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REPORT OF UNIVERSITY OF HAWAII

FOR THE PERIOD

JULY 1, 1973 TO JUNE 30, 1974

A. TITLE: A Grant to Strengthen the Capabilities of the University of Hawaii in Special Problems of Tropical Soils (Grant AID/CSD 2833)

B. GRANTEE: University of Hawaii

C. DIRECTOR: Dr. Wallace G. Sanford

D. STATISTICAL SUMMARY

1. Period of Grant: November 2, 1970 to November 2, 1975

2. Amount of Grant: $500,000

3. Expenditures

3.1 For report period: $198,800

3.2 Accumulated: $478,000

3.3 Anticipated for next year: $20,000

E. NARRATIVE SUMMARY

The objectives of this grant are to strengthen the existing competency of the University of Hawaii by collaborating with the members of the Consortium. To this extent, several Hawaii faculty members have gone on sabbatical leaves not only to increase their competency but also to extend the expertise and experience of Hawaii to other institutions. Several faculty members from other institutions have also come to Hawaii to work in their area of specialization and to engage in the exchange of ideas.

The contribution to soil mineralogy by the University of Hawaii was presented to the members of the Consortium when a soil mineralogy workshop was held in Hawaii during July, 1973.

Funds have been used to hire research personnel and graduate students to conduct research which will enhance the capability of

the University in tropical soils for teaching, further research, service, and consultation. At the completion of a study, most of the findings have been published in journals or as theses or dissertations or have been presented in a seminar or symposium.

Funds have also been used to provide travel for several individuals to increase their knowledge of tropical soils other than in Hawaii. At the same time, these individuals were able to see and sometimes to suggest the possibilities of applying what is known in Hawaii to other parts of the tropics.

A summary of the activities at the University of Hawaii shows that continuous efforts are being made to up-grade the undergraduate teaching. Illustrated concepts pertaining to tropical agriculture are still being published and a laboratory manual has been revised for classroom use. In microbiology research, nitrogen fixation and biological activities in soils are being studied. In soil mineralogy, emphasis is being placed in developing research techniques, for example, by use of the X-ray quantometer, to understand the role of minerals in imparting special behavior in tropical soils. Chemical and physical properties of soils are also being investigated in great detail. Soil characterization and classification are used to determine which of the soils have similar behavior and thus aid in soil interpretation. Finally, emphasis is being placed on the management of soils by conducting soil fertility experiments.

F. DETAILED REPORT

1. General Background and Purpose of the Grant: In making this grant, the principle criterion used was the degree of commitment a university is making or willing to make in increasing its competence

in tropical agriculture. Development of this competence would lead to a better understanding of significant agricultural problems relevant to emerging nations in the tropics. To this end, AID awarded five-year grants to establish centers of competence in tropical agriculture at existing institutions with permanent sources of funding and commitments on problems of international development.

2. Objectives of the Grant

2.1 Objectives restated: This grant will strengthen the existing competency of the University of Hawaii by means of a collaborative effort with Cornell University, North Carolina State University, Prairie View A&M College, and the University of Puerto Rico, to provide training, related research, technical assistance and consultation, and conduct related research in soil science for increasing food production in soils of the tropics. The grant will be used to:

(1) Further strengthen the soil mineralogy group at the University by the addition of a soil mineralogist, a technician, and appropriate support and equipment

(2) Provide for visiting professorships to be used to bring the University of Hawaii additional expertise and experience from either the cooperating institutions or from other services

(3) Provide graduate assistantships in order that students of the other four cooperating institutions may have access to the special strength of Hawaii

(4) Provide graduate assistantships to conduct research in tropical soils toward advanced degrees at the University of Hawaii

(5) Provide funds for travel by assistantships that are exchanged among the institutions, for visiting professorships, and for staff to consult with other cooperating institutions

(6) Strengthen the existing curriculum in tropical soils so that it will be more useful to AID and other personnel involved with tropical soils, crop management, and other related activities in the less-developed countries

(7) Strengthen library and other information services with special emphasis on the preparation of manuals or other training materials on tropical soils and other related fields

2.2 Review of the objectives: The objectives listed above will remain essentially the same except more emphasis will be placed on extension work particularly when such work, is compatible with the work being done in teaching and research. In meeting the fulfillment of this objective, section 5 of this report should be perused. In the future, individuals traveling to other areas whether on 211(d) or other funds, will continue to make available their services as experts when requested by appropriate individuals.

3. Accomplishments

3.1 Teaching: Continuous efforts were made to up-grade the undergraduate courses in introductory soil science: "Soils and Man" and "Tropical Soils" taught by R. E. Green and H. Ikawa, respectively. Results of student evaluations conducted by the Office of Academic Development showed positive progress. In addition to the basic principles of soil science, special considerations were given to current problems, such as environmental concern, in both of these courses. Further improvements are being considered when a College Learning Center becomes available for expansion of the audio visual tutorial programs associated with these courses. An increase in class enrollments in these courses suggests that more students outside the College of Tropical Agriculture are beginning to enroll in these agricultural courses.

During the fall semester, the graduate course in soil formation and classification was offered by A. R. Southard, Professor of Soils at Utah State University, who is spending his one-year sabbatical leave at the University of Hawaii from August 1973 through August 1974. In addition to 13 registered students, several faculty members and other students attended the lectures. The students had opportunity to go on several field trips to study soil properties and to describe soil pedons.

Two "Illustrated Concepts in Tropical Agriculture" were prepared and published during 1973 by R. L. Fox. These are used as handout materials for classroom use and to acquaint visitors and others with special features of tropical agriculture. The two concepts deal with the N and irrigation control for producing quality sugarcane and the adverse influence of low soil temperature on nutrient uptake by pineapple.

The soil physics laboratory manual prepared by G. Y. Tsuji and L. T. Santo during the last fiscal year was revised. This manual will serve as the basic reference for measurement and characterization of physical properties of most Hawaiian soils.

3.2 Research: In the area of soil microbiology, a project was undertaken by Jean Oya, graduate student partly supported by 211(d) grant, under the guidance of B. L. Koch, to evaluate the rate of non symbiotic nitrogen fixation in select pasture soils of Hawaii. Attempts are being made to relate various environmental factors to rates of nitrogen fixation, population of nitrogen-fixing organisms, and overall microbial population. Several aerobic and facultative anaerobic bacteria capable of nitrogen fixation have been isolated, and it is likely that identification of these organisms will result in new bacteria previously not considered to fix atmospheric nitrogen.

Analytical techniques for the isolation and identification of the herbicide diuron and its metabolites from soil and culture are being developed by V. Elder, graduate student, also under the direction of B. L. Koch. These techniques include the development of thin-layer and gas chromatograph procedures. Once perfected, these procedures can be used to study degradation of diuron in Hawaiian soils.

The X-ray quantometer which is used for total analysis of rock, soil, and plant samples is now in operation under the guidance of project leader R. C. Jones and Junior Researcher E. N. Okazaki. Jr. Researchers A. Chang and A. Chu, graduate students G. W. Gribble, W. H. Hudnall, and J. Braide and several student-help are also employed in this project under the 211(d) grant. Considerable progress has been made in calibrating the instrument by using primary or secondary standards of rocks obtained from the USGS, the Japan Analytical Laboratory and the Hawaii Institute of Geophysics. Clay minerals, kindly furnished by S. B. Weed of North Carolina State University, were also used.

The Hawaii quantometer can be used to obtain the total analysis of rocks, soils, and minerals in the following concentration ranges:

SiO_2	36.01 - 78.93%	CaO	0.24 - 24.44%
Al_2O_3	6.77 - 37.16	MgO	0.04 - 29.98
Fe_2O_3	0.79 - 29.87	Na_2O	0.11 - 8.35
TiO_2	0.12 - 3.03	K_2O	0.09 - 10.68
MnO	0.01 - 1.65	P_2O_5	0.01 - 1.09

In his study, Gribble has shown that if the concentrations of the above oxides are within the calibration ranges, the results of the analysis is within one percent or less of the reported concentration.

Improvement in the results for concentration outside of the calibration ranges for these 10 oxides are now in progress. Special emphasis is being made to obtain a higher concentration of Fe_2O_3 and a lower concentration of SiO_2. The cost of the total analysis of the 10 oxides of a sample ranges from $150 (Japan) to $200 or more (U.S.). The same analysis can be performed on the Hawaii quantometer at an estimated cost of $20 per sample; 20 samples per week.

Mineral characterization and allocation of soil samples can be performed at the University of Hawaii by utilizing the combined data obtained by X-ray diffraction analysis, electron microscopy, and total analysis by quantometer. Sixty-six horizons of 11 pedons from Puerto Rico were examined recently by Hudnall.

Although still experimental, the use of the quantometer's scanning spectrometer is being investigated to determine the coordination number of Al in crystalline and non-crystalline inorganic materials. Such a technique can indicate Al substitution of Si in the silica tetrahedral positions in minerals and the source of net negative charge in these minerals.

Progress has also been made during the past year in calibrating the quantometer for plant tissue analysis. The developmental procedure was similar to that used for rock, soil, and mineral analysis; that is, secondary standards were used to calibrate the instruments. These standards were based on results obtained by atomic absorption, colorimetry, flame photometry, turbometric analysis, and/or gravimetric analysis. Standard curves for plant tissue have been developed for the following concentration ranges:

Mg	0.04 - 1.21%	K	0.44 - 9.05%
Al	30 - 800 ppm	Ca	0.08 - 5.68%
Si	0.02 - 1.38%	Mn	4 - 1185 ppm
P	0.055 - 0.872%	Fe	19 - 514 ppm
S	0.01 - 1.66%	Cu	2 - 76 ppm
Cl	0.32 - 2.46%	Zn	8 - 200 ppm

These concentration ranges were established for macadamia leaf, papaya petioles, sugarcane sheath, pangola and kikuyu grasses, corn leaf, pineapple leaf including the basal whites, iceburg lettuce, chinese cabbage, cucumber leaf, and tomato leaf and petiole. Extension of the standard curves and the addition of other plant tissues are planned.

Plant root simulation by use of cation and anion exchange resins is progressing satisfactorily; quantometer calibration curves have been developed by Braide for the uptake of Na, Mg, Al, K, Ca, Mn, Fe, Cu, Zn, and Mo by cation exchange-impregnated filter discs. These discs, after being equilibrated with the salt solution of the respective cations, were washed, freeze-dried, and analyzed by means of the quantometer. These results were correlated with the results obtained by atomic absorption

after the same discs were ashed and the elements were taken up into solution. Plans are underway to investigate ammonium acetate extract by a similar procedure.

The Alfisols and Ultisols of Hawaii are being studied by A. R. Southard, Visiting Professor of Soils from Utah State University, with interests in soil genesis and classification.

Study of these soils will reveal why Alfisols occur in Hawaii in relation to the occurrence of Ultisols and some other soils. The study of Ultisols will provide more data for soil interpretation and subsequently recommendations for land use. The field work and sampling has been completed for Oahu by Southard, G. Y. Tsuji, H. Ikawa, S. P. Periaswamy and others, and laboratory characterization of the soils is now in progress.

Field observations in numerous locations on Windward Oahu revealed the presence of materials with a smeary consistence in both soils and saprolyte. This material is yellow (10 YR 5/6) and gray (5Y 4/1). Associated red material (10 R 4/6) is usually not smeary. These smeary materials have low bulk densities of less than 1.0 g/cc and particle densities range from 3.0 - 4.2 g/cc. The mineralogy by X-ray diffraction analysis shows the presence of Fe, Ti, and Al oxides with goethite and gibbsite being most common. After heating to 105°C, these materials still retain the smeary consistence and can be rewetted to 60-100% moisture by weight. At these moisture contents, the material has low sheer strength. Waikane and Lolekaa (Tropohumults) soils which contain weathered gravels with smeary consistence, retain 40-50% by weight at 15-bar tension. These soils show tendencies to slip on moderate to steep slopes. The importance of the behavior of these soils in watersheds and construction sites needs investigation.

The influence of soil micro structure on the water release characteristics of several soils were examined by G. Y. Tsuji, R. T. Watanabe, and W. S. Sakai. Intra-aggregate voids, viewed under the scanning electron microscope, were prominent in the Molokai (Typic Torrox), Wahiawa (Tropeptic Eutrustox), Manana (Orthoxic Tropohumults), and Paaloa (Humoxic Tropohumults) soils. The high water holding capacity of these soils at high suction was attributed to these voids. In the lower suction range of 0-200 cm, the influence of the interaggregate voids is most pronounced. The role of soil water hysteresis in this range is the subject of an M.S. thesis by L. T. Santo who is supported by the 211(d) grant. A 5-7% difference in water content was found between the absorption and desorption water release curves for the Molokai and Wahiawa soils.

An M.S. thesis research on the zero point of charge of soils differing in mineralogy was completed by J. C. Keng, also supported by the 211(d) grant. It was concluded that the majority of the soils in Hawaii have minerals which behave as colloids of the constant potential type. Soil minerals in this category include oxides and hydrous oxides of Fe and Al, kaolinite, halloysite, and non-crystalline hydrous oxides. Constant potential type colloids were distinguished from the constant charge type, such as those with montmorillonitic mineralogy, through potentiometric titration and determination of the existence of non-existence of a well-defined zero point of charge; i.e., the point of intersection of the titration curve.

Data collection by Tsuji on the vertical water infiltration has been completed and the analysis of the data is being made. Tsuji, together with S. Wann, who is supported by 211(d) grant, are also involved in a cooperative study with Southard and Ikawa in characterizing and correlating selected soils in Hawaii.

Studies on the nature of solute movement in Oxisols and Hydrandepts were continued by R. E. Green. Laboratory column measurements of displacement of aqueous solutions of tritiated water, chloride, picloram (herbicide), and methanol provided an assessment of the fraction of soil water in the soil which actively participates in solute movement. Solute dispersion in moving water determines the distribution of fertilizers and herbicides in the soil under different irrigation regimes. Inter-aggregate water in Oxisols is highly mobile, but all intra-aggregate water was also found to participate in solute movement. In an Hydrandept containing over 200% water by weight at field capacity, only 10% of the water was found to be non-solvent in character; the exclusion of solutes from this water was indicated principally by displacement of an aqueous methanol solution through the soil in a miscible displacement experiment. Current work includes testing various mathematical models designed to describe the effects of soil structure (pore geometry) on solute dispersion.

A field experiment was conducted on the Molokai (Typic Torrox) soil to determine the distribution of two soil-applied herbicides and nitrate under trickle irrigation. Soil-water tension during and between water applications was monitored by tensiometers spaced at regular intervals in two dimensions (vertically in the soil profile and horizontally perpendicular to the irrigation line) with the origin at the emitter. A graphical plot of equal total-potential lines provides a description of water flow direction at various times. Water flow will thus be related to the solute distribution in the soil as determined by analysis of solutes in samples of soil water obtained from ceramic-cup samplers placed in the soil. Changes in the soil structure with depth and the presence of a "plow pan" at the top of the B horizon are expected to have important effects on water and solute distribution in the soil profile. M. Furukawa, graduate assistant supported by 211(d) grant works on this experiment.

Nitrogen transformation and adsorption studies were made by Y. Kanehiro and V. Balasubramanian. a graduate student supported by 211(d) grant (Jan. 1 - Mar. 31, 1974). Of two liming materials, calcium carbonate was found to be more effective than calcium silicate in increasing ammonium adsorption and decreasing nitrate adsorption in two Hydrandepts (Hilo silty clay loam and Akaka silty clay) and in one Gibbsihumox (Halii gravelly silty clay). The former compound was also more effective in raising soil pH than the latter. At around pH 5.5, the limed soils began to repel nitrate. For the same pH in limed soils, the Hydrandepts showed a higher affinity for ammonium than the Gibbsihumox. This is most likely due to the high surface areas available for adsorption in the Hydrandepts.

In a denitrification capacity study, a special incubation apparatus was designed to monitor the process periodically without disturbing the inside atmosphere of the soil incubation flask. Under controlled conditions in the complete absence of oxygen, about 40-70% of the applied nitrogen (application rate of 30 mg NO_3-N/100 g soil) was lost as nitrogen and nitrogen oxide gases in two Hydrandepts. A Chromustert (Lualualei clay) was similar in denitrification capacity to the Hydrandepts, while a Torrox (Molokai silty clay loam) and a Tropohumult (Paaloa silty clay) showed low capacities. A readily available energy source appears to be the most important factor in denitrification; moisture and soil pH are also important.

Organic matter incorporation and decomposition studies were also conducted by Y. Kanehiro and M. Asghar, a graduate student partly supported by the 211(d) grant. A survey of organic matter status in soils was carried out by collecting samples from cultivated and virgin areas on the island of Oahu. Percent organic matter was invariably much higher in virgin as compared with cultivated soils, C/N ratio was also higher in virgin than in cultivated soils. Soil pH of cultivated fields was generally lower than that of adjacent virgin soils. Phosphorus fertilizer requirement was generally higher for cultivated than for virgin soils. Electrical conductivity of saturation extract was found to be above 4 mmhos/cm in some cultivated soils.

Effects of lime on legumes were investigated by D. Munns, Visiting Professor from the University of California at Davis, who is supported by the 211(d) grant. The lime response of 25 tropical and temperate crop and forage legumes were compared on an Oxisol containing high amounts of Mn. The trial had a 4-replicate continuous function design covering a pH-span from 4.7 to 7.2. Observations are being made on growth and yield, nodulation, nitrogen fixation (acetylene reduction), mineralization of soil nitrogen, and the availability and uptake of P, Ca, and Mn. The most striking result 6 weeks after planting is the lack of any large benefit from lime in Glycine max or representatives of the genera Stylosanthes, Desmodium, Lotus, Vigna, Arachis, Leucaena, or Acacia. Some benefit is evident in Trifolium subterraneum and considerable benefit in T. repens, Medicago sativa, Dolichos axillaris and a Glycine wightii cultivar. Diversity of response appears to be the rule, cutting across groupings as to taxonomy or tropical vs temperate origin. Above pH 5.5-6.0, liming depresses nodulation and acetylene reduction in most species. In some species, growth is also depressed. Such an observation supports existing evidence that liming

of highly weathered soils much above pH 5.5 is likely to be not only expensive but also damaging to crop performance.

The immobilization and desorption of phosphate in tropical soils were also studied by Munns. In laboratory studies, the apparent hysteresis becomes much smaller with time (months) following the addition of phosphate to the soil, indicating that non-equilibration is partly responsible for the large hysteresis observed early after phosphate addition, when immobilization is proceeding rapidly. The rate of the slow immobilization process at any one time appears to be a linear function of phosphate in solution (first order), but the rate constant declines with time. Liming of the soil has had little effect on the immobilization rate except by strongly enhancing the initial sorption of phosphate. Immobilization is proceeding faster in an Andept and a Gibbsihumox than in the less-reactive Ustox. Drying to −15 bars potential has had no important immediate effect of phosphate solubility. Long term data are not yet available.

In another soil fertility project, the study of the use of phosphate sorption isotherms for determining immediate and recurring phosphate fertilizer requirements were continued by R. L. Fox, with the aid of a technician partly supported by the 211(d) grant. The emphasis was on determining the internal and external P requirements on different varieties of the same species of plant. The general conclusion is that the external P requirement (the concentration of P required in the soil solution) is similar for two varieties of the same crop growing in the same soil or for the same variety growing in different soils (within the range of soils investigated), although the internal P requirement (the concentration of P required in the plant) can be very different for two varieties growing at the same location at the same time. Different species have different external and internal P requirements. For example, the external

requirement for grain sorghum is about 0.05 ppm P in solution and for chrysanthemum is about 0.2 ppm. The internal requirement for chrysanthemum for two varieties was 0.36 and 0.5% and for two varieties of sorghum, Savanah II and Funks BR 79, was 0.4 and 0.5% respectively.

The nutrition of Giant Cavandish banana was also examined. Using a field plot technique of his own design (continuous function), Fox sought a wide range of plant composition which can be related to banana yield. N deficiency symptoms of N were quickly recognized, and the tentative N requirement in the No. 3 fully unfurled leaf at shooting was established at 2.7%. Levels of P and K have not been strongly limiting for banana production, but low levels of S (0.12%) were detected in the plant even though S fertilizers have been used and the experiment is situated within a mile of the ocean.

Research on the relationship between sulfate adsorption, solubility and availability in highly weathered soils has been aided by 211(d) funds. Assistance has mostly been with analyses for S. The work has centered on calibrating the X-ray quantometer using plant material in which S has been determined by wet chemistry. Results of this work indicate that good sulfur nutrition of macadamia is attained when sulfate-sulfur in the soil solution is about 5 ppm and sulfur in the plant is about 0.2%.

Research and publication continued on a design for field experiments which should greatly increase the efficiency of field plots. The design is a systematic arrangement of treatments and has been called a Continuous Function Design. It should be very useful for survey investigations in underdeveloped areas.

Further, major emphasis has been placed by Fox on developing data for, and writing, "A study of highly weathered soils of Puerto Rico, Part III. Chemical Properties". This is in cooperation with the Univeristy of Puerto Rico. The completed 50 page manuscript has been approved for publication. The soils studied fall into 3 orders; 6 Oxisols, 4 Ultisols and 1 Inceptisol. There seemed to be real differences between soil orders; relative to the other soils the Oxisol differ in pH (higher), extractable aluminum (lower), and exchangeable K (higher). For other properties investigated, there was much overlap among the orders. Sulfate adsorption characteristics correspond closely with data for highly weathered soils of Hawaii developed from volcanic ash. This suggests that the reactive fraction in the Puerto Rico soils, as far as sulfate is concerned, is amorphous gel-like hydrated iron and aluminum oxides which coat mineral surfaces. Nitrification is much more sluggish than ammonification in the acid soils of Puerto Rico.

Cooperative work by Fox is also in progress with Prairie View A & M on the external P requirement of crops growing on sandy soils. Quartz sands are very important in certain areas of the tropical zone but Hawaii has no quartz sand soils. One field experiment (corn) was carried out during 1973. The results indicate that the external P requirement of the sandy soil of Prairie View is about the same as for the clay soils of Hawaii. Unfortunately for this experiment, the soil at Prairie View equilibrates at 0.1 ppm P in solution (0.01M $CaCl_2$) which exceeds the external P requirement of 95% yield of corn.

One of the soil fertility research projects of J. A. Silva is a cooperative sugarcane experiment with the Hawaiian Sugar Planters' Association Experiment Station. A crop was harvested in the fall and a significant

response to pH was observed with two liming materials. The optimum pH for $CaCO_3$ was 6.0 and sugarcane yields decreased at higher pH values. The optimum pH for $CaSiO_3$ was 6.5 where yields were slightly higher than at pH 6.0 or pH 7.0. Plant samples and soil samples (to a depth of 3 feet) were collected at harvest time for analysis.

Three other studies are being conducted under the guidance of Silva. A solution culture experiment currently in progress is being used to study the effects of pH and calcium concentration on growth and nutrient uptake by sugarcane. A. El-Tahir, a graduate student, is conducting the research on sugarcane.

A comparison of plant extraction and chemical extraction of Si from soil was conducted by R. A. Khalid, a graduate student supported on 211(d) funds. Rice plants extracted larger quantities of Si from a small volume of soil than did exhaustive extraction with 0.1N acetic acid adjusted to pH 3.5 with ammonium hydroxide and containing 50 ppm P as $Ca(H_2PO_4)_2$. However, recovery of Si applied five years earlier was similar with the two methods. These data were incorporated in Khalid's Ph.D. dissertation entitled "Residual Effects of Calcium Silicate on the Movement and Availability of Nutrients in Tropical Soils".

The chemical reaction of calcium silicate with gibbsite are being studied by R. Alvarez, a graduate student also supported by 211(d) funds. Adsorption of calcium silicate appears to be affected by pH, concentration and accompanying ions.

In addition, the data on the lime requirement study collected by W. S. Reid of Cornell, while on sabbatical leave at the University of Hawaii, are being summarized and interpreted.

Results of several studies are reported by C. A. Bower, who is supported by the 211(d) grant. Information on the salt tolerance of crops grown under cover in the tropics and on standards for assessing soil salinity to plant growth on tropical soils is one study.

The salt tolerance of "Tropic", a principal variety of tomato grown in Hawaiian greenhouses, was determined in the plastic greenhouse at the Kona Research Station. The Honuaulu clay loam, a Hydric Dystrandept, having saturated paste, field capacity, and wilting water contents of 70, 60, and 32%, respectively, was adjusted to five levels of salinity by the addition of a 1:1 mixture of NaCl and $CaCl_2$. The levels of salinity were such that at saturation the electrical conductivities of the soil solutions were approximately 1, 4, 8, 12, and 16 mmho/cm. Thirty-three pound weights of each batch of treated soil were placed in 5-gallon capacity pots having a drainage outlet. The water content of the potted soil, when drainage ceased (60.5%), was almost equal to the field capacity content. A single one-month old seedling was transplanted to one pot, ample nutrients were applied and each treatment was replicated four times. More or less uniform distribution of salt in the pots was maintained by partially leaching the pots periodically and returning the saline leachate to the top of the pot. Otherwise, irrigation was with salt-free water. The growth period was five months. Relations between the relative yield of marketable tomato and the electrical conductivity of the soil water at the field capacity and saturated paste water contents were determined. The absolute yield at the lowest yield of salinity was 9.1 pounds per plant. The relations at the field capacity water content showed that the Tropic variety, when compared with similar data (U.S. Salinity Lab) for temperate soils and for varieties of tomato grown in Western U.S., is only half as salt tolerant. On the other

hand, the relations at the saturation water-content erroneously indicated that the varieties have similar tolerance. The discrepancy results from the fact that with most temperate zone soils the saturation water content is about twice the field capacity rather than about the same as is the case for the Honuaulu soil. The Manu soil, also a Hydric Dystrandept, used for the greenhouse production of tomato at Volcano, Hawaii, actually has a higher field capacity water-content (98%) than saturated paste water-content (90%), apparently owing to disruption of aggregates during preparation of the paste. Additional data are needed on the relation between the saturated paste and field capacity water contents of tropical soils. If the relation is around 1:1 rather than 1:2, then most published data relating the electrical conductivity of saturation extracts to crop yield reductions should be divided by two.

With the marked increase in the commercial growing of tomato under plastic cover in the tropics, information is needed on irrigation practices and amounts of irrigation water required. In cooperation with B. A. Kratky of the Hawaii Agricultural Experiment Station Horticulture Department, Bowers initiated a split-plot irrigation experiment with the Tropic variety of tomato in the Kona Research Station plastic greenhouse. The experimental variables are two methods of irrigation, drip and 18-inch wide basins (main plots), and three levels of water achieved by irrigating when the soil-water tension 6 inches to the side of the plant at the depth of 6 inches reached 200, 400, and 600 cm of water (subplots). For all treatments, two quarts of water per plant are applied at each irrigation and a record of the amounts of water applied is maintained. Presently, 45 days after initiation of the experiment, the superiority of drip irrigation at the 400 and 600 cm-water

tension treatments is evident but larger amounts of water are required to maintain a given soil-water tension with drip irrigation.

Response of macadamia seedlings to liming is also being studied by Bower in soils which are as acid as pH 4.0 at the Kona Research Station. Crushed coral limestone was applied to small plots at rates of 0, 2 1/2, and 5 tons per acre; the lime was incorporated to a depth of 6 inches by rototilling, and young ungrafted seedlings about 12 inches in height were transplanted. The treatments was triplicated. Eight months after treatment, no visual response is evident.

Development of quantitative methods of assessing the tendency of K to leach from various tropical soils is still another study of Bower. This study includes predicting leaching losses as a function of depth of water moving through the soil. Equations have been developed for two volcanic ash soils.

3.3 Travel: Several faculty travels were supported by the 211(d) grant to fulfill some of the objectives of the project, to coordinate project activities, or to provide the faculty in developing further competence in carrying out the objectives of the project.

A summary of the travel activities are:

L. D. Swindale attended two joint meetings of the 211(d) Council of Deans and the Executive Committee and one separate meeting of the Council of Deans in Washington, D.C. during 1973-74. These meetings considered current progress and the future of the Consortium. The Council has paid particular attention to developing policies and recommendations to the Executive Committee that will ensure the continuation of the Consortium, strengthen it and enable it to provide greater service to AID in the future.

W. G. Sanford also attended the annual meeting of the 211(d) Council of Deans and the Executive Committee in November, 1973. Then, he presented a paper "Effect of Temperature on the Uptake of Nutrients by Pineapple Roots" at the annual meeting of the American Society of Agronomy in Las Vegas, Nevada (November, 1973).

R. C. Jones and G. W. Gribble attended the annual meeting of the American Society of Agronomy at Las Vegas, Nevada (November 11-16, 1973). Two papers were presented: "Plant Tissue Analysis by X-ray Fluorescence Quantometry" by R. C. Jones and E. N. Okazaki and "Total Elemental Analysis of Rocks and Soils by X-Ray Fluorescence Quantometry" by G. W. Gribble, R. C. Jones, G. Uehara, and E. N. Okazaki.

J. A. Silva presented a paper at the annual meeting of the American Society of Agronomy in Las Vegas, Nevada (November, 1973). The paper entitled "Fate of Applied Silicon in an Oxisol during Five Years Cropping" was authored by R. A. Khalid, J. A. Silva, and R. L. Fox.

J. A. Silva also spent a week in Puerto Rico (March, 1974) working with F. H. Beinroth of University of Puerto Rico to formulate plans for the Workshop on Experimental Design which was held in Hawaii during May 20-24, 1974. Plans for coordinating the AID project on the "Technology Transfer" were also made with the staff of the University of Puerto Rico. Some soils and crops of Puerto Rico were observed during the visit.

D. P. Bartholomew traveled to Raleigh, North Carolina, where he is on a half-year sabbatical leave at North Carolina State University (starting December, 1973).

W. T. Harada attended a course in project evaluation which was presented by the AID in Washington, D. C. (December, 1973).

H. Ikawa traveled September 29-October 6, 1973 to participate in Park City, Utah, in an AID-sponsored symposium, "On-Farm Management Research and Implementation" and to present a paper entitled "Systems of Soil Classification and their Relation to Water Management" by L. D. Swindale, G. Y. Tsuji, and H. Ikawa.

H. Ikawa also participated in the Western Regional Technical Work Planning Conference of the National Cooperative Soil Survey (Soil Conservation Service, USDA) held in San Diego, California during January 21-25, 1974. Benefit of this conference is to be informed of the latest developments in the soil survey program which includes soil characterization, classification, and interpretation at the University.

H. Ikawa attended a seminar on "Soil Management and the Development Process in Tropical America" in Cali, Colombia (February 10-14, 1974) and also participated in a post seminar soils tour of Colombia, Peru, and Brazil (February 15-25, 1974). Contacts with individuals from different countries, universities, and research institutes were most beneficial. Information gained and compiled during the seminar and the soils tour (including numerous photographs) are also very beneficial for use in research and teaching by the individual and others in the Department.

S. A. El-Swaify, while on a sabbatical leave in Australia, traveled from Adelaide to Perth during October 22-November 3, 1973 to meet with the scientists at CSIRO and at University of Western Australia. Conferences were held in the subject areas of soil structure, mineralogy, conservation, and properties and roles of sesquioxides. He also traveled to Brisbane and Townsville during December 1-13, 1973 to consult with and discuss research programs of colleagues at CSIRO in Queensland, at the Universities of Queensland, Grifith, and James Cook, and at the Sugar Bureau. Information gained on these trips will benefit the research program of the individual as well as that of the Department.

R. L. Fox was given partial support to attend the following meetings:

(a) Colorado State University - Prairie View A&M College - Texas A&M. Attended the Western Regional P Work group meetings and presented a report "Relationships between yields and the external and internal phosphorus requirements of crops"; presented a seminar on problems associated with growing crops on highly weathered soils at Texas A&M and gave guest lectures at Prairie View.

(b) University of W. I., Trinidad - Windward Islands - Dominican Republic. Presented papers "Examples of Anion and Cation Adsorption by soils of Tropical America" and participated in field trips to several of the Windward Islands.

(c) Nevada - Florida. Presented paper on "Internal and external P requirements for corn and sorghum growing on highly weathered soils" before the Soil Science Society of America and presented an invited paper on "Management of Andepts" before the Florida Soils and Crops Society and participated in seminars before the Department of Soils, University of Florida.

3.4 Reports, Working Papers, and Publications

Balasubramanian, V., Y. Kanehiro, P. S. C. Rao and R. E. Green. 1973. Field study of solute movement in a highly aggregated oxisol with intermittent flooding: 1. Nitrate. Jour. of Environ. Qual. 2(3):359-362.

Balasubramanian, V. and Y. Kanehiro. 1974. Adaptability of nitrate specific ion electrode for nitrate analysis in tropical soils. Hawaii Agr. Exp. Sta. Dept. Paper 19. 16 pp.

Beinroth, F. H., G. Uehara, and H. Ikawa. 1974. Geomorphic relationships of Oxisols and Ultisols on Kauai, Hawaii. Soil Sci. Soc. Amer. Proc. 38:128-131.

Beinroth, F. H., H. Ikawa, and G. Uehara. 1974. Classification of the soil series of the State of Hawaii in different systems. AID Bulletin (manuscript submitted).

Fox, R. L. 1973. Fertility of the savanna soils. Seminario Sorbe Suelos de Sabana en el Tropico. Dominican Republic.

Fox, R. L. 1973. Phosphorus of Oxisols. Proceedings Colombia Soil Sci. Soc. (in press).

Fox, R. L. 1973. Management of Andepts. Soil and Crop Sci. Soc. Florida Proc. (in press).

Fox, R. L. 1973. Agronomic investigations using continuous function experimental designs--Nitrogen fertilization of sweet corn. Agron. Jour. 65:454-456.

Fox, R. L. 1974. Examples of anion and certain adsorption by soils of Tropical America. Tropical Agric. (Trinidad). In press.

Fox, R. L. and B. Isobe. 1973. Crop quality control through soil management techniques: manipulating nitrogen and water to ripen sugarcane. Illustrated Concepts in Tropical Agriculture No. 5.

Fox, R. L. A study of highly weathered soils of Puerto Rico. Part III. Chemical properties. Geoderma (Manuscript submitted).

Goswami, K. P. and R. E. Green. 1973. Simultaneous extraction of hydroxy-atrazine, atrazine, and ametryne from some Hawaiian soils. Soil Sci. Soc. Amer. Proc. 37:702-706.

Jones, R. C., and G. Uehara. 1973. Amorphous coatings on mineral surfaces. Soil Sci. Soc. Amer. Proc. 37:792-798.

Kagbo, R. B., R. S. de la Pena, D. L. Plucknett, and R. L. Fox. 1974. Mineral nutrition of taro (colocasia esculenta) with special reference to phosphorus. Third Intern. Symposium, Tropical Root Crops, Sierra Leone.

Keng, J. C. and G. Uehara. 1974. Chemistry, mineralogy, and taxonomy of oxisols and ultisols. Submitted to Proc. of Florida Soil and Crop Science Society.

Rajan, S.S.S. and R. L. Fox. 1974. Phosphate adsorption by some Indian soils and its application for predicting phosphate requirements of millet. Indian Journal of Soil Science (Manuscript submitted).

Rajan, S.S.S. and R. L. Fox. Phosphate adsorption by soils II. Interpretation of adsorption isotherms and influence of phosphate adsorption on release of hydroxyl, sulfate and silicate. (Manuscript being reviewed).

Rao, P.S.C., R. E. Green, V. Balasubramanian, and Y. Kanehiro. 1974. Field study of solute movement in a highly aggregated Oxisol with intermittent flooding: 2. Picloram. J. Environ. Quality 3(3). (In press).

Ravoof, A. A., R. L. Fox, and W. G. Sanford. 1973. Low soil temperatures depress root activity in the tropics. Illustrated Concepts in Tropical Agriculture No. 6.

Santo, L. T. and G. Y. Tsuji. 1974. Soil bulk density and water content measurements by gamma-ray attenuation techniques. Accepted as Tech. Bull. Hawaii Agr. Exp. Sta. No. 98.

Swindale, L. D., G. Y. Tsuji, and H. Ikawa. 1973. Systems of soil classification and their relation to water management. Symposium on "AID's Role in On-Farm Management Research and Implementation." Park City, Utah. 10 pp.

Tsuji, G. Y., R. T. Watanabe and W. S. Sakai. 1974. Influence of soil micro-structure on water characteristics of selected Hawaiian soils. Submitted to Soil Sci. Soc. Amer. Proc.

Uehara, G. and J. C. Keng. 1974. Management implications of soil mineralogy in Latin America. Symposium on "Management of Tropical Soils." Cali, Colombia.

Uehara, G., M. S. Nishina, and G. Y. Tsuji. 1974. The composition of Mekong river silt and its possible role as a source of plant nutrient in Delta soils. Report submitted to the United Nations Committee for Coordination of Investigations of the Lower Mekong Basin, Bangkok, Thailand.

Warner, R. M., R. L. Fox and S. Prasomsook. 1974. Preliminary report on banana nutrition research. Hawaii Farm Science (in press).

3.5 Theses and Dissertations

Balasubramanian, V. 1974. Adsorption, denitrification, and movement of applied ammonium and nitrate in Hawaiian soils. Ph.D. dissertation. Univ. of Hawaii.

Gribble, G. W. 1974. Total chemical analysis of rocks, soils, and clay minerals by x-ray fluorescence quantometer. M.S. thesis. Univ. of Hawaii.

Hirunburana, N. 1974. Inorganic nutrition of papaya (Carica papaya L.) and macadamia (Macadamia integribolia, F. Muell). Ph.D. dissertation. Univ. of Hawaii.

Keng, J. C. W. 1974. Surface chemistry of some constant potential soil colloids. M.S. thesis. Univ. of Hawaii.

Khalid, R. A. 1974. Residual effects of calcium silicate on the movement and unavailability of nutrients in tropical soils. Ph.D. dissertation. Univ. of Hawaii.

Nishina, M. S. 1974. The composition of Mekong River silt and its possible role as a source of plant nutrient in the Delta. M.S. thesis. Univ. of Hawaii.

Santo, L. T. 1974. Soil water hysteresis in the inter-aggregate voids of two Hawaiian Oxisols. M.S. thesis. Univ. of Hawaii.

3.6 Dissertation Abstracts

Balasubramanian, V. 1974. Adsorption, denitrification, and movement of applied ammonium and nitrate in Hawaiian soils. Ph.D. dissertation. Univ. of Hawaii

The factors influencing adsorption, denitrification, and movement of applied ammonium and nitrate in tropical Hawaiian soils were investigated. Suggestions are incorporated to maximize crop utilization of field-applied fertilizer nitrogen and to minimize loss of mineral nitrogen through leaching and denitrification.

Some oxidic tropical soils, such as the Hydrandepts and Gibbsihumox, in Hawaii were found to adsorb nitrate significantly in pH ranges below 6. Non-specific anion adsorption is believed to be the major mechanism by which nitrate was adsorbed.

The zero point of change (ZPC), which has a close relation with non-specific anoin adsorption, is defined as the pH where the net sum of change is zero. The high ZPC of the subsoil of the Hydrandepts was attributed to the extensive hydration of their iron and aluminum oxides. Hydrolysis and polymerization of the hydrated oxides were suggested as major mechanisms for the decrease of ZPC and pH on drying the Hydrandepts.

Any change in the ZPC was shown to vary the nitrate adsorption. The significant decrease of nitrate adsorption due to dehydration of the Hydrandepts was explained by the change in the ZPC, pH, crystallinity, and surface area on drying. Since this dehydration process is irreversible, it was concluded that these soils should not be allowed to dry excessively by exposure to direct sun and wind so as to preserve their high exchange capacities, both for anions and cations.

The surface of the Hydrandepts and Gibbsihumox became less positive or more negative on liming, and this was reflected in the (increased) ammonium and (decreased) nitrate adsorption by the limed soils. The finding that raising of soil pH beyond 5.5 with liming produced NO_3^- repulsion in these soils should be taken into consideration in any liming program.

Denitrification loss was found to be important only in soils with large amounts of water-soluble organic matter and nutrients. Available energy source appeared to play a dominant role in denifrification. N_2 and N_2O gases were the prime denitrification products in all the soils studied. Denitrification potential was very low in Oxisols with poor organic carbon (both water-soluble and total) content.

In an infiltration study, it was found that the practically irreversible adsorption of ammonium was responsible for its retention in the Molokai soil. It was further shown that the higher the amount of water infiltrated, the deeper was the position of nitrate peak. An explanation is given on how to take advantage of the lag of nitrate peak with respect to the wetting front in the initially moist soil during transient water flow. For soils with the same initial moisture content, the depth of nitrate peak was in direct proportion to its wetting front. Thus by controlling the wetting front, one can control the depth of maximum solute concentration, irrespective of the rate of water application.

In short, modified management practices based on the knowledge of nitrogen transformation and transport in soils as well as nitrogen uptake by crops will ensure efficient (nitrogen) fertilizer use in crop production with a minimum chance for the pollution of ground water by nitrate.

Hirunburana, N. 1974. Inorganic nutrition of papaya (Carica papaya L.) and macadamia (Macadamia integribolia, F. Muell). Ph.D. dissertation. Univ. of Hawaii.

Nutritional requirement study of papaya and macadamia were conducted in three parts: (i) visual deficiency symptoms for N, Mg and B and the internal concentrations of these three elements associated with the symptoms in the greenhouse experiment were established; (ii) the effects of calcium carbonate and calcium sulfate with various sources of N on the nutrient composition and growth of papaya were investigated in the field experiment; (iii) the role of B in reducing Mn toxicity of papaya on the Wahiawa soil in this field was studied.

Papaya trunk weight, as well as trunk circumference, was found to be usable as an index for final yield of papaya. Maximum trunk weight was obtained at the 120 ppm N in the substrate with 1.73 percent N content in petiole No. 6. Concentrations of N in excess of 120 ppm resulted in decreases of Mg, S, K, Fe, and Mn, and increased concentrations of P, Ca and Zn.

The external Mg requirement for optimum growth of papaya was about 12 ppm. At this level, Mg content of papaya was found to be 0.22 percent in the leaf blade and 0.61 percent in the petiole. The increase in Mg concentrations in the substrate did not affect the internal concentrations of P and K but caused Ca, Fe, Mn and Zn concentrations to decrease.

Under greenhouse conditions, maximum growth of macadamia was obtained at the 30 ppm N in the substrate which was associated with 1.6 percent N in recently matured leaves. The excess N applications injured macadamia roots. The content of P, Ca, Mn, Zn and probably Fe in leaf decreased when N was increased beyond 120 ppm.

Visual symptoms of Mg deficiency in macadamia appeared at 0 to 1.5 ppm Mg in the added solution. The critical level of Mg in macadamia tree was established as 0.12 percent Mg in recently matured leaves. There was no pronounced effect of Mg on other nutrient composition of macadamia with the exception of K decrease.

Recently matured leaf blades seemed to be the best plant part to be used as an indicator of B status in papaya. Boron deficiency symptoms were associated with B content in leaf blades below 12 ppm whereas B toxicity occurred at 0.4 ppm added B. It was recommended to keep the internal B content at the range of 30 to 50 ppm B.

The critical B content of macadamia was 10 ppm in recently matured leaves. A 20 ppm B content in leaves was recommended as the sufficiency level. The concentrations of B above 65 ppm in recently matured leaves were probably in the range of toxicity.

The effect of calcium carbonate and calcium sulfate with various sources of N on growth and nutrient composition of papaya was investigated in the Wahiawa soil. Applications of Ca in either forms at the rates of 400, 800 and 1200 ppm resulted in highly significant dry weight increase over the control. Reduction of growth caused by overliming was shown at the level of 1200 ppm Ca as calcium carbonate. Therefore, the optimum level of liming the soil to improve papaya growth should be to the pH range of 5.7 to 6.1 or 5.5 to 6.5 me/100g of Ca.

The application of calcium carbonate and calcium sulfate alleviated Mn toxicity in Wahiawa soil. The preplanting N NH_4OAc extractable soil Mn at 7.2 ppm was considered enough to cause injury to papaya growth. The tolerable content of Mn for papaya growth was below 140 ppm in leaf blades and 35 ppm in pestioles.

The amount of Ca in the soil as well as soil pH were used to approximately estimate a toxic concentration of Mn in papaya by using a multiple regression analysis. A more precise estimation was obtained when soil Mn and soil Mg were also included as variables in the analysis.

Calcium sulfate applications increased the concentrations of leaf N, P, K and S. A similar trend was found in calcium carbonate experiment except leaf N and P decreased at the highest level of Ca application (1200 ppm). Urea application significantly increased soil pH in both calcium carbonate and calcium culfate plots, and lowered extractable Mn than did ammonium nitrate and ammonium sulfate.

The effect of B application on alleviation of Mn toxicity was demonstrated in Wahiawa soil using papaya as the indicator plant. Application of B to the soil tended to decrease Mn content of leaf blades at postplanting, especially at the levels of 0.2 and 0.4 ppm adjusted B levels in soil solution. Below or above these concentrations, the influence of B seemed to be less effective. It can be concluded that the effect of B on papaya growth in high Mn soil of Wahiawa is an indirect one. Possibly, B can react in the following ways: (1) forming complex molecules with soil Mn directly as it does with the hydroxides of Al and Fe; (ii) depressing amounts of Mn absorbed by plant roots, and (iii) increasing availabilities of other elements, such as Ca, Mg, P and Fe, which in turn may enable papaya plants to survive the high Mn content in the soil.

Khalid, R. A. 1974. Residual effects of calcium silicate on the movement and unavailability of nutrients in tropical soils. Ph.D. dissertation. Univ. of Hawaii.

The residual effects of calcium silicate on plant uptake and movement of nutrients in a Gibbxihumox were studied in a series of three experiments. First, Kikuyu grass and desmodium were grown in the field to determine the magnitude of response to residual Si applied several years earlier at various P and pH levels; second, the partial recovery of applied Si during five years of cropping was determined at 3 pH levels; and third, uptake of residual Si by rice grown on soil collected from the field experiment at the end of five years was studied in a growth chamber. A study of soil Al extraction methods in relation to plant Al uptake and yield was also conducted on some Hawaiian soils.

The combined yields of seven harvests of kikuyu grass and desmodium increased significantly with increasing residual P levels, but was not significantly affected by residual Si or soil pH. The relative yield differential between the three Si treatments decreased sharphy with time and at the end of 56 months yield from 1660 Si was only 2.5% higher than that without Si, whereas yield from 830 Si was less than the yield without Si. The decline with time in relative yield response to P applications, on the other hand, was small indicating a continued efficiency of P applied 56 months earlier in increasing yields on a Gibbsihumox. However, it should be pointed out that two supplemental additions of P were made 21 and 27 months after the initial treatments. Although residual Si produced highly significant increases in water-extractable soil Si, the levels at the end of the experiment were low which suggests that supplemental amounts of calcium silicate may be required to maintain yield response to Si. Modified Truog-extractable P was significantly higher at 1660 Si than at zero Si five years after Si applications. Phosphorous requirements of a Gibbsihumox were decreased significantly by residual Si and P in samples collected after 5 years of cropping. However, residual P was

about 7 times more effective than residual Si in reducing P requirements. Multiple regression analysis indicated that in addition to the initially applied treatments, soil P and Al and plant P, K, Mg and possibly also Mn, Zn, Al and Ca were important to plant growth in both species.

Plant uptake by the sugarcane plant and ratoon crops, corn, and seven harvests of kikuyu grass accounted for 12 to 21 percent of the applied Si while exhaustive extraction of profile samples taken at the end of five years with 0.1N acetic acid, adjusted to pH 3.5 and containing 50 ppm P, recovered 14 to 28 percent of the applies Si. There was no evidence that applied Si moved below 30 cm. Total recovery of applied Si ranged from 28 to 43 percent which means that 57 to 72 percent of the applied Si remained in the soil in some form not readily displaced by phosphate solution.

Rice plants extracted proportionately more native Si than did phosphate solution which resulted in comparable amounts of added Si being recovered by the two methods. Silicon uptake by rice accounted for 8 to 30 percent of applied Si and exhaustive phosphate extraction recovered 13 to 23 percent of applied Si.

The amount of Al extracted by various solutions decreased in the order of 1N ammonium acetate + 0.2N barium chloride, pH 4.8 > 1N barium chloride ≥ 1N potassium chloride ≥ water ≥ 0.01M calcium chloride. Aluminum extracted from five soils was in the order: Akaka (Typic Hydrandept) > Halii (Typic Gibbsihumox) > Wahiawa (Tropeptic Eutrustox) > Lualualei (Typic Chromustert) = Kawaihai (Ustollic Camborthid) which was related to the degree of weathering and the amount of rainfall affecting the soil. Soil Al extracted with unbuffered solution, ecially 1N potassium chloride, was more closely related to plant Al where as Al extracted with buffered solutions, especially 1N ammonium acetate, pH 4.8, was more closely related to plant yield than

that extracted with other methods. However, R values for the soil Al-yield relationships were generally lower than those for soil Al-plant Al relationships suggesting that while soil Al has a strong influence on plant Al, it has considerably less effect on yield.

4. Impact of Grant Supported Activities in Developing Institutional Capabilities: Through the 211(d) grant, the University of Hawaii has been able to improve the teaching and research capabilities. In undergraduate teaching, continuous efforts were made to up-grade the courses by further improvement in the audio visual tutorial approach and by publication and distribution of illustrated concepts. In graduate teaching, the students and staff were given the opportunity to attend the soil formation and classification class which was offered by a visiting professor. There were also opportunities to attend several seminars presented by visiting Professors Southard, Munns and Doxtader who were supported by the grant. Through travel and participation in seminars or like activities in out-of-state institutions, the teaching faculty developed further competency by contact with other of similar interests and by collecting teaching aids or materials.

In research, special effort was made to strenghten the programs of soil mineralogy. Instrumental methods of analysis have been or are being developed, and these developments have directed influence on the other research programs in the Department; for example, mineral composition of soils and the relation to plant nutrition. Input also has been made in the areas of soil chemistry, soil physics, and soil characterization and classification. The studies of these areas are significant because they have direct bearing on the knowledge of the behavior of soils. Then by conducting research in soil fertility and crop production, further understanding of the management of tropical soils was obtained. In this fourth year of the grant, the University of Hawaii,

together with the other members of the consortium are beginning to show the capability to undertake projects which deal with less developed countries. Hawaii and Puerto Rico, for example, are planning to carry out a Benchmark Soils Project which will investigate crop prodiction and land capabilities of a network of tropical soils in Hawaii, Puerto Rico, Africa, Asia, and South America.

5. Utilization of Institutional Resources in Development: The following activities were performed by L. D. Swindale, Associate Director of the Hawaii Agricultural Experiment Station:

(a) Development of an AID contract with the University of Hawaii on "Crop Production and Land Capabilities of a Network of Tropical Soil Families"

(b) Organizing and participating in a workshop on "Experimental Designs for Predicting Crop Productivity with Environmental and Economic Inputs" which was jointly sponsored by AID, the University of Puerto Rico, and the University of Hawaii, and involved all the Consortium Soils Departments.

(c) Developed an agreement with ARS for establishment in the University of Hawaii of on-line bibliographic and current research awareness services for tropical agricultural research.

(d) Worked towards the establishment of a Tropical Agricultural Research and Training Center at the University of Hawaii under the authority of section 406 of the Ford for Peace Act (PL - 480).

G. Uehara is on a year's sabbatical leave (September 1973 - August 1974). He was at Cornell University until December 1973, working with M. Drosdoff and M. G. Cline; and is now at North Carolina State University working with C. B. McCants and others. At both institutions, he held seminars and classes on the physics, chemistry, and mineralogy of tropical soils. During the year, he presented papers at the Florida Soil and Crop Science Society and

at a seminar on "Soil Management and the Development Process in Tropical America" in Cali, Colombia (February 10-14, 1974). He also participated in a post seminar soils tour of Colombia, Peru, and Brazil (February 15-25, 1974).

D. P. Bartholomew is on a half-year's sabbatical leave at North Carolina State University. He has taken four soils from Hawaii, two Oxisols and two Ultisols, for study in the phytotron at North Carolina State.

J. A. Silva coordinated the program for the workshop in Hawaii on "Experimental Designs for Predicting Crop Productivity with Environmental and Economic Inputs" (May 20-24, 1974). He also presented a position paper of Hawaii "Field Experimentation to allow Economic Evaluation of Management and Environment Effects on Soil Productivity. Silva was assisted by G. Y. Tsuji, H. Ikawa, and others in carrying out the program of the workshop. The results of the workshop can be used to guide a new AID-sponsored project on correlating food crop yields on a network of benchmark soils and in determining scientifically the trasnferability of agroproduction technology among developing tropical countries.

Following are students and faculty or staff in the Department of Agronomy and Soil Science at the University of Hawaii: Graduate Students [support from State, East-West Center (U.S. State Department), Rockefeller and Ford Foundations, Country of Origin, FAO, etc.]

Name	Arrival Date	Advisor	Home Country
Agronomy--M.S.			
1. Aragon, Ernesto L.	Fall '72	D. L. Plucknett	Philippines
2. Ayers, Dennis W.	Fall '71	H. Y. Young	U.S.
3. Hurdus, Alan R.	Fall '71	P. P. Rotar	U.S.
4. Ingamells, James L.	Fall '74	P. P. Rotar	U.S.
5. Kadzimin, Saleh B.	Fall '73	P. P. Rotar	Malaysia
6. Kagbo, Robert	Fall '72	W. G. Sanford	Sierra Leone
Agronomy--Ph.D.			
1. El-Tahir, Awad	Spring '70	J. A. Silva	Sudan
2. Eriksen, Flemming I.	Spring '74	A. S. Whitney	Denmark
3. Floresca, Emmanuel	Fall '71	D. L. Plucknett	Philippines
4. Guevarra, Anacleto	Fall '71	P. P. Rotar	Philippines
5. Pellek, Richard	Fall '71	Y. N. Tamimi	U.S.
6. Pyon, Jong Yeong	Fall '72	D. L. Plucknett	Korea
7. Seng, Tee	Spring '68	W. G. Sanford	Malaysia
8. Skolmen, Roger G.	Fall '73	P. P. Rotar	U.S.
9. Walters, Gerald A.	Fall '73	P. P. Rotar	U.S.
Soil Science--M.S.			
1. Daud, Abdul R. S.	Fall '72	S. A. El-Swaify	Malaysia
2. Elder, Vincent	Spring '73	B. L. Koch	U.S.
3. Furukawa, Michael N.	Spring '73	R. E. Green	U.S.
4. Oya, Jean	Fall '72	B. L. Koch	U.S.
5. Tama, Kato	Fall '72	S. A. El-Swaify	Cook Is.
6. Tengah, Abdullah B. C.	Fall '72	S. A. El-Swaify	Malaysia
Soil Science--Ph.D.			
1. Alvarez, Robustino	Fall '72	J. A. Silva	Argentian
2. Asghar, Mohammad	Fall '72	Y. Kanehiro	Pakistan
3. Arain, Mohammad Saeed	Fall '71	R. L. Fox	Pakistan
4. Braide, Jonathan	Fall '68	G. Uehara	Nigeria
5. Hudnall, Wayne H.	Spring '72	R. C. Jones	U.S.
6. Jellinger, Alice	Spring '69	P. C. Ekern	U.S.
7. Mukhtar, Muhammad	Fall '72	R. E. Green	Pakistan
8. Periaswamy, Sirapalli	Fall '70	H. Ikawa	India
9. Qureshi, Ara H.	Fall '73	Y. N. Tamimi	Pakistan
10. Rao, Palakurthi	Spring '70	R. E. Green	India
11. Stoop Willem	Fall '71	R. L. Fox	Netherlands
12. Syed, Muhammad M.	Fall '69	S. A. El-Swaify	India
13. Wann, Shing-Sun	Fall '73	G. Uehara	Republic of China
14. Watanabe, Roger T.	Fall '69	G. Uehara	U.S.

Research and Teaching Staff (Support from State funds)

Name	Specialty
Agronomy	
1. Bartholomew, Duane P.	Crop Physiology, Plant Nutrition
2. Bullock, Richard	Tree Physiology
3. De La Pena, Ramon	Root Crop Production, Crop Physiology
4. Plucknett, Donald L.	Crop Management, Weed Control
5. Rotar, Peter P.	Plant Breeding, Cytogenetics
6. Sanford, Wallace G.	Plant Nutrition, Physiology
7. Tamimi, Yusuf N.	Forest Soils, Nutrition
8. Thompson, John R.	Crop Production
9. Urata, Ukio	Plant Breeding
10. Whitney, A. Sheldon	Plant Nutrition, Crop Physiology
11. Young, Hong Yip	Plant Nutrition, Chemistry
12. Matsuyama, Dennis	Research Associate
13. Yoder, Ronald	Research Associate
Soil Science	
1. Ekern, Paul C. Jr.	Soil Management, Soil Physics
2. El-Swaify, Samir A.	Soil Physics, Irrigation
3. Fox, Robert L.	Soil Fertility, Crop Management
4. Green, Richard E.	Soil Physics and Soil-Pesticide Behavior
5. Ikawa, Haruyoshi	Soil Genesis and Classification
6. Jones, Rollin C.	Soil Mineralogy
7. Kanehiro, Yoshinori	Soil Chemistry, Soil Fertility
8. Koch, Burton	Soil Microbiology
9. McCall, Wade. W.	Soil Fertility
10. Silva, James A.	Soil Fertility, Soil Chemistry
11. Swindale, Leslie D.	Soil Genesis and Classification
12. Uehara, Goro	Soil Physics, Mineralogy, Water Science
13. Watanabe, Roger T.	Soil Testing

Research Staff (Contractual)

Name	Title
1. Ahuja, Lajpat	Assistant Soil Scientist
2. Ayers, Dennis	Research Associate
3. Bower, Charles	Soil Scientist
4. Chang, Annie	Junior Researcher
5. Dangler, Edgar	Assistant Soil Scientist
6. Escalada, Rudolpho	Junior Agronomist
7. Mapes, Marion	Assistant Agronomist
8. Mishima, Helen	Research Associate
9. Okazaki, Ernest N.	Junior Soil Scientist
10. Tsuji, Gordon Y.	Assistant Soil Scientist

Staff and Students (Full or Partial Support from 211(d) Grant during 1973-74)

Position	Name	Specialty
Graduate Research Assistant	Robustiano Alvarez	Soil Fertility
Soil Scientist	Charles Bower	Soil Chemistry
Graduate Research Assistant	Jonathan Braide	Soil Chemistry & Mineralogy
Jr. Researcher	Annie Chang	Analytical Chemistry
Visiting Associate Professor	Kenneth Doxtader	Soil Microbiology
Graduate Research Assistant	Vincent Elder	Herbicide Decomposition
Graduate Research Assistant	Ericksen Flemming	Pasture Management
Graduate Research Assistant	Michael Furukawa	Soil Physics
Graduate Research Assistant	Grant Gribble	Soil Mineralogy
Graduate Research Assistant	Niwat Hirunburana	Soil Fertility
Graduate Research Assistant	Wayne Hudnall	Soil Mineralogy
Graduate Research Assistant	Alice Jellinger	Soil Physics
Graduate Research Assistant	Rashid Khalid	Soil Fertility
Visiting Soil Scientist	Donald Munns	Soil Fertility
Jr. Soil Scientist	Ernest Okazaki	Soil Chemistry & Mineralogy
Graduate Research Assistant	Jean Oya	Soil Microbiology
Graduate Research Assistant	Richard Pellek	Forest Soils
Graduate Research Assistant	S. P. Periaswamy	Soil Genesis
Assistant Soil Scientist	William Sakai	Electron Microscopy
Graduate Research Assistant	Lance Santo	Soil Physics
Visiting Soil Scientist	Alvin Southard	Soil Genesis
Assistant Soil Scientist	Gordon Tsuji	Soil Physics
Graduate Research Assistant	Shing-Sun Wann	Soil Physics

6. Other Resources for Grant-Related Activities: Approximately 15 members of the staff who are supported by state or federal funds are directly and indirectly related to the research activities of the 211(d) grant. Many of them serve as academic advisors to graduate students who are supported by the 211(d) grant. The state or federal-supported salaries exceed $200,000 annually.

The study of the Lower Mekong Basin by G. Uehara, principal investigator, reported in the previous year's report, has provided $40,000 to the Department.

The recent grant from AID for the benchmark soil project to study crop production and land capabilities of a network of tropical soil families will provide still another $680,630 within a period of two years.

7. Next Year's Plan of Work:

7.1 Teaching and Extension Services: A Tropical Agronomy Short Course will be held in Honolulu in June, 1975. The program of this short course will be planned and coordinated by W. G. Sanford, G. Uehara, and W. W. McCall.

At least two of the staff members may participate in the ICRISAT meeting which will be held in December, 1974.

Plans are being made to organize a file of reports and other materials obtained at various seminars or symposia attended by the various members of the Department. The file will also include colored slides with notes or narration. These materials can then be available to other members of the Department for use in their teaching and extension activities.

7.2 Research: The mineralogical and chemical research programs of R. C. Jones, E. N. Okazaki, W. H. Hudnall, J. Braide, and others will continue with further work by means of the x-ray quantometer, electron microscope, and the x-ray diffractometer. As cited under the Accomplishment section, efforts will be directed toward improvement in the total analysis of rock, soil, and mineral samples, especially in the high concentrations of Fe_2O_3 and the low concentration of SiO_2.

The mineralogical investigation of two sequences of volcanic ash soils will be initiated by W. H. Hudnall. Aside from detailed studies by transmission and scanning electron microscopy, techniques such as neutron activation analysis will be used to differentiate the soils formed from andesitic ash and basaltic ash. Special emphasis will also be placed on identification of amorphous inorganic materials.

The ion exchange resin study will be continued by J. Braide. Accomplishment of the objectives will facilitate analysis of many soil

samples which are being characterized for soil classification, nutrition or fertility, and crop production.

The distribution of the Alfisols or soils with high base status will be examined on the other islands of Hawaii by A. R. Southard and H. Ikawa. The geographical areas of investigation will be similar to that of Oahu; that is, on the northern slopes which are exposed to the Northeast trade-winds, in areas where there is influence of sea spray, or in areas where the parent rock or parent material are alkalic. Several pedons will be collected for laboratory characterization. Southard and Ikawa will also seek soils in Hawaii which would be similar in classification to those of Puerto Rico.

The laboratory characterization of the Humults on the island of Oahu will be made by S. P. Pariaswamy, with special emphasis on the mineralogical and physical properties and their relation to behavior. When the study is completed, it is expected that soil date interpretations can be used more effectively in supporting, for example, (1) construction of houses and other dwellings, (2) erosion control, (3) crop production, and in evaluating (4) watershed behavior and areas subject to soil shippage in Windward Oahu.

Research work on soil water hysteresis and vertical infiltration in the Molokai and Wahiawa (Oxisols) soils will be published by G. Y. Tsuji. The new Benchmark soils project, recently funded by AID, will also be coordinated by Tsuji. Sample sites must be selected; samples must be collected, characterized, and classified; and fertility experiments must finally be established to fulfill the objectives of the new project.

Further studies on nitrate accumulation in tropical plants and soils, on the movement of applied ammonium and nitrate, and on the decomposition of organic matter residue are planned by Y. Kanehiro.

The experiment of J. A. Silva and his graduate student on the pH requirements of crops will be planted to sorghum, following the harvest of the ratoon crop of sugarcane. The nutrient culture solution will be completed and the data from the sugarcane experiment will be used in preparing a Ph.D. dissertation. Work on the reaction of Si will also be continued and new instrumental procedures will be used to analyze the samples.

On sabbatical leave from the University of Hawaii will be R. L. Fox, who will be conducting soil fertility experiments at IBADAN in Nigeria.

Joining the staff at the University of Hawaii on a six-month sabbatical leave from New Mexico State University will be J. U. Anderson. He will participate in meneralogical research, particularly electron microscopy of soil clay minerals, with R. C. Jones.