhassa was performed on request of the Kashin-Beck Disease Foundation (KBDF). Four Kashin-Beck disease (KBD) affected villages with and without KBD-affected families and one non-KBD-affected village were surveyed to assess if soil type and topsoil fertility are related to the KBD occurrence and more especially if a soil selenium (Se) deficiency is a predisposing factor. Fifty-seven fields were selected and a total of 114 soil samples were analysed for the following measurements: pH_{water} and pH_{KCl}, particle size distribution, total carbonates, total organic carbon, total nitrogen, cation exchange capacity, exchangeable (Na, K, Mg, Ca), available (K, Mg, Ca, P, Mn, Cu, Zn) and total (Na, K, Mg, Ca, Fe, Al, Mn, Cu, Zn, Ni, Cr, Cd and Se) elements. Soils are mainly Leptosols and Regosols. Comparing KBD and non-KBD family fields within the same KBD village, nothing can be deduced but the risk of Se deficiency seems higher in KBD villages than in the control village where the total Se content is four times higher. It is concluded that the diagnosis depends not only on soil types but also on their pedogeochemical backgrounds and that soil parent materials have to be more completely characterized.

Key Words
Human big bone disease, geomorphopedology, agropedology, vernacular soil qualification, WRB qualification.

Introduction
Kashin-Beck Disease is an endemic osteochondropathy primarily affecting children. More than 30 million people live in areas where the disease is endemic. The unknown aetiology of the disease represents a continuing challenge to medical and agro-environmental sciences. Currently, it is possible to identify a few predisposing factors, such as a mountain environment, Se deficiency, poor nutrition, a high concentration of organic matter in drinking water, and contamination of barley grain by fungi-producing mycotoxins (Malaisse *et al.* 2001). In a context where environmental factors and agricultural practices seem to affect the incidence of KBD, the aim of this contribution was in 2007 to identify the main soil characteristics and to assess the topsoil fertility of cultivated fields in southern Tibet (Lhassa region). Similar results were first presented in the 24th Triennal World Congress of the "Société internationale de chirurgie orthopédique et de traumatologie (SICOT)" – Hong Kong, 24-28 August 2008 – Kashin Beck Disease Symposium, 25 August 2008.

Methodology
At field level
In four KBDF-monitored villages, on the basis of a quick soil-relief survey by augering (down to 120 cm if possible) and from farmer's answers to a questionnaire, 2 soil samples, one composite in topsoil and one in subsoil, have been taken in 3 fields of 2 KBD-affected families (Randomised Clinical Trial list) and of 2 non-KBD-affected families. A similar strategy was conducted in a non-KBD-affected village but the sampling targeted only 3 families. In this way, 57 fields have been selected and a total of 114 samples collected.

Soil analysis
The following analyses and methods have been performed:
- pH_{water} and $pH_{KCl.1n}$ at 2/5,
- particle size analysis by chain hydrometer measurement after H_2O_2, HCl 0.2n, HCl 4n if needed and Na-hexametaphosphate treatments,
- total carbonates by 0,1n. sulfuric acid in double boiler and titration,

- total organic carbon by modified Springer Klee (controlled warming of the potassium dichromate – sulfuric acid reaction),
- total nitrogen by macro-Kjeldahl,
- cation exchange capacity and exchangeable Na, K, Mg and Ca with 1n. ammonium acetate at pH 7 by shaking, centrifugation and distillation,
- available K, Mg, Ca, Mn, Cu, Zn and P with 0.5n ammonium acetate + EDTA at pH 4.65,
- total Na, K, Mg, Ca, Fe, Al, Mn, Zn, Cu and Ni contents by tri-acid mineralization (HF 48 %, $HClO_4$ 70 % and HCl 10 %),
- and total Se, Cr and Cd contents by HNO_3 65 % and HCl 37 %.

Village location and physical context

The four villages monitored by KBDF are located north of the High Brahmaputra River (Yarlung Tsangpo in Tibetan) in the geological Tibetan block and the non-KBD-affected village is located south of the river in the geological Himalayan block. Effectively, the river flowing from west to east seems to underline relatively well the southern limit of the disease extension. The characteristics of the villages are as follows:

* Tsingda (4,200 m asl) and Wapuk (4,000 m) in Pondo county, ~ 60 km north east of Lhassa, along the Reting Tsangpo, as representative of a volcano-sedimentary geology and semi-nomad tradition (yak breeding). Fields are mainly distributed on old glacio-fluvial surfaces highly perched above the present riverbed, on foothill colluviums or on alluvial fan materials.

* Sheu (4,100 m) and Lume (3,850 m) in Nyemo county, ~ 90 km south west of Lhassa, along a tributary (flowing north-south inside a graben) of the Yarlung Tsangpo, as representative of a granitic context and a more sedentary farming tradition. Fields are mainly distributed on colluviums or partly on glacio-fluvial/alluvial deposits in valley plain.

* Targye (4,000 m) in Rinbung county, ~ 130 km south east of Lhassa, as representative of a sedimentary context and of a semi-nomad tradition but also as a non-KBD reference village. Fields are distributed on coarse alluvial fan materials, on colluviums or on alluviums (alluvial terraces and valley plain).

Results

Field observations

In this context of highlands, the cold semi-arid climatic conditions seem to be a little more severe in Tsingda where cracks and broken stones due to frost at the soil surface and cryoturbation features in a talus have been observed. Most fields present a slope < 10 % or even less, except some steep fields on colluvium (20-40 % slope). Soils are: (i) brownish black to dull yellow orange but frequently paler in topsoil than in subsoil, (ii) 15/20 cm (in Targye) to ~ 60 centimetres thick and (iii) slightly stony (< 15%) to stony (in Targye). As evidence of land improvement, removal and piling up of stones, man-made terraces, (old) irrigation channels (except in Tsingda) and levees along the main river (Targye) were observed. Calcrete mined out for wall whitewhashing (Wapuk), loamy soil mined out for bricks (Wapuk) and charcoal remains (Sheu, Lume) in soil are other anthropic features.

Soil analysis (0-20 cm)

The pH_{water} values are never below 6.1 and frequently between 6.9 and 8.2 but in any case, the total carbonate content was ≤ 1.8 %; the most "acid" conditions occurred in Tsingda and Wapuk. According to the FAO diagram, the soil texture corresponds to (i) loamy sand/sandy loam in Sheu, (ii) sandy loam/loam in Lume and Targye, and (iii) loam in Tsingda and Wapuk; the cumulative particle size curves of Wapuk showing a S shape (suggesting aeolian material) and of Targye, a rectilinear shape typical of an *in situ* weathering. The total organic carbon and total nitrogen contents ranged between 0.8-3.9 % and 0.07-0.34 %, respectively with the highest values in Tsingda. C/N ratios were between 8.0 and 13.5. The cation exchange capacity (CEC) measurements ranged between 8.5 and 20.8 $cmol_c$/kg; the highest values corresponding to the higher carbon contents (Tsingda) and the lowest to the loamy sand texture (Sheu). Considering the texture, the CEC values suggest that clays had a relatively high activity. Moreover according to the pH values, the base saturation ratios were frequently higher than 80 % or reaching 100 %. Exchangeable Ca and Mg represent frequently more than 70 and 8 %, respectively, of the CEC; on the other hand, the exchangeable K percentage was frequently too low inducing a too high Mg/K ratio. Available Cu, Zn or even K (for 3 villages) contents were low and available P content was relatively satisfactory in Tsingda and

Wapuk, higher in the 3 other villages, or even sometimes excessive. The potassium total content with ~ 2,500 mg/100g DM was always far higher than those of Na, Mg and Ca but Sheu and Lume showed the higher contents of Na and Ca. The lowest total contents of Fe, Al, Mn, Cu, Zn, Ni, Cr, Cd and Se were obtained for Sheu and its sandier texture, the highest ones of Fe and Cu for Lume and Targye and their loamier texture, and that of Cd with 0.2 mg/kg DM for Tsingda and its higher organic content. But if the total contents of Ni, Cr and Se were similar in Tsingda, Wapuk and Lume, the highest Ni and Se total contents were observed in Targye with 40,0 and 0.2 mg/kg DM respectively; this Se value in Targye being four times higher than in other villages.

Discussion

Pedological diagnosis

A range of indicators attest a prevalence of weakly developed soils in the study area, viz: (very) shallow and (very) stony in certain places (especially in Targye); more or less sandy (Sheu) to loamy (Wapuk); slightly acid (Tsingda and Wapuk) to neutral or even alkaline; mainly base saturated; relatively variable in their organic content but with a satisfactory index of mineralization, and consequently showing a certain capacity to adsorb and delivery nutrients to soil solution.

According to the FAO World Reference Base (WRB), they are mainly:

* Skeletic ((if not Hyper) Leptosols (Hypereutric) in Targye
* Colluvic Regosols (Eutric if not Hyper) in the other villages, (Skeletic) in some places, (Humic) namely in Tsingda and (Arenic) in Sheu.

Some Cambisols (in Wapuk) and Fluvisols could be also part of this context. However, soil depth and stoniness influence greatly the soil volume for roots and its fine earth percentage and thus the real soil element contents. Moreover, fertility is not only a question of element quantity but also of nutrient availability in well-balanced proportions (e.g. generally soils had an excessive exchangeable Mg/K ratio); availability depending also on pH (e.g. some Fe and P deficiency risks exist when pH is > 7.5. Thus, climatic conditions seem more severe in Tsingda (highest altitude, most northern location, at the confluence of two windy valleys), physical constraints including probably water supply dominate in Targye and chemical constraints, if any, would be most probable in Sheu.

Farmer's assessment and KBD versus non-KBD family field comparison

Farmers in each study area use vernacular expressions to qualify high, medium and low soil suitability. Except for K, the fertility estimation by farmers corresponds very well to the available element assessment in Tsingda, Wapuk and Lume. This comparison is not so conclusive in Sheu where soils were sandier and in Targye where soils were shallower and stonier. But due to the small size of the plots and unit conversion problems, information about yields is difficult to assess; that obtained for barley range between 0,77 t/ha in Lume and (the overestimated) 5,9 t/ha in Sheu… the average FAO reference being 2,7 t/ha. Comparing KBD and non-KBD family fields, nothing can be deduced from total element and available element measurements. Therefore, considering that ~ 0.10 mg/kg DM of available Se can represent a possible limit of excess (Dhillon and Dhillon 2003) and that the soluble form of Se can be very depleted in slightly acid to neutral soils, it is assumed that the risk of Se deficiency, with a total Se content < 0.05 mg/kg DM, is effectively higher in the four KBD-monitored villages located north of the High Brahmaputra river than in Targye located south of the river where the total Se content is ~ 0.20 mg/kg DM and pH frequently > 7.5. Moreover, if Deckers and Steinnes (2004) in their review suggest that KBD is more prevalent in the eroded hills where Regosols and Leptosols dominate the landscape, this appraisal with Master student contributions shows the importance to take into account the influence of the pedogeochemical background and the need to build local land information systems integrating the rock-relief-soil-land use relations in view to practice a more operational pedology (Bock 2002) in terms of land use planning, personalized advice, product quality, agro-environmental sustainability and finally of food chain security and human health.

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