Partial Rejuvenation of the Soil in Intavas Techno Demo Farm, Bukidnon, Mindanao, Philippines by Volcanic Ash Material

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Keywords : Philippine soils, Oxic Dystrudepts, tephra, volcanic glass, halloysite, gibbsite, dark and high humus surface

Abstract

Intavas Techno Demo Farm is situated in high elevation of 1,220 meters above sea level, with cool temperature and without pronounced dry season. The soil has low pH (5.24, average) and medium total carbon (4.3%) in the surface. Phosphorus retention is relatively high (77.5 %, ave.), low cation exchange capacity (12 cmol(+) kg^{-1} ave.) and low base saturation (13 %, ave.). Clay content is 45% (ave.) and bulk density of 1.1 Mg m^{-3} in average.

Micrograph of the thin section of Bw_1 horizon reveals that void content is very small (6%). Voids are vughy and are not interconnected. In crossed nicol there were no clay illuviation seen.

Total element analysis revealed that Intavas soils have about 60 % Al_2O_3 but very low in SiO_2, 16.05 % only. This indicates an advanced weathering that Si has been leached out and Al precipitated.

As to the primary minerals, opaque minerals predominate with the presence of hornblende in heavy minerals. For light minerals, weathered particles predominate with the presence of mica, quartz and volcanic glass.

Selective dissolution analysis reveals that Al_o is relatively high as compared to Fe_o and Si_o. However, these elements have the same pattern that irregularly decrease with depth and increase in the buried A horizon. Fe_p is relatively high followed by Al_p that significantly decreases with depth. The data show that amorphous materials are higher in surface and buried A horizons.

Electron micrograph of BA shows no defined form that can be considered as amorphous materials. Bw_2 shows angular shapes that correspond to gibbsites and halloysite as indicated by spheroid configurations.

X–ray diffraction pattern exhibits small and weak peak at 7 Å in BA horizon. This peak corresponds to the presence of halloysite. The sharp and strong peaks at 4.8 Å and 4.3 Å in BA and Bw_2 horizons correspond to gibbsite.

According to the selective dissolution analysis, electron microscopy and X–ray diffraction analysis, the dominant clay mineral in BA horizon is gibbsite and followed by amorphous material and small amount of halloysite. On the other hand, gibbsite dominate Bw_2 horizon followed by halloysite.

Based on the physical, chemical, mineralogical and thin section analyses, the TDF soil can be classified as fine clayey, acid, isothermic, gibbsittic, Oxic Dystrudepts. It can be considered as soil with partial rejuvenation by volcanic ash material. As compared with soils without rejuvenation, this soil has higher total carbon, phosphorus retention, lower bulk density relatively, high amorphous materials in the surface and halloysite in the subsoils.

Introduction

In agricultural lands, considerable areas have been converted to non–agriculture prompting agriculture to shift to sloping to steep marginal areas. To cope up with the increasing population but diminishing land resources for food security, these marginal lands must be surveyed and evaluated. There is a need to understand the characteristics, genesis and classification of these soils in order to obtain basic information for soil utilization and management. Corollary to this, the Bureau of Soils and Water Management (BSWM) of the Department of Agriculture implemented the Environmental and Productivity Management of Marginal Soils in the Philippines (EPMMA) through Technology

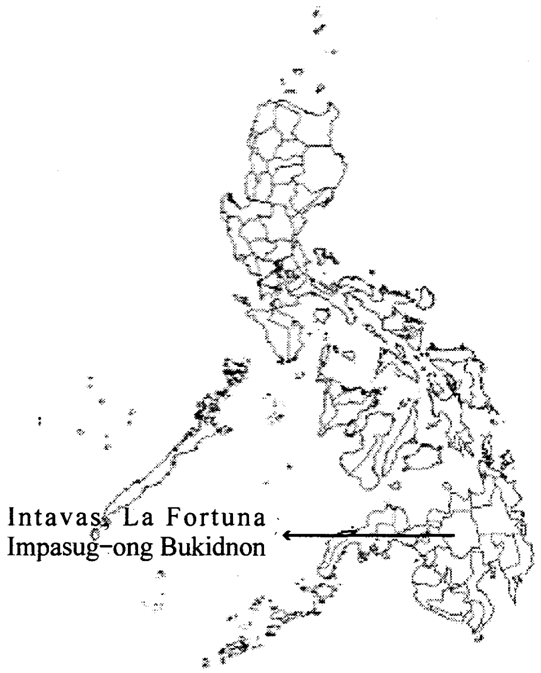


Fig. 1. IntavasTechno Demo Site

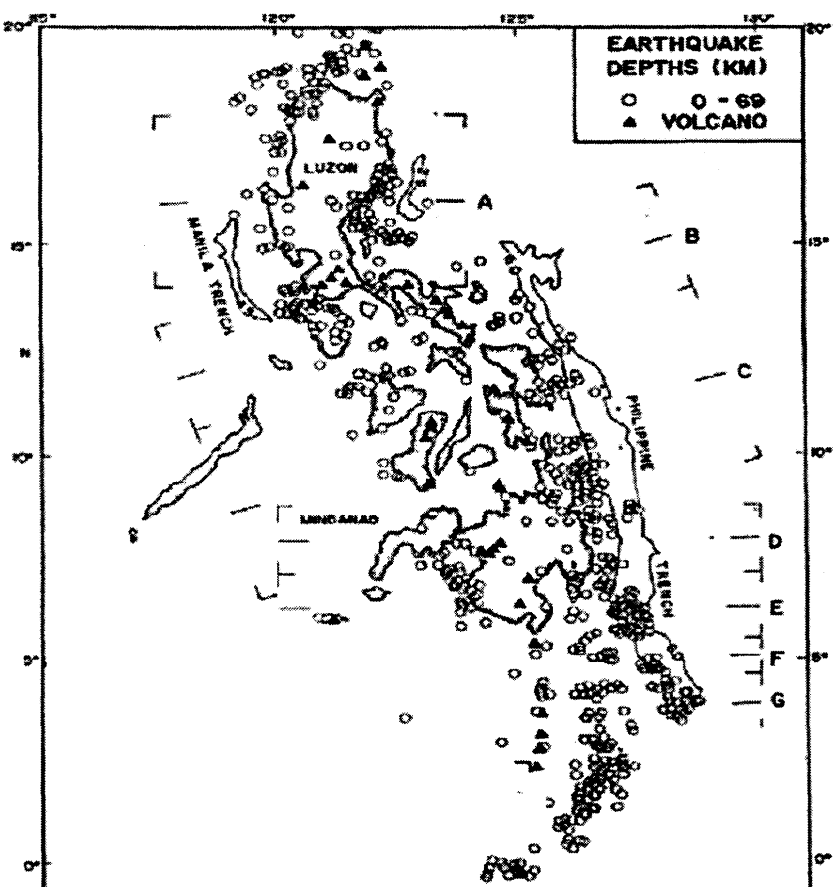


Fig. 2. Distribution of Volcanoes in the Philippines

Demonstration Farms (TDFs). This is a cooperation project between the governments of Japan and the Philippines under the auspices of Japan International Cooperation Agency (JICA) starting February 2000 to January 2005.

The EPMMA TDF sites were selected to represent the pedo-ecological zones where marginal soils are most likely to occur, namely : upland represented by Bulusukan TDF in San Ildefonso, Bulacan, hillyland by Agoho TDF in Sampalok, Tanay, Rizal and highland by Intavas TDF in La Fortuna, Impasug-ong, Bukidnon.

The Intavas TDF soil is characterized by dark and relatively deep surface like volcanic ash soil, but this is classified as Typic Hapludults by profile observation. In this study, the mineralogical, physical and chemical properties of Intavas TDF soil were investigated for an environmentally sound management in the highlands (Fig. 1).

The Philippine Archipelago belongs to the Circum-Pacific Volcanic Zone, otherwise known as "ring of fire". There are about 35 known volcanoes, nine of which are active (Fig. 2). Mariano (1964) and Otsuka (1988) reported that Andepts are present around Mt. Banahaw and the Taal volcano, Mts. Isarog and Mayon in Southern Luzon, some parts of Negros Island in the Visayan Region and in Cotabato plain in Mindanao island. Though there were findings of the wide existence of volcanic soils, only few studies on the physico-chemical and mineralogical properties, genesis and classification had been conducted in Mindanao Islands. Therefore, only a limited data are available.

Materials and Methods

Site characterization

Intavas Techno Demo Farm represents the pedo-ecological zone in the highland in Barangay La Fortuna, Municipality of Impasug-ong, Province of Bukidnon, Mindanao Island (Figure 1) with an elevation of 1,220 meters above sea level. The TDF falls under Type IV climate characterized by evenly distributed rain throughout the year with annual rainfall of 2,590 mm. Parent material is dominantly diorite and formerly vegetated with grasses and shrubs.

Morphological description

The pit profile and auger boring were described using the FAO Manual.

Methods of Analysis

Particle size distribution

Silt and clay were measured by pipette method. Fine (0.2-0.02 mm) and coarse sands (2-0.2mm, International method) were separated by wet sieving method.

Bulk density

100 ml core method was done.

Thin Sections

The core sample from Bw1 horizon of the TDF where the increase in clay was most likely to be found was collected. The sample was impregnated with polyster resin and benzoil peroxide in a vacuum container and heated in an oven until the consolidation was completed. Thin section cutting across the samples was prepared to see the occurrence of translocated or illuviated clay within the profiles in the form of coatings on ped faces or in pores.

pH (H_2O)

The supernatant suspension of a 1 : 2.5 soil liquid mixture of distilled water was immersed by electrode in the upper part of the suspension.

Total Carbon and Total N

N-C elemental analyzer measured total Carbon and Nitrogen of ground 10 to 15 mg samples.

Phosphorus retention

Phosphorus retention was done by Blakemore method.

Exchangeable cations (Ca, Mg. Na and K) and Cation Exchange Capacity (CEC)

Exchangeable cations, base saturation and cation exchange capacity were determined semi-micro Schollenberger method (Kamewada, 1997). Ca and Mg were done by ICP while K and Na were determined by AAS.

Total Elements

Total elemental composition (SiO_2, Al_2O_3, Fe_2O_3, TiO_2, MnO, CaO, MgO, K_2O, Na_2O and P_2O_5) was analyzed by X-ray Fluorescence.

Primary minerals

Light and heavy minerals of 0.1 to 0.2 mm fractions were separated by using heavy solution, TBE with a specific gravity of 2.97. The composition of these heavy and light primary minerals was determined by polarized microscope by counting about 200 particles.

Clay mineralogy

Selective dissolution

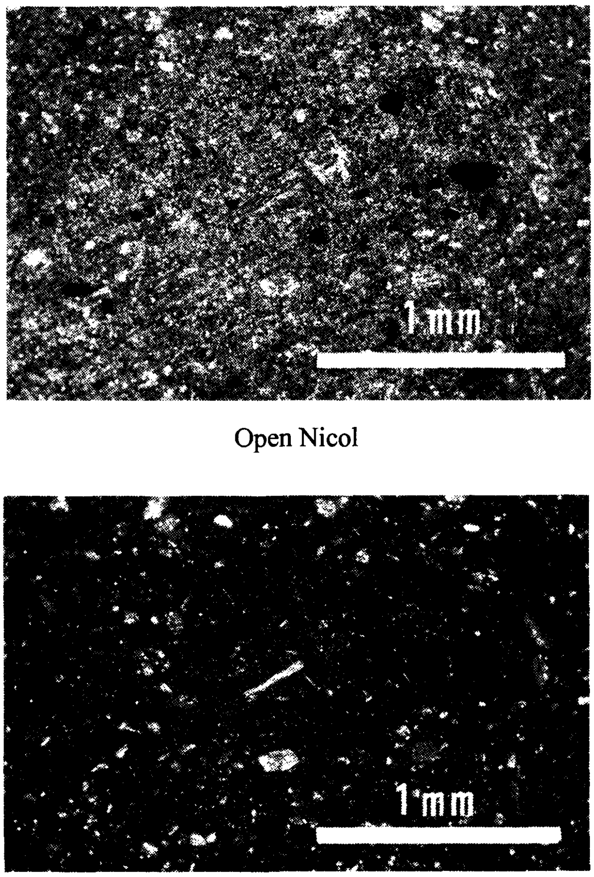
Extractable Silicon, Aluminum, and Iron elements were determined by Dithionite- citrate (Blakemore, et.al), Pyrophosphate and Acid oxalate Reagents and Inductively Coupled Plasma- Atomic Emission Spectroscopy (ICP-AES).

Electron Microscopy

Sodium clays of the samples from the BA and Bw2 horizons where decrease and increase of clay occur were analyzed through electron microscopy.

X-ray Diffraction

Clay minerals were determined using a Rigaku Geigerflex with a Cu-K a radiation of 40 and 35mA, with a scan speed of $2^0 \mathrm{min}^{-1}$



Open Nicol

Closed Nicol

Fig. 3 Micrographs of Thin Section of Bw1 horizon.

Results and Discussions

Morphological Characteristics of Intavas Profile

Table 1 shows the morphological characteristics of Intavas soil. The description indicates that the profile is very deep, dark surface that becomes lighter in the lower horizons but darker in the last horizon. Texture is fine loamy that is heavier in the fourth and fifth horizons and lighter in the last horizon with soil consistency that is slightly sticky and plastic. The structure is weak all throughout the profile suggesting good root penetration and good tilth. Only few to none moderately weathered gravel sized fragments are present in the first to fifth horizons. However, these gravels increase in the last horizon.

Table 1. Morphological Characteristics of Intavas TDF soil (Costelo, et al, 2000).

Horizon Symbol.	Depth (cm)	Description
Ap	0-16	Brownish black (10YR3/2) moist; clay loam; weak fine subangular Blocky and granular structure; slighty sticky, slightly plastic; common fine to very fine and few medium pores; no cutans; few fine slightly weathered gravels (5YR 3/6 in soil and 5YR 4/1 surface) abrupt smooth boundary; Yamaha hardness, 20 mm;
BA	16-37	Yellowish brown (10YR 5/8) moist; clay loam; weak fine subangular blocky structure; slightly sticky; slightly plastic; common fine to very fine pores; no cutans few fine roots; diffuse smooth boundary; Yamaha hardness, 24 mm.
Bw1	37-64	Yellowish brown (10YR 5/8) moist; clay loam, weak medium subangular blocky structure; slightly sticky, slightly plastic, no cutans, common fine to very fine pores; few moderately weathered diffused smooth gravels (2 cm); very few fine roots; boundary; Yamaha hardness 22 mm.
Bw2	64-98	Yellowish brown (10YR 5/6) moist; clay; moderately weak coarse subangular blocky structure; slightly sticky, slightly plastic; no mottles; no cutans; common fine to very fine pores; few moderately weathered gravels (5-6 cm); no roots; diffused smooth boundary; Yamaha hardness, 21 mm.
BC1	98-117	Yellowish brown (10YR 5/6) moist; clay; weak coarse sub angular blocky structure; slightly sticky, slightly plastic, no cutans; common fine to very fine pores; no gravels; no roots; diffused, smooth boundary; Yamaha hardness, 22 mm.
BC2	117-150	Yellowish brown (10YR 5/6) moist, clay loam; weak fine to medium sub angular blocky structure; slightly sticky, slightly plastic, many very fine and few fine pores; no roots; many moderately weathered gravels (9-1cm);Yamanaka hardness, 19mm

Table 2. Physical, Chemical and Extractable Si, Al and Fe and Total Elements

Soil Characteristics	Horizons					
	Ap	BA	Bwl	Bw2	BC1	BC2
1. Particle size distribution (mm)						
2.0 - 0.2	9.8	10.6	7.5	2.2	3.1	6.2
0.2 - 0.02	20.0	29.7	21.2	11.2	16.6	33.9
0.02 - 0.002	29.7	28.6	21.9	22.4	27.5	26.5
<0.002	40.5	31.1	49.4	64.3	52.8	33.4
2. Bulk Density (g/m^3)	0.85	1.18	1.12	1.06	1.18	1.06
3. pH (H_2O)	5.0	5.6	5.4	5.0	4.8	5.4
4. Total Carbon (%)	4.31	1.73	1.09	0.43	0.57	1.27
5. Total Nitrogen (%)	0.35	0.12	0.1	0.06	0.07	0.15
6. Phosphorus retention (%)	78	75	75	67	58	76
7. Exchangeable bases (cmol/kg)						
Ca	1.42	0.19	0.14	0.48	0.31	0.2
Mg	0.1	0.04	0.03	0.06	0.05	0.03
K	0.21	0.05	0.09	0.15	0.17	0.13
Na	0.1	0.04	0.01	0.04	0.04	0.03
8.Cation Exchange Capacity (cmol/kg)	17.3	9.2	7.4	10.2	11.1	9.5
9. Base saturation (%)	11	3	3	7	5	4
10. Extractable Al, Fe & Si (%) by Acid Oxalate						
Si	0.28	0.46	0.24	0.07	0.06	0.58
Al	0.98	1	0.52	0.22	0.21	1.02
Fe	0.88	0.7	0.42	0.34	0.41	0.51
by Pyrophosphate						
Si	0.08	0.07	0.03	0.02	0.02	0.04
Al	0.61	0.25	0.19	0.05	0.07	0.15
Fe	1.13	0.46	0.46	0.02	0.09	0.09
11. Total Element(%)						
SiO_2	21.92	11.55	11.43	17.04	17.89	16.2
Al_2O_3	56.35	62.65	62.92	58.01	57.26	58.2
Fe_2O_3	17.87	22.05	22.16	21.86	21.04	21.11
TiO_2	1.99	2.43	2.48	2.39	2.32	2.33
Others (MnO, CaO, MgO, K_2O, Na_2O and P_2O_5)	1.88	1.33	1.02	0.71	1.49	2.16
Sum	100.0	100.0	100.0	100.0	100.0	100.0

Physical and Chemical Characteristics

Table 2 shows that the soil profile described has fine loamy textures in the 1st and 2nd horizons, clayey in the 3rd to 5th horizon and back to fine loamy in the last horizon. Soil reaction ranges from strongly to slightly acidic. Bulk density is relatively low, ranging from 0.85 to 1.18 gm/m^3. Total carbon of the surface horizon is high (4.3%) that irregularly decreases with depth as it increases in the last horizon. Phosphorus retention is relatively high (78%) that irregularly decreases with depth as it increases in the last horizon. Exchangeable bases (Ca, Mg, K and Na) are deficient in all horizons. Cation exchange capacity ranging from 7.4 to 17.3 cmol kg^{-1} is low to very low and so with base saturation ranging from 3 to 11%.

Thin section

The micrographs of Bw1 horizon TDF in Figure 3 show that there is small void content of 6%. Microstructures are vughy and are not interconnected . No clay accumulation can be observed in closed nicol. The climatic condition in Intavas TDF, characterized by rain throughout the year retarded clay illuviation and ped development.

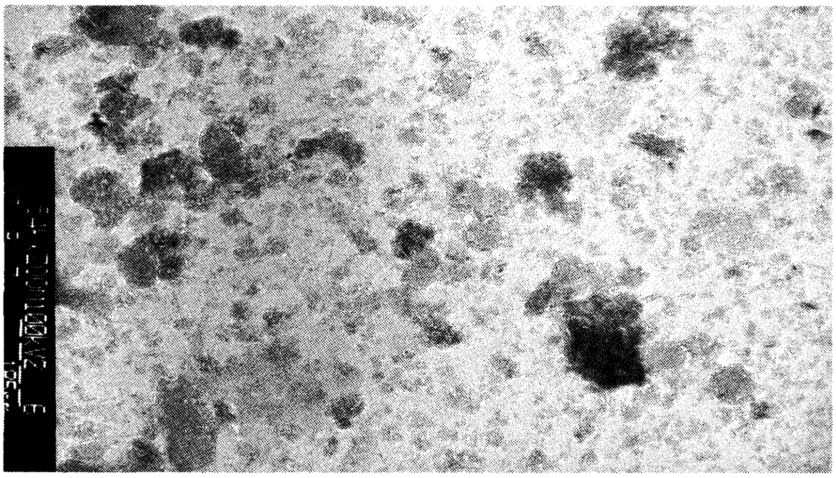
Extractable Si, Al and Fe

Table 2 shows that Al_o is relatively higher as compared to Fe_o and Si_o. However, these elements have the same pattern that irregularly decrease with depth and increase in the last horizon. Fe_p is relatively high followed by Al_p that irregularly decreases with depth as it also increases in the last

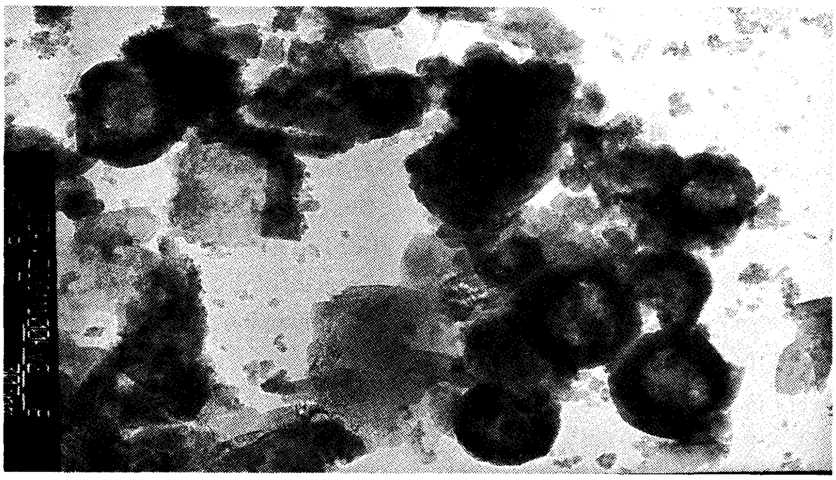
Table 3. Primary Mineral Composition

Soil Profile		Heavy minerals (particle %)[1]					Light minerals (particle %)[2]					HM[3]
		Opx	Cpx	Ho	Op	Wp	Fd	Qz	Mica	Vg	Wp	(wt%)
Intavas	Ap	–	1	64	33	1	2	17	3	3	76	16
	BA	–	–	33	66	1	–	1	3	1	95	13
	Bw_1	1	1	13	57	28	2	2	3	1	93	19
	Bw_2	–	–	4	95	2	1	9	3	1	85	30
	BC_1	–	1	13	86	1	–	1	6	2	91	34
	BC_2	–	1	37	60	2	–	6	17	1	76	20

Note :
[1] Opx : orthopyroxene, Cpx : Clinopyroxene, Ho : Hornblende, Op : Opaque mineral, Wp : weathered mineral
[2] Fd : Feldspar, Qz : Quatz, Mica : Mica, Vg : Volcanic glass, Wp : weathered particles
[3] HM : Heavy minerals

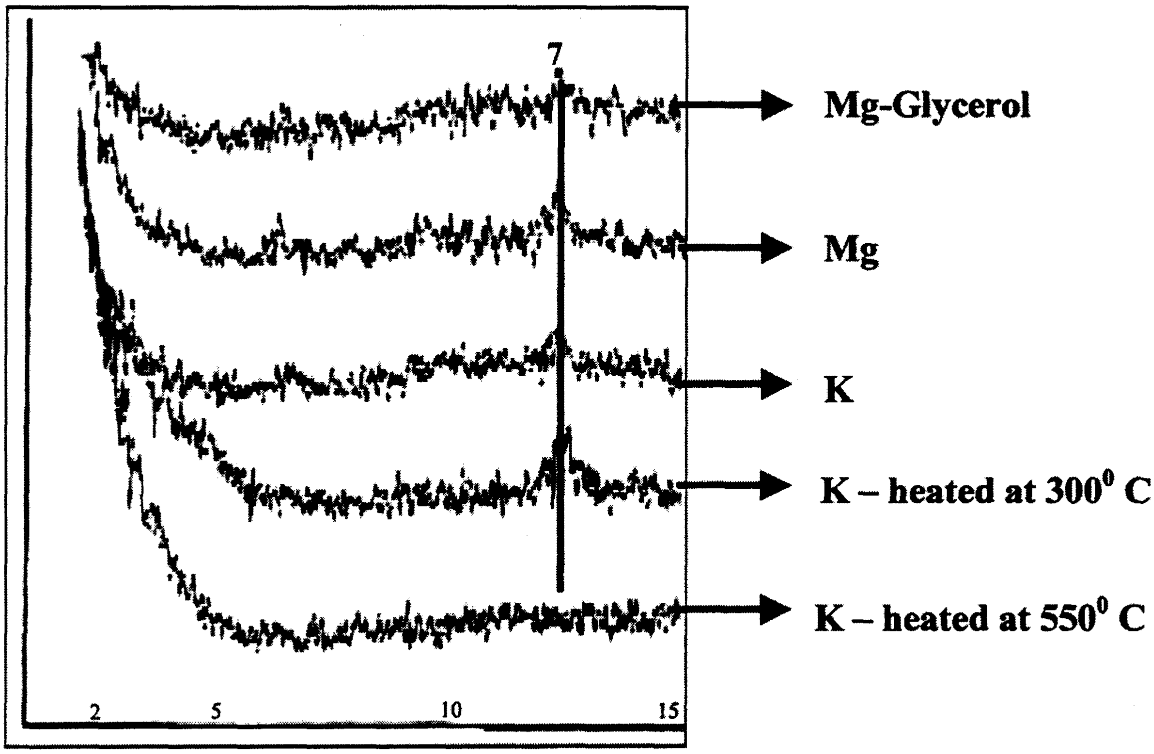


BA Horizon



Bw2 Horizon

Fig. 4 : Electron Micrographs



BA Horizon

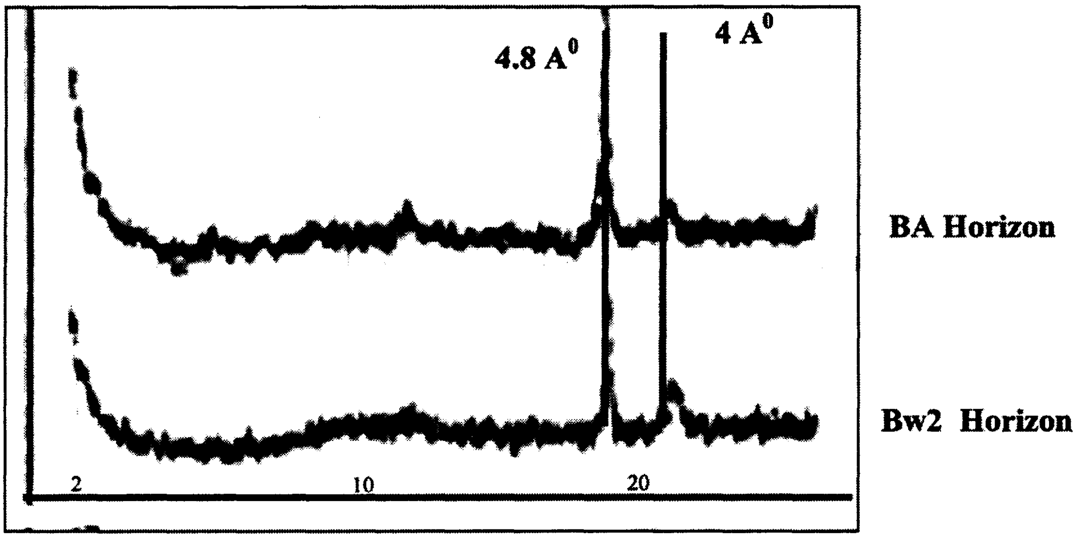


Fig. 5. X–ray Diffractograms

horizon. These data show that amorphous materials are higher in the surface and last horizon suggesting the presence of buried A horizon.

Total elements

As to the total elements (particularly Al_2O_3, and SiO_2), Al_2O_3 is higher (about 60% maximum) than SiO_2 (20% maximum) as shown in Table 2. This indicates that this soil is advanced in weathering that Si had been leached out while Al precipitated.

Primary Minerals

For the heavy minerals, the opaque particles predominate seconded by hornblende followed by pyroxene and weathered particles (Table 3). Weathered particles, small amounts of quartz, mica and volcanic glass composed the light minerals. The presence of small amount of volcanic glass in all horizons shows that Intavas TDF soils are affected by volcanic ash material.

Clay Mineralogy

Figure 4 shows the electron micrographs of BA and Bw_2. BA shows no defined form that can be considered X-ray amorphous while Bw_2 show angular shape that seems to be gibbsites and spheroid configurations indicating the presence of halloysites.

The X-ray diffractogram of BA (Fig. 5) shows small and weak peaks at 7 Å of kaolinite minerals when treated with Mg, Mg-glycerol, K, K-heated at 300 °C that totally collapsed when heated at 550°C. However, a sharp peak of 4.8 Å can be observed when treated with Mg indicating the dominance of gibbsites both in BA and Bw_2.

Partial Rejuvenation by Volcanic Ash Material

The Intavas soil has unique characteristics like relatively high organic matter in the surface, dark color and relatively high phosphate retention, relatively low bulk density, relatively high amorphous clay in the surface and high halloysite in the subsoils similar to relatively young soils that are affected by volcanic ash. On the other hand, this soil has highly weathered characteristics like high aluminum and very low silica content in major elements and very high gibbsite in clay minerals. These contrasting characteristics are recognized by the partial rejuvenation of the volcanic material into the very old parent material.

Conclusions

Based on the morphological, physical, chemical, thin section and clay minerals, soil of Intavas TDF was classified as fine clayey, acid, isothermic, gibbsitic, Oxic Dystrudepts.

The Intavas TDF soil can be evaluated in terms of its physical and chemical properties. Physically, this soil is suited for root development, good aeration, good tilth and workability that can be attributed to low bulk density and good soil structure. The surface soil and the buried A horizon show the properties of volcanic ash affected materials characterized by dark and high carbon residency. As to the chemical properties, this soil has many limitations, namely : low pH that affect the availability of most plant nutrients; relatively high phosphate retention that causes phosphorus deficiency; low cation exchange capacity and base saturation that both affect the ability to adsorb plant nutrients in ionic forms.

Primary minerals show that this soil is dominated by weathered particles as similar to highly weathered soils. But small amount of volcanic glass, which is highly weatherable primary mineral is found in all horizons. This shows that Intavas soil is affected by volcanic ash material.

The clay mineralogical analysis shows that the dominant clay mineral in BA horizon is gibbsite and followed by amorphous materials and small amount of halloysite and Bw_2 horizon is dominated by gibbsite followed by halloysite.

In comparison to non-rejuvenated soils, Intavas TDF can be considered partially rejuvenated soil by volcanic ash material brought about by medium total carbon, relatively high phosphorus retention, relatively low bulk density and higher acid oxalate and pyrophosphate soluble Al and halloysite clay.

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