CHARACTERISTICS AND FERTILIZATION OF ANDEPTS IN THE PHILIPPINES

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Introduction

The ring of fire surrounding the Pacific Basin identifies the area of recurring volcanic activities which includes the Philippine Archipelago. Volcanic ejecta such as basalts, andesites and ash are very common materials from which most of the soils are derived. Soils formed or forming from basic rocks are sometimes overlain by ash or soils of ash origin are often buried many layers deep which are themselves forming or have formed soils, the remnants of which are preserved in such layers. Considering the number of active and extinct volcanoes in the country it is sometimes difficult to locate soils without apparent or distinct influence of volcanic materials.

Soils that developed from volcanic ash have been observed on gentle to steep slopes in the western part of Batangas and south central Quezon provinces both in Southern Luzon, around Mount Isarog in Camarines Sur of the Bicol Peninsula, in the southern part of Oriental Negros of the Visayas Islands, and in the Cotabato plains of Mindanao. Most of these soils can be classified under the suborder Andept, a derivative of the term Andosol first coined by Thorp and Smith (1949) to include a great soil group of volcanic ash origin. Soil Taxonomy (1975) defines Andepts as soils that possess low bulk density (less than 0.85 g/cm^3) of the fine earth fraction where amorphous materials dominate the exchange complex or where the vitric ash, cinders or other pyroclastics dominate the total weight of the soil. Such group of soils occupies more than 8% of the total area of Japan according to Kanno (1956), an extent far greater than may be present in the Philippines as shown in the modified soil map of the country by Briones (1981). For this reason, researches on the nature of these soils and their management problems have not been as extensive and exhaustive compared for instance with studies on soils normally planted to grain crops such as rice or corn. On the other hand, these soils have not been ignored altogether and some attention has been directed over the years to confirm and verify well known properties associated with these soils that may be favorable or adverse to production. It is the purpose of this paper to present certain observations and results of such efforts in the Philippines.

Occurrence and nature of volcanic ash materials

Volcanic ash soils can be located in any part of the topography. For instance they occur from sea level to the mountain ridge in the western section of Batangas province clearly influenced by deposition from Taal volcano located in the area. Sanchez (1976) observed as much, although there exists certain association of Andepts at higher elevations that grades into red soils such as Ultisols at decreasing elevations. This is similar to the notations of Dudal and Soepraptohardjo (1960) along a slope and base of a volcano in Indonesia. Above 700 meter, Andepts dominate due to high rainfall and lower temperature that favors organic matter accumulation impeding the crystallization of amorphous material, such as allophane. In the lowland areas where moisture regime is lower (ustic) both Ultisols as well as Vertisols may form, the presence of the latter however implying that allophane has transformed directly to montmorillonite or was formed by a resilication process.

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Under humid conditions, rapid weathering of crystalline and non crystalline ash can take place to produce the soil material known as allophane (Birrel and Fields, 1952). Loganathan (1967) mentioned that allophane was already observed by Seki in 1914 in Japanese soils, as in the case of some Hawaiian soils found in later years by Kelly and Page (1943), and Tamura *et al.* (1955). Khan (1969) found that allophanes were present in all the profiles obtained from Mt. Makiling in Laguna province. It is therefore a common assumption that soil materials from volcanic ash are likely to contain allophane in varying amounts.

A quick test for allophane using 1 N KF and phenolphtalein indicator normally used to detect the presence of these clays yielded negative results for some ash-derived soils in Batangas, Laguna, Cavite, and Quezon provinces, all in the Southern Luzon region. This may indicate that the ash deposits in this area have crystallized into other minerals, or the ash composition differs from the usual, as observed in other areas. Galvez (1957a and 1957b) working with four major soil types of the Philippines showed that the dominant mineralogy of the clay fraction is montmorillonitic with an indication that ferro-allophane-like materials are also present. Although the soils used are not necessarily Andepts, they are located in areas influenced by volcanic ash deposition in the past.

Using volcanic ash-derived soils in varying stages of development, Briones (1964) showed the dominance of montmorillonitic mineralogy in clays from soils obtained in Laguna and Quezon provinces. The X-ray diffractograms for the two soils used are reproduced in Fig. 1. The sand and silt fractions indicated abundance of primary minerals with quartz and feldspars dominant. The feldspars are either andesine or labradorite. Present also are magnetite, hematite, olivine, hornblende and augite. Examination of the sand grains using petrographic microscope revealed the presence of glass shards changing to some moderately birefringent mineral likely to be montmorillonite.

These soils were originally intended to show some physical properties associated with drained and reclaimed paddy areas. Subsequent observations have indicated that such soils are formed or forming from volcanic ash deposits of the past. Differences in the intensity and sharpness of peaks in the X-ray patterns for the clay fraction may be a reflection of variations in age of parent material and rainfall that produce soils belonging to different orders. Moreover the composition of the ash materials examined indicated andesitic type of ash using the classification of Swindale and Sherman (1964).

Whereas allophanic materials are not apparent from weathering of volcanic ash in this area of Luzon (Batangas, Laguna and Quezon), soils surrounding the piedmont area of Mount Isarog have been found by Ikawa (1979) to contain allophane along with the other chemical-physical properties, a requirement for the establishment of field experiments for the Benchmark Soils Project of the University of Hawaii for the purpose of using the soil family in agrotechnology transfer. Recent soil survey investigations conducted by Japanese soil and crop scientists* along with the author revealed the presence of allophane in the soil of this area using the quick test for this material. It is not certain whether such differences in mineralogies between these areas are due to compositional variation of the original ash, age of the material, thus, degree of weathering, or rainfall affecting drainage conditions, or a combination of the three factors.

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* Dr. Y. Amano and Dr. H. Ichiki, TARC, March 1981.

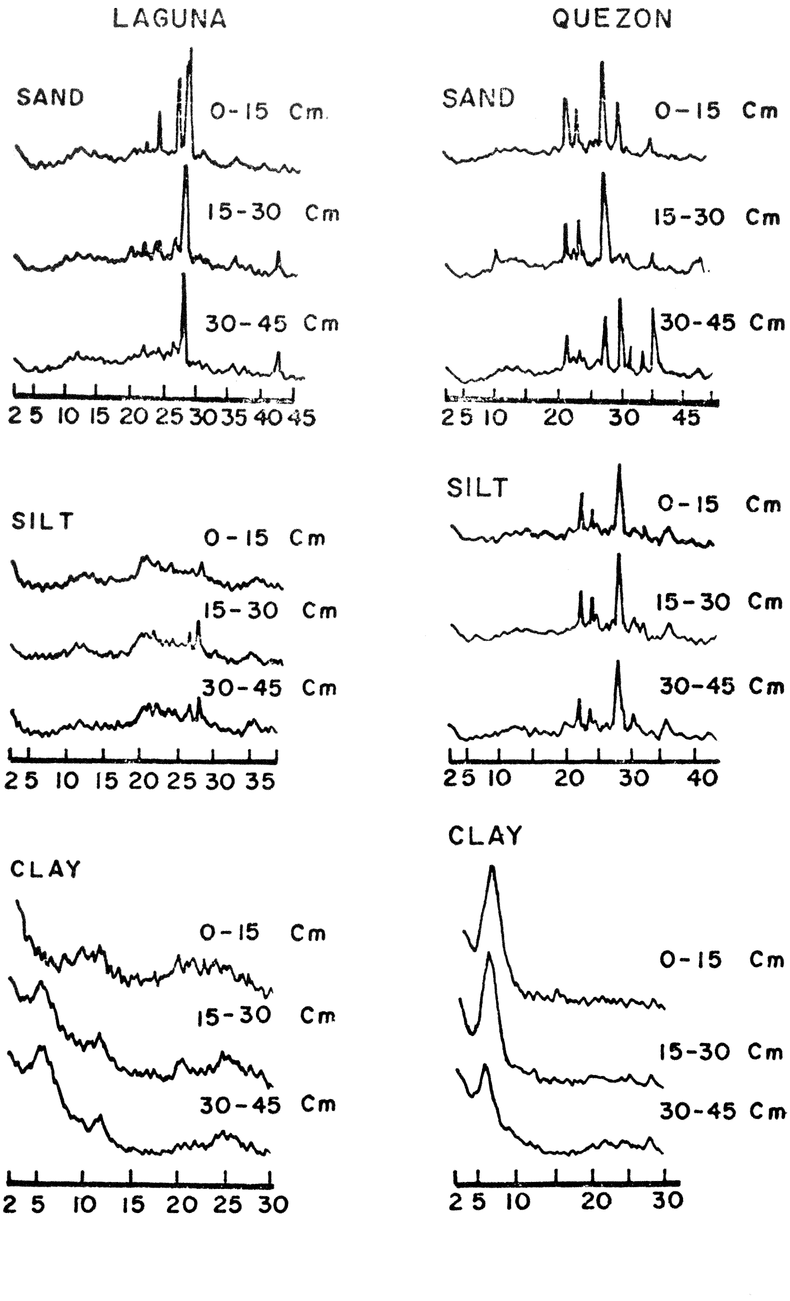

Fig. 1 Diffraction patterns of some fractions from volcanic ash soils of Laguna and Quezon provinces, Luzon. (Source: Briones, 1964).

Physical and chemical characteristics of some Andepts

Soils of this class particularly Dystrandepts are generally considered to possess excellent tillage properties but their chemical properties are associated with some of the most severe problems for crop production. Such characteristics which are considered unique for these soils have drawn the attention of a number of research workers particularly in the tropical world. The moisture retention properties of some of these soils are well known where values as high as 200% moisture content by weight were observed by Loganathan (1967) at 15-bar suction for some of the horizons of certain Typic Dystrandepts of Hawaii. Similar pattern of moisture retention at higher degrees of saturation was observed by Kalpage (1974) in agreement with the observations of Maeda and Warkentin (1975) even in allophanic soils where the sand content is twice as high as the amount of clay.

Drying however irreversibly decreases the magnitude of this moisture retention pattern which can be accounted for by a reduction in volume of microvoids with an increase in volume of macrovoids. It is assumed that there is a collapse and closure of necks of microvoids during drying, a phenomenon not normally observed in soils containing crystalline clays known to exhibit first a reduction in macrovoids upon compaction or drying or both. These properties and features are ordinarily associated with the amount and type of clay as well as organic matter although the allophane content is regarded as one of the main factors for such unusual properties. It is also claimed that this allophane reacts with organic matter to form complexes resistant to mineralization. Thus, despite high organic matter contents in some of these soils, application of N fertilizers is still required to obtain desirable yields of corn and other crops as well.

The very high moisture retentivity of some Andepts does not necessarily ensure continuous availability of water. For water to be more useful, the soil must be able to supply not only the needed amount but also the required rate demanded by plants. The physical properties of these soils are known and often assumed to cause rapid intake of water but are associated with their inability to retain available water for longer periods in the profile, which becomes a limiting condition for plant growth. The need to establish soil-water relations is as important if not more so than what can be obtained from studies on retention alone. This is the subject of a report by Briones *et al.** whose objective was also to elucidate the properties that may provide additional bases for classification of such soils.

Textural differences can often account for variations in the soil-water relations. For soils that exhibit irreversible drying texture may not however sufficiently explain the various aspects of the behavior of soil water.

1 Pore size distribution

The moisture characteristic curve of a soil reflects its pore size distribution which indicates water held as a function of the suction. S. Childs (1940) was among those who showed that suction of the water is inversely proportional to the effective diameter or radius of the pore. These channels are interconnected through necks whose effective size is estimated through the retention curve. It is not difficult to show that as the prevailing suction increases the pores retaining the water progressively decrease in size.

Using suction plates, pore size distribution was assessed for each layer of three Andepts from 0 to 210 cm suction. This range removes most of the readily available water from these soils. The distribution is calculated from corresponding total porosity which is presented in Table 1. It is to be noted that the samples used have been air-dried which can cause irreversible drying of aggregates particularly for Dystrandept. Even so, the data still show high total porosity even for the Vitrandepts of relatively recent ash deposition and therefore much less exposed to weathering.

The data indicate that a substantial amount of water is contained in large pores which can

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impart to the system ease and readiness of movement of water and air. On the other hand, high amount of water is still retained by pores of less than 0.2 μm in effective diameter in Dystrandepts and Eutrandepts (15-bar suction and higher) in agreement with well established findings by other workers of high moisture retentivity. Such soils of this pore size distribution exhibit steep slopes in the low suction range, which implies large withdrawal of water for small increase in suction. Taylor and Ashcroft (1972) stressed that soils with sharp and sudden change in the water suction relationship are likely to reach the permanent wilting point quickly. Plants grown on these soils may show little or no signs of water stress but may wilt a day or two later. Thus, despite the fact that the areas where some of these soils occur (particularly Dystrandepts) receive relatively high rainfall the droughty characteristic of the soil requires some type of water control.

Table 1 Average profile of pore size distribution from total porosity for three Andepts of the Philippines

Soil	Effective pore diameter (micron)					
	> 97	32–97	14–32	0.2–14	≤ 0.2	Total porosity (%)
Dystrandepts	4.14	4.55	3.37	26.04	61.9	70.58
Vitrandepts	9.21	13.12	9.36	41.61	26.7	66.0
Eutrandepts	3.91	5.37	5.50	30.82	54.4	63.1

2. Infiltration properties

The capacity of soils to absorb water which defines infiltration capacity is dependent upon the rate of infiltration. The matter of infiltration becomes significant as a consequence of high rainfall intensities that occur in certain cases where despite expected favorable features for rapid movement of water, erosion is still commonplace. So long as the rate of infiltration exceeds the added water supply rate, all the water will enter the soil. Conversely, if the supply rate exceeds the infiltration rate only a part of the total water will be redistributed in the profile while the remainder is lost through runoff to cause different degrees of erosion of affected areas.

A number of empirical descriptions of the process of infiltration have been known but the series of studies by Philip (1954, 1957) have provided the details and insights into the process including the factors that affect it. The relation that describes vertical infiltration is given as,

$$I = St^{1/2} + At$$

where I is cumulative infiltration, t is time, S and A are constants. S represents sorptivity that measures water uptake or release while A is related to the ability of the soil to transmit water so that at infinite times, this constant approaches the hydraulic conductivity of the saturated soil. The infiltration rate, i, is the derivative of I with respect to time and is given as,

$$i = 1/2\, St^{-1/2} + A$$

a relationship that permits evaluation of the constants S and A.

Figs. 2a, 2b, and 2c show the behavior of infiltration rate i, with the reciprocal of the square root of time at various intensities of water added on the surface layer of three Andepts. Infiltration properties are comparable wherein infiltration rate is nearly linear at the lower rates of water

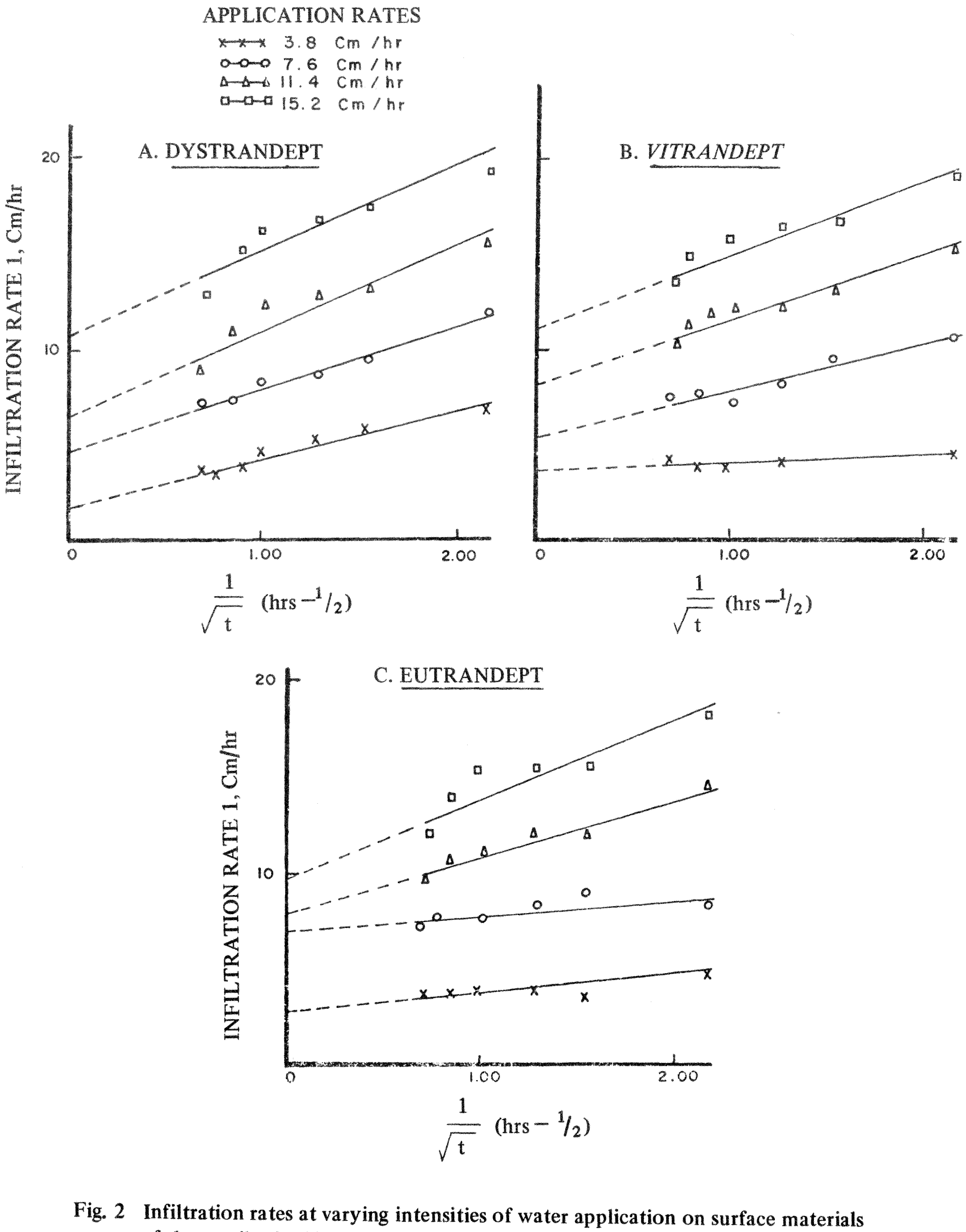

Fig. 2 Infiltration rates at varying intensities of water application on surface materials of three soils classified under the Hydric Dystrandepts.

application. There is departure from linearity at high water application rates which may indicate rearrangement of particles and aggregates either enhancing or impeding downward movement of water.

In this study, no ponding was observed on all surface soil material from an application rate of 3.8 cm/hr. Such ponding behavior is predictable from the data on the advance of wetting front which is not presented here. One would note from the infiltration rates however that the rate of advance of the wetting front increases as the intensity of water application increases, but this advance decelerates with time when this rate exceeds the infiltration rate of the soil at which time ponding ensues.

These results show that the ability of soils to allow entry of water is determined by surface soil properties related to infiltration and the intensity of water added (rainfall). In the case of Hydric Dystrandepts where sometimes as much as 30 inches of rain may occur in 36 hours, even the excellent physical properties of this soil allowing rapid movement will not be able to prevent the consequences of runoff because such intensity may exceed the infiltration rate of the surface. It is to be noted that the capacity of the soil for unrestricted entry of water with continuous addition on the surface will also depend on the properties of the layers below to absorb water continuously. A high state of aggregation, large proportion of sand particles and deep layer will usually enhance the capacity to permit downward movement with less resistance.

Adsorption and P requirement of some Andepts

It is known that availability of phosphates as well as other anion nutrients in soils is affected by the adsorption process that takes place in a number of soils such as those that contain amorphous clays. The anion so adsorbed is considered to be fixed in varying degrees. The work of Hingston *et al.* (1967) demonstrated the specific or non specific mechanisms of adsorption of say, phosphate on clay surfaces which was defined in a series of studies where the Langmuir theory was used to describe adsorption process on aluminum and iron oxides (Hingston *et al.*, 1972). Similar confirmatory results were obtained by Obihara and Russel (1972) for the adsorption of silicate and phosphate by soils.

A significant corollary of these studies is the matter of determining P requirements of soils for crop production. Fox and Kamprath (1970) proposed the use of the P adsorption isotherm through equilibration of a fixed amount of soil sample and incremental amounts of phosphorus added. The phosphorus which disappeared from the solution was considered to have been sorbed. The sorbed phosphate is then plotted against P in solution to characterize the soil. Subsequent work of Fox *et al.* (1974) has shown that Hydrandept sorbed more phosphate than either a Eutrustox or a Gibbsihumox which was attributed to the amount of amorphous materials. One consequence of a high sorption capacity is to increase the amount of P fertilizer to apply in order to obtain a given solution concentration that has been observed to provide desirable yields in the field. Studies by these workers indicated that the external P requirement to obtain 95% yield potential of corn ranged from 0.05 to 0.07 ppm P in solution of either Eutrustox or Hydrandept, two soils of widely different properties. Because of this it was assumed that the P fertilizer required for a certain crop on a given soil can be determined from the P sorption for the soil when the external P requirement of the crop is known. This is regarded as the Fox criteria.

Adsorption isotherm of Dystrandepts

From its inception, the Benchmark Soils Project intended to apply the Fox criteria in the determination of P treatments that were to be used to test the transfer of technology hypothesis through the soil family. Thus, prior to experimentation in the three sites selected, namely Palestina, Carolina, and Burabod, all in the province of Camarines Sur, surface materials of each plot from a number of blocks were obtained to determine their respective P isotherms.

Plotted isotherms varied from each other in terms of native P as well as slope not to mention observed differences from one site to the next. Using 0.05 ppm P in solution as the optimum level, different plots of the same P rate treatment needed varying amounts of phosphorus fertilizer. Results of experiments over a number of seasons definitely showed a response of corn to P application. However, only slight increase was observed beyond the first P level applied which was suspected to be caused by an over-estimation of phosphorus requirement attributed to the Fox criteria. Repeated failures to obtain differential increase in yields from increasing P application using the P isotherm technique consequently led to the abandonment of this methodology.

Past results from the network of experimental sites however provided a means to determine the actual optimum P level as determined by relating yields and rates of P application. From a curve of applied P against extracted P by the modified Truog method, any desired P treatment can be estimated using an empirical relation that was established between applied P and extractable P. It is not the purpose of this paper to present a critique on the use of P isotherm but it seems apparent that an in-depth analysis of these adsorption phenomena and the P requirement of crops has yet to be carried out particularly for soils containing substantial amounts of amorphous clays. For instance, is there any relation between extractable P using the modified Truog method and P in solution using the Fox criteria? This and other related questions may be pursued.

Notwithstanding certain experiences on the application of the P isotherm, it may be interesting to note the behavior of this phenomenon using the Langmuir theory from the plot-by-plot observations of the three experimental sites mentioned. Figure 3 shows a nearly linear relationship of the curves following the equation used by Veith and Sposito (1977) expressed as,

$$C/(x/m) = 1/Kb + C/b$$

where C is the equilibrium P concentration in solution in μgP/ml, x/m is the adsorbed P in μgp/gram soil, K is an affinity parameter, while b is related to a capacity parameter. Each point in the curve is a mean of 45 observations intended for 15 treatments in three replications. Table 2 shows some similarities or differences in the slope and intercept of the lines drawn from each replication

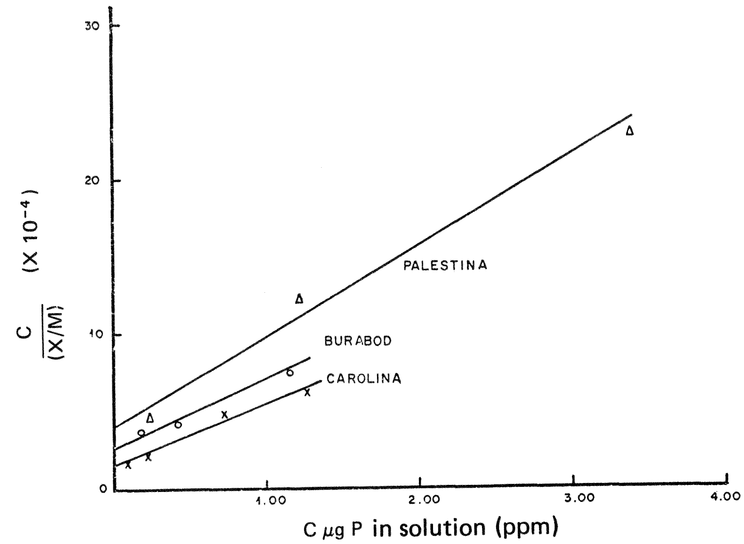

Fig. 3 P adsorption of three sites classified in the same soil family of Hydric Dystrandepts using the Langmuir equation.

Table 2 P adsorption parameters using the Langmuir equation of the three sites belonging to the same soil family

Replication	Parameters		
	Intercept (l/kb)	Slope (l/b)	K
	Palestina		
1	6.75×10^{-4}	5.41×10^{-4}	0.802
2	2.83×10^{-4}	5.63×10^{-4}	1.989
3	3.23×10^{-4}	5.57×10^{-4}	1.724
	Carolina		
1	1.44×10^{-4}	3.86×10^{-4}	2.681
2	1.45×10^{-4}	4.07×10^{-4}	2.807
3	1.54×10^{-4}	3.99×10^{-4}	1.591
	Burabod		
1	4.27×10^{-4}	3.29×10^{-4}	0.770
2	1.95×10^{-4}	5.12×10^{-4}	2.626
3	1.56×10^{-4}	5.15×10^{-4}	3.301

for the three sites. T-tests of K's reveal no evidence that the three sites are statistically different from each other although such may occur with a probability of 0.90. This is expected because the sites were carefully selected as soils belonging to the same family although other criteria were used for this purpose.

It is indicated from these observations that while adsorption isotherms may show apparent differences, affinity parameter K may still behave similarly for soils classified under the same family. Thus, an additional criterion for a soil family may include the phosphate affinity parameter K for P-deficient or P-fixing soils. If this is correct, capacity parameter b can also be used in the same manner.

Fertilization studies on Dystrandepts

Soil fertility work for Andepts has been biased towards the Hydric Dystrandepts for the simple reason that this group of soils presents the most serious difficulties associated with severe deficiency in phosphate. Among a number of soils used by Sanchez (1968), Isarog soil was included not only for comparative purposes but expressly to use a soil which was suspected to be allophanic at that time. From the location of sampling (Pili, Camarines Sur) and the results of laboratory analysis, the sampling area may be considered to have soils of the Hydric Dystrandept group.

Sanchez observed that the soil had a very high organic matter content and had an excellent granulated structure where the clay particles are aggregated to form sand and silt size aggregates that resist dispersion. Due to phosphorus deficiency, there was a positive response to phosphorus application when rice was grown on a puddled and non puddled system. However, puddled Dystrandept had a tendency to reduce the efficiency of phosphorus utilization when shrinkage occurred because of drying conditions from a rainfed type of agriculture.

The alarming rise in the cost of commercial fertilizer during the last decade has increased the awareness and use of indigenous fertilizer materials such as guano, and guano-derived rock phosphate composed of apatite (Ca-phosphate), strengite (Fe-phosphate) and variscite (Al-phosphate). Owing to the non uniformity of the deposits that exist in the country, the need to establish some guidelines on the use of such deposits for crop production was essential. Briones (1980) conducted a comprehensive characterization of the major components of a number of deposits concerning properties associated with fertility. Field testing of certain of these materials was then conducted by Briones and Vicente (1981) which include the Hydric Dystrandept on the same experimental location (Carolina, Camarines Sur) of the Benchmark Soils Project. Some results of this work are reproduced in Figs. 4 and 5.

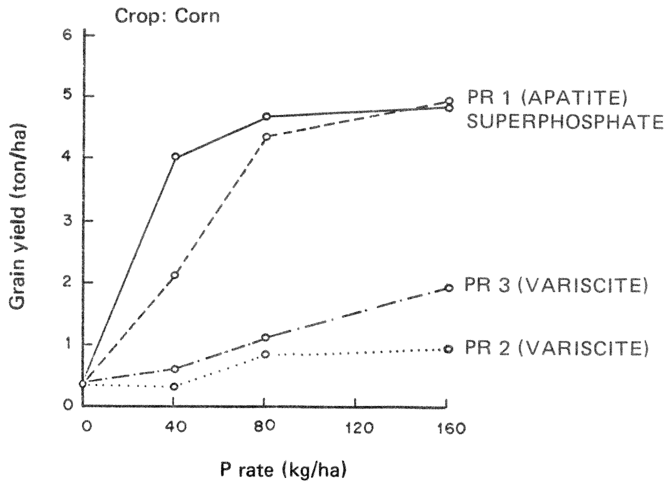

Fig. 4 Influence of varying sources and rates of applied P on the yield of corn in a Hydric Dystrandept. (Source: Briones and Vicente, 1981).

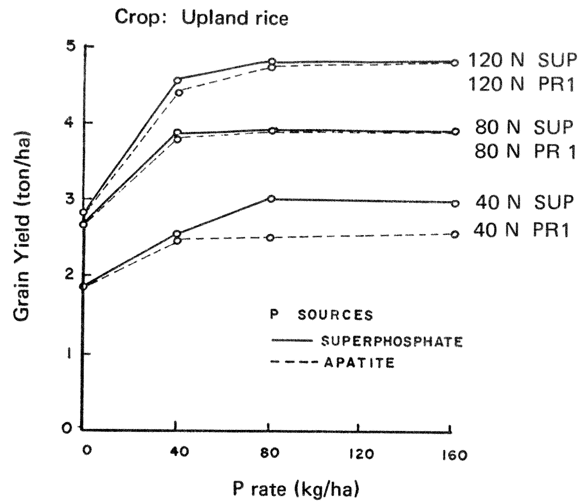

Fig. 5 Comparative effects of apatite and superphosphate in combination with nitrogen on the yield of upland rice in a Hydric Dystrandept. (Source: Briones and Vicente, 1981).

As before, there is substantial response in corn and upland rice due to the application of phosphorus, and phosphorus and nitrogen, respectively. In both crops, the performance of apatite was lower than that of the superphosphate at the lower rates of application. On the other hand, at higher rates of P the effect of this material on yield of corn and rice was equal if not superior to that of superphosphate. Additionally, because the soil is acidic, there was hardly any effect on yields by adding variscite (Al-phosphate) since this material is known to be stable at low pH. The results of this study lead to some obvious conclusion: that apatite can be used directly as a P-fertilizer in acidic soils whereas, variscite/strengite may be more effective in alkaline systems.

The well established property of Hydric Dystrandepts to adsorb large amounts of applied P places a heavy burden on the small farmers who will shoulder the cost of this phosphorus investment. For this reason, the need to determine the method or manner of fertilizer and soil manipulation was stressed by the Benchmark Soils Project to increase the efficiency of each unit of phosphorus added. The virtues and limitations of phosphorus placement have been known in the literature for many years particularly the treatise on the physical theory of fertilizer placement by De Wit (1953). Placement of phosphorus would therefore have direct relevance and may bring about more benefits in soils that can fix high amounts of phosphorus. Simply stated, placement limits the volume to which the fertilizer is mixed which can also limit the propensity of the soil to adsorb the nutrient. But Harris (1980) reasoned that such placement also reduces the spatial availability of phosphorus due to decreased root contacts, an effect opposed to the other. It was assumed however, that an optimum placement can be found which is fertilizer rate dependent directly affecting P availability.

Harris conducted a series of placement experiments in the soil network of the Project. The observations obtained from the first study in the Caroline area are reproduced in Fig. 6. The different band placements refer to the fractional width based on the distance between rows of corn. The effect of placement is clear although at higher rate of P application, the broadcast method remains superior. However, the most significant part of this result concerns the effect of placement at low rates of applied phosphorus resulting in higher yields compared to the broadcast or drilled methods. This being so, dissemination of such fertilizing method would most certainly be beneficial to the resource-poor farmers who till soils of this kind.

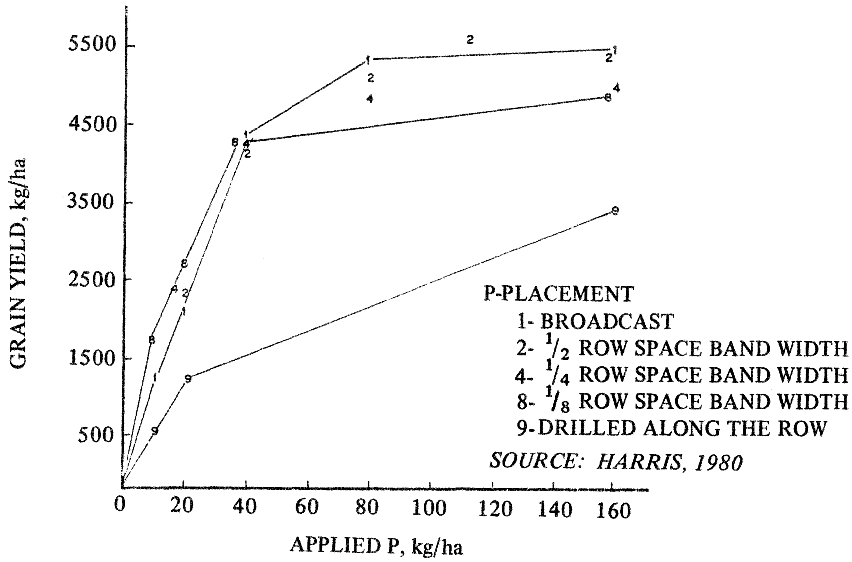

Fig. 6 Influence of placement of various rates of applied P on yield of corn in a Hydric Dystrandept.

This paper is replete with the experience and observations made by the Benchmark Soils Project. This is so because the Project has conducted and continues to conduct an array of crop production experiments that of course include the central study on agrotechnology transfer. The results of such experimentations are documented in project reports of 1977, 1978 and 1979. The group effort of Beinroth *et al.* (1980) presented the theory, prospects, and other important features of this tropical soil project along with the first evidence that the hypothesis on transfer of agrotechnology is valid using the network of the family of the isothermic, thixotrophic Hydric Dystrandepts. The reader is referred to these publications for greater details and more insights.

Summary and conclusions

Soils that have developed from volcanic ash whether or not the deposits were subsequently altered by water to form other types of parent materials are extensively distributed in Southern Luzon, Bicol Region, and some portions of Southern and Central Mindanao. But soils that have been classified as Andepts or Andosols possessing a number of unique chemical and physical properties such as those exhibited by Dystrandepts have still to be studied in relation to their distribution and extent.

Where these soils occur, problems of fertility associated with severely limited phosphorus and soil water conditions are encountered. The properties that have been determined largely confirmed those reported in the literature and agrotechnology experiences of local research centers and from elsewhere in the world using the same soil have been demonstrated to be transferable.

To render research efforts more meaningful and immediately utilizable, the matter of conducting a careful survey of such areas wherever they exist in the country should then be given full attention along with other equally if not more important soils. If the objective is to demonstrate application of agrotechnology, the imperative nature of knowing where the soils are and their extent would provide some of the basic elements to pursue a given land use accompanied by known and proven agrotechnology to achieve a desirable productivity.

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Discussion

Wada, K. (Japan): You mentioned that in your study it was difficult to apply the Fox criteria for phosphorus retention determinations. What modification did you bring to the Truog method for extracting phosphorus from Andosols?

Answer: The strength of the acid used was modified. The modified Truog procedure gave a good correlation with the results of the field experiments and a calibration could be made.

Shoji, S. (Japan): What is the morphology of the Andepts commonly found in the Philippines, with respect to the depth and color of the A horizon? Does the A horizon have a dark color?

Answer: In the Andepts with allophane, the chroma is very low (less than 2) and the organic matter content is above 10%. The depth of the A horizon is about 40 cm but less than 20 cm in the Andepts of Mindanao. In the ash derived soils of the lowland areas there is a mixture of Vertisols and Ultisols. Some contain montmorillonite, other contain inter-stratified clay minerals. Eutrandepts can be found in the IRRI area for instance.

Tanaka, A.(Japan): In Japan phosphorus application must be very high on the Andosols to obtain high crop yields. Which is the level of phosphorus fertilizer application which enables to obtain moderate to high yields on Andosols in the Philippines.

Answer: We need to apply about 80 kg phosphorus (superphosphate) maximum per hectare.

Kyuma, K. (Japan): What is the lower limit of occurrence of Andosols in the Philippines?

Answer: The limit appears to be 400 m elevation.