

PRNC119

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BIOLOGY AND MEDICINE (CTID-4500)

PUERTO RICO NUCLEAR CENTER

THE RAIN FOREST PROJECT

ANNUAL REPORT

Jerry R. Kline, Carl F. Jordan, George E. Drewry

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Movement of ^{86}Sr and ^{137}Cs by the Soil Water of a

?Tropical Rain Forest a

---Page Break---

?TERRESTRIAL ECOLOGY PROGRAM I

?THE RAIN FOREST PROJECT

Jerry R. Kline, Ph.D. Heat

?ABSTRACT

The Rain Forest Project is a series of studies on one small area of montane rain forest 1500 feet up the side of El Yunque mountain in eastern Puerto Rico. It has three objectives: 1) to study the effects

of gamma radiation on the tropical ecosystem; 2) to study mineral cycling and dispersion in the system; 3) and to study the basic biological functions of this ecosystem such as respiration, transpiration, and photosynthesis to better understand phenomena related to the first two objectives. The project is in its fifth year. A section of the forest was irradiated and many follow-up studies have been completed, (For details of the radiation experiment see PRIC-82, Annual Report 1965). Present effort is being directed to long term studies on recovery and succession of vegetation in the irradiated area, and to detailed investigations of mineral cycling and distribution in the tropical ecosystem. Studies are carried out at both the PRIC Rio Piedras laboratories and at the El Verde field laboratory.

This year's report contains sections on recovery of the irradiated area, light measurements in the forest, water and nutrient cycling in the forest and radionuclide behaviour in certain animals. An appendix lists papers which have been published or have been submitted. The report is assembled from subsections which contain preliminary summaries of subprojects. Each subproject is a convenient work unit which may or may not be sufficient unto itself, in providing explanations for processes

place in the rain forest. The subsections are signed by the investigator who prepared them and who took the greatest initiative in carrying out the work. Final summaries are prepared by combining subsections in appropriate ways under the co-authorship of various project

scientist:

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Figure 1, Irradiated area, Nov. 1966. Pipes and cenent platform
in center supported source.

---Page Break---

RADIATION RECOVERY*

C.F, Jordan

The objective of these studies ie to determine how the radiation
danaged area recovers, and to compare this recovery vith recovery of
another area in the forest that was mechanically stripped of leave
Total biomass, number of individual plants, ani species diversity vere
determined in 1966 and 1967 by measuring every plant within a 676 me
grid that surrounds the radiation source location. Data was broken down

into several categories; new vegetation (started from seed after radiation ceased), sprouts, old vegetation (plants existing prior to radiation), and vegetation occurring on the two soil types within the irradiated area. Biongs data was determined by digging up 150 small trees, 35 sprouts and 20 mé of grass in another area, measuring them, getting their dry weight, correlating weight with dianeter, and applying these correlstions to plants in the irradiated area. Correlation coefficients ani other statistics are given in Table 1,

Radiation recovery was compared to recovery from mechanical strip-ping ty leaf area index measurements. ?Table 2 shove that while quantity of new vegetation in the irradiated area has been increasing, quantity in the stripped area began to decline in the sumer of 1967. The decrease in new vegetation in the stripped area coincides with an increase in the strip-ped canopy (old vegetation). Dieback of the irradiated canopy apparently has ceased,

Species diversity and mmber of iniividuals increased by about a half, between 1966 and 1967 (Table 3). Biomass more than tripled in this one year (Table 4). Biomass of important species and groups of species in 1966 is given in Table 5.

?Continuing effort

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Table 1

Biomass correlation statistics

A Correlations

Y = Biomass in grams of dry weight

X = Basal diameter in 1 of an inch

al dteneter in sh

N= Number of samples on which regression was based

Tree-shaped species (less than 2 inches diameter)

$Y = .0289x^2 - .2525x + 13.4557$ (1 = 150)

Sprouts

$Y = .0203x^2 + .7657x - 2h.ho$ (w= 35)

Prytolecea

$$Y = .0376x^2 - 2.10T6x + 28.1843 \quad (w = 13)$$

Grasses and Sedges

$$Y = 426. \quad (\$ \text{ coverage of one nm?}) \quad (w = 10)$$

Desmodium

$$Y = 615. \quad (\% \text{ coverage of one n}^\circ) \quad (w = 10)$$

B Fitting all tree species to one correlation

Slope and Y intercept of the regression and log of biomass on log of basal diameter for *Drypetes glauca* was tested against slope and Y intercept for *Piper aduncum* by analysis of covariance to test for differences in these two species, both of which have a tree-like shape, that is, a single stem. An "F" test indicated no difference in slope nor in Y intercept. Therefore one correlation was used for all tree-like species.

---Page Break---

Continued Table 1

© Determining best correlation

Determined from 10 samples of *Piper aduncum*

x x Correlation coefficient,

atancter weight oT

height weight 9h

Ataneter height +93,

height weight

(adjusted for dia.-wt, correlation) 2h

little, if anything, is gained by height measurement, after weight measurement is made.

D Reliability of regression

The 95% Limit of confidence around the regression line generated

by the log of data derived from 10 samples of *Piper aduncum* at 5 values of X, te:

Diameter (X) Dry Weight (¥) 3 (a=.95)

(qh 8 of an inch) (grams) ?

20 Le 3.0

50 20.4 27

10 56.9 27

100 168.5 2.8

200 1395.0 3.0

---Page Break---

eat area tnteses of nev ant old vegetation in
the tiredtated and bechanteally stripped areas

Rag RE GT he. IT AE

Trradiated area, new

?wartation 6 hag 8.06

Trettation Ls 663 als

Tevadinted area, old

?reaetation 20 2k

Stripped area, old

weectation 253 a aBe 3.08

|

mnie 3

?Summary of epectes and intivisuals in yartous categories,
fn the trvadiated aren, in 1960 and 1967,

ee

Mo of apectes Mo, of intividunis

1

pe dean ett (3)

ew vegetation o aor

Sproute. 2 es

Old vegetation a st

Poorly drained sot (2900)

ev vegetation © Le

Sprouts 2 i

01d vegetation 2 ar

Total, 1966 ome 5,26

967

Weld drained aot1

Tew vegetation 2 4m

Sprouts & ?eet

Old vegetation 38 oS

Poorly dretoed eoi1

ev vegetation 8 3,268

Sprou a 258

Old vegetation a ie

?otal, 1967 rae 8en

?Several speces occur in several groups. Therefore, total
number of species for entire aren doce snot equal the six?of the
fottviduat groupe.

a

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Table &

Bionass of nev plants and sprouts in the irredisted erea in 1966 and 1967

?Total gms. in area fn?

?(ary weight) (ary vetght)

1966

Well drained sot) (386n)

New vegetation 951388 aur

Sprouts 26,678 6

Poorly drained soil (290m?)

ew vegetation 36,691 126

Sprouts 43899 16

Total, 1966 163,656 hoe

1967

Well drained soil

New vegetation 323,256 837

Sprouts My Ter 123

Poorly drained soil

ew vegetation 139,893, id

Sprouts 8) 7h 30

Total, 1967 519,620 168*

*This is the average bionass/n° for total area.

?

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Figs. 1 and 2 show the change in the irratiated area in 16 months

Due to growth of new vegetation,

Table 6, which shows numbers of indi-

viduals for every species, is a reference list for future studies,

Both the mechanically stripped area and the irradiated area are

recovering, but in different ways.

The stripped area is recovering by

regrowth of the old canopy, while in the irradiated area, recovery is

mainly by growth of new vegetation.

Rates of increase of species

diversity and number of individuals are very high in the irradiated area

at the present time. Species diversity is now higher than the species

diversity of the mature forest. Within the next few years, diversity

and number of individuals should start a downward trend toward the levels

of the mature forest. Standing biomass will of course continue to increase

from year to year,

but it will be very interesting to see at what stage

the forest will have the highest rate of biomass production.

Table 5

Biomass of important species and groups of species of
new vegetation in the irradiated area in 1966.

Species or group	Grams, dry weight
------------------	-------------------

<i>Piptocarpha teosandra</i>	11,406
------------------------------	--------

<i>Desmodium procumbens</i>	Ano
-----------------------------	-----

<i>Psychotria berteriana</i>	25,779
------------------------------	--------

<i>Palicourea riparia</i>	13,033
---------------------------	--------

<i>Cecropia peltata</i>	15,497
-------------------------	--------

<i>Tabebuia heterophylla</i>	5,967
------------------------------	-------

<i>Didymopanax norotoni</i>	12,559
-----------------------------	--------

Grasses and sedges	32,804
--------------------	--------

Sprouts	31,577
---------	--------

Other herbs	Ths
-------------	-----

Other trees	10,199
-------------	--------

Percent, total biomass

6.9%

2.5%

15.7%

1.9%

9M

3.66

7.66

20.0%

19.28

hg

6.28

---Page Break---

Table 6

Number of individuals of each species in 676m² surrounding the radiation source in 1966 and 1967. Species are grouped according to whether vegetation originated before or after radiation, whether the individuals are sprouts, soil type on which individuals occur, and year of sampling. An asterisk

indicates a grass-like plant, and numbers in "individuals" column for these species indicate number of quadrats in which species was found.

Vascular plants, originating after radiation from seed, in the radiation area in the fall of 1966, on the soil showing oxidized conditions.

Species Individuals

Psychotria berteriana D.C. 509

Fallicoures riparia Benth. & Hook. ash

Gecropia peltata 1. 21k

Didymopanax morototont (Aubl.) Dene. & PL. igi

Isnanthus pallens (Sw.) Munro; Benth. 183*

Gasearia bicolor Urban. 150

Aichornea latifolia Sw. 32

Tinociera doningenis (Lam.) Knobl. 2

Miconia racemosa (Aubl.) ?De. 108

?*Tabebuia pallida* Miers, 98

Securidaca virgata Sv. &

Rajania cordata L. 58

Eyrsonina coriacea (Sw.) De. iy

Prytolaces icosandra L. 43

?*Aichorneopsis portoricensis* Urban. pt

Miconia tets Sw.) D. Don. 31

Paspalum conjugatum Berg. 3

Drypetes glauca Vahl. 31

Nepsera aquatica (Aubl.) Naud. a

Miconia prasina (Sw.) De. 3

Dacryodes excelsa Vahl. 19

Desmodium procumbens (Mill.) Hitchc. 16"

Solanum rugosum Dunal. 45

Gasearia arborea (L.C. Rich.) Urban. ah

?*Inga vera* Willd. B

Groton poecilanthus Urban, 20

Clidemia strigillosa (Sw.) De. 10

Spermacoce confusa Rendle. 10

Heteropteris laurifolia (L.) Juss. T

Ocotea jucunda (Sw.) Mez. T

Sapium laurocerasus Desf,

---Page Break---

?

Continued Table 6

?

Sloane berteriana Choisy

Gcotea moschata (Pavon) Mez.

Snilex coriacea Spreng.

Solanun tormm Sw,

idendrun nocturnim Jacq.

Iponea ?repanda Jacq.

Icorudolphia volubilis (Willa,) Britton,

Tetragastris balsanifera (Sw.) Kuntze.

Guettarda laevis Urban.

Matayba Gomingensis (De.) Radlk.

Qcotea portoricensis Mez.

Hedychiun coronarium Koenig

Peperomia rotundifolia (L.) H.B.K.

Euterpe globosa Gaertn.

Gasearia syivestris Sy.

Piper aduneun ?E.

Ficus sintenisti Warp.

Grille raceniflora 1.

Piper analago E.

Piper treleaseamm Britton & Wilson

Citrus spp.

Gordia suleata De.

Fanicus boliviense Hack.

Folypodium spp.

Guatteria caribaea Urb.

Bugenia stahlia (Ktze) Krug & Urban.

Naregravia rectiflora Tr. & Pl.

Henrietta fasciculata (Sw.) C. Wright

Guarea raniflora Vent.

Gottia borinquensis Vian,

Manilkera bidentata (A.DC.) Cher.

Inga fagifolia (E.) Willd,

Meliosma herberti Rolfe.

Elephantopus mollis L,

Rourea glabra Griseb.

BO WUU REE EUE HEHE EH HEE ME BAD 11ND

Continued Table 6

Sprouts, originating after radiation, in the radiation area in the fall of 1966, on the soil showing oxidized conditions.

Species Individuals

*Soanea berteriana*_ Choisy. 15

Palicourea riparia Benth. & Hook. 33

Rourea glabra Griseb. G4

Daczyodes excelsa Vail. 2

Matayba domingensis (De.) Radlk. 22

Drypetes glauca Vahl. 18

Higenia stahlia (Kiacrok) Krug & Urban. Y

Manilkara bidentata (A.De.) Cher. 16

Hirtella 3 serosal Bese %

Inge fagifolia (L.) Wiad. u

Geotea moschata (Favon) Nez. _ 2

Guettarda leavis Urban, 2

Miconia prasina (Sv.) Dc. 10

Groton poceflanthus Urban. 10

Nelioana herberti Rolfe.

krugit Urban

Tetragastris balsamifera (Sw.) Kuntze

Micropholis garcinifolia Pierre.

Maregravia rectiflora Tr. & Pl.

?*Byrsonima coriacea* (Sw.) De.

heteroptenis *tmifolis* 1, Tie,

Poliocarpus calinoides (Eichl.) Gilg.

?*Faychotria berteriana* De.

iedisia gisuciflora Urban.

igreia epleniens (Sv.) De.

Hajania cordata 1.

Wiconia racemosa (fubl.) De.

Qeotea portoricensis Moz.

Txora ferrea (Jaca.) Benth.

---Page Break---

Continued Table 6

Vascular plants, at least partly living, originating before radiation,
growing in the radiation area in the fall of 1966, on the soil showing
oxidized conditions.

Species Individuals

Sloanea berterfana Choisy ~

Bourea glabra Griseb,

Eugenia stahlii (Kiaerok) Krug & Urban 5

Dacryodes excelsa Vahl. rs

Fallicourea ripartii Benth, & Hook. a

Nanilva bidentata (A.Dc.) Cher. 2T

?*Tetragastris balsamifera* (L.) Kuntze es

Esteropterys laurifolia (L.) Juss.

?*nga fagiifolia* (L.) Wid. 20

tes glauca Vahl, bs

Iyreta leptoclada De! a

Heliosma herberti Baise.

Natayta domingensis (De.) Radlk.

Sascaria arborea (L.C, Rich.) Urban.

Hirtella rugosa Pers.

Euterpe globosa Gaertn.

eropholis garciniaefolia Pierre.

Miconia prasina? (Sr) De

Guettarda laevis ?Urban,

Grmosia krugit Urban.

nora ferrea (Jacq.) Wee

Geotea Leucoxylon (Sv.) Mee.

onia tetrandra (se) D. Don.

Geotea moschata (Pavon| or

Zinociera domingensis (Lax.) Knobl.

Gordie boringuensis Urban.

Aichornea latifolia sw.

Georopia peltata 1,

Eyrsonima coriacea (Sw.) De.

Homaliun racenosum Jacq.

Cascaria sylvestris Sv.

Snilax coriacea Spreng. ,

Casearia guianensis (Aubl.) Urban,

Aichorneopsis portoricensis teen.

Didymopanax norototent = (hib1.) Dene, & BL

Buchenavia capitata (Vahl.) Bichl,

Tabebuia pallida Miers,

Qeotea floribunda (Sw.) Nez,

Daphnopsis philippiana Krug. & Urban.

PEPE HEE PER RRUWUU REE EE ON OO

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Continued Table 6

Ardisia glauciflora Urban

iiigreta uetieea (Boir.) De.

Geotea yortoricensis ?Nez.

Schlegelia brachyantha Urban.

?Saaree rani Fiore vent

Unknown species

GCordia sulcata De.

PePPE ee

Vascular plants, originating after radiation from seed, in the
radiation area in the fall of 1966, on the soll showing reduced conditions,

Species Individuals

Palicourea riparia Benth. & Hook. 203

Tabebuia pallida Miers. 199

Tenanthus pallens (Sw.) Munro; Benth, 133*

Seouridaca vilgats Sw, on

Paychotria berteriane ?De. 9

morototoni (Aubl.) Dene. & Pl. 63

Beotegte ?Pelteata L. 56

ichornea latifolia? sw. i

Groton poecilanthus Urban, 3

Drypetes glauca Vahl. 2

Desmodium procumbens (Muhl.) Hitch. 26%

Linociera doningensis ?(Lam.) Knobl. 23

Miconia tetrandra (Sw.) D. Don. 20

Inga vera Willd. 1T

Miconia racemosa (Aubl.) De, It

Daoryodes excelsa Vahl. B

Rajania cordata L. 3B

Fanioum bolivense Hack. a

Seleria spp. oe

Eugenia stahlit (Kisensk) Krug & Urban,

Inga fosifolia (L.) Willa.

Gesesia blssior Urban

Bprsonina coriacen (Sv.

Paspalum conjugatia ?Berg.

Miconia tetrandra (Sw.) D. Don.

Hegeers aquahice (Ach) neva,

Miconia prasina (Sw.) De.

Howes glabra oriseb.

PUM agassa

13,

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Continued Table 6

Casearia arborea (1.C. Rich.) Urban

Matayba domingensis "De. Radlk.

KeoFuialphia volubilis (Willd.) Britton

Bye ey!

Alchorneopsis portoricensis petan

Heteropteris laurifolia L. (Juss.

ixora ferrea ?(Jacq.) Benth.

Smilax coriacea Spreng.

Brytolacea icosandra 1,

Piper hispidum Sw.

Cissampelos parira L,

Bauregesia erecta L.

Sloanea berteriana Choisy.

Maroegravia rectiflora Tr. & Pl,

Piper treleaseanum Britton & Wilson

Trichilia palliata Sw.

Henriettella tascularis (Sw.) C. Wright.

Bolanum rugosum Dunal.

Guarea raniflora Vent. ;

Gayaponia americana (Lam.) Cogn.

Euterpe globosa Gaertn,

Toumefortia hirsutissima L,

?lon (8.

Coceolobis pirifolia Desf.

Galyeogoniun squamulosun Cogn,

Deoten *Teucogion* (ov) Meee

Guettarda laevis near

Dendropanax arboreun (i.) Dene. & P.

Mikania fragilis Urban.

Guettarda carfbaea Urban,

Philodendron Lingulatun (L.) C. Koch,

Cordia boringuensis Urban

Gasearia sylvestris Sv.

PEP EHEE EE HHO DUN DUD RUWWUWUWL EE ee

uh

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Continued Table 6

Sprouts, originating after radiation, in the radiation area in the
f911 of 1966,?on the soll shoving reduced conditions.

Species

- Groton poecilanthus Urban.
- Palicourea riparia Benth, & Hook
- Warcgravia rectiflora Tr. & Pl.
- Rourea glabra Griseb.
- Sloanca berteriana Chotey.

Drypetes glauca Vahl.

Heteropteris laurifolia (L.) Juss.

Casearia sylvestris Sv.

nga vera Willd.

Eugenia stahli: (Beene) Krug. & Urban.

?*Byrsonima coriacea* (Sw.) De.

Ixora ferrea (Jacq.) Benth.

Manis Didentata (A.De.) Cher.

Casearia arborea (L.C. Rich.) Urban.

(Se.)_D. Don.

Geotea portoricensis Nez.

nga fagifotia (LJ Willa.

Calycogoniu squamilosun Cogn.

Cordia boringuensis Urban.
roa domingensis (Dc.) Radlk.

Wiconia prasina (Sw.) De.

15

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Continued Table 6

ee

Vascular plants, at least partly living, originating before radiation,
growing in the radiation area in the fall of 1966, on the soil showing reduced
conditions.

Species Individuals

Palicourea riparia Benth. & Hook. f.

Rourea glabra Griseb. AL

Ficus laurifolia L. Juss. 38

Byenia stemit (Kiaersk.) Krug. & Urban 18

Euterpe globosa Gaertn., 18

Drypetes glauca (Hyacinth.)

Inga fagifolia (L.) Wierzb., 10

Guarea raniflora Vent. do

Nanilarga bidentata (A. DC.) Chod.

Cordia borinquensis Urban

Sloanea berteriana Chodat

Miconia tetrandra (Sw.) D. Don.

Dasylirion exaltatum Vahl

Ilex ferrea (Jacq.) Benth.

Tabebuia pallida Miers.

Ocotea pertoricensis Mez.

Caleoglyphis squamulosa Cogn.

Aichornea latifolia Sy.

Matayba domingensis (De.) Radlk.

Casearia sylvestris Se.

Maregravia rectiflora tr. & Pl,

Tetragastris balsamifera (Sw.) Kuntze.

Homalium racenonae Jost.

Miconia sina (Sw.) De.

Micropholis garetnifolia perme.

Hirtella rugosa Per:

Groton poccsianthus Urban.

Gecropia peltata L.

Inga vera? Willd.

Zasearia arborea? (1.C. Rich.) Urban

Gyrilta racenifiora ?r,

Piper analoago 1.

Myreia splendens "(sv.) De.

Ormosia krugit Urban

Cassipourea alba Grised.

iiia deflexa (Poin) De.

Pisonia subcordata Sw.

Dennstacdtia adiantoides

BPP E EEE EER RRR MWWWU FEE EON OOO

(H. & BL) Moore

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Continued Table 6

Vascular plants, originating after radiation from seed, in the
radiation area in the fall of 1967, on the soil showing oxidized conditions.

Species Individusis

Psychotria berteriana De. 643

Di orotoni (Aubl.) Dene. & Pl. 323

Tenanthus pallens (Sv.) Munro; Benth. Bee

Fallicourea riparia Benth. & Hook. ett

Ballida Mers. 2a

Einociera domingensis (Lam.) Knobl. an

Miconia sintensis Cogn. 263

Securidace virgata Sv. 126

Casearia bicolor Urban. 126

Casearia arborea (1,C, Rich.) Urban. 91

Wiconia prasina (Sv.) De. 7

Gecropia peltata L. 95

Fospalum conjugatum? Berg. gx

Desmodium procumbens (Mill.) Hitchc. bo

Rourea glabra Griseb. 6

Erythronium coriacea (Sw.) De. 58

Aichroea latifolia Sv. 51

Mikania fregii Urban, 56

Dryopteris deltoidea (Sw.) Kuntze. 3

Euterpe globosa Gaertn. 50

?*Alchorneopsis portoricensis* Urban. ig

Matayba domingensis (De 49

Drypetes glauca Vahl. a

Dacryodes excelsa Vahl. 39

Nepenthes aquatica (Jacq.) Naud. 31

Miconia tetrandra (Sw.) 30

Guarea trichilicarpa 1. 29

Gynerium arborea (L.) J.B. Smith 26

Guaree raniflora Vent. 21

?Eugenia stahlia (Kiersk) Krug. & Urban. 19

Menilkea bidentata (A.Dc.) Cher. ag

Bloanea berteriana Choisy. 1

Heterotrichum cymosum (L.) Urban. 18 oe

Wepthrolepis rivularis (Vahl.) Mett. ar eZ

Solemum rugosum Dunal. 6

Ocotea leucaxyon (Sw.) Mex. 15

Hisophila boringuefia Maxon. &

Inga vera Willd. 3B

aT

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Continued Table 6

SSS

Heteropteris laurifolia (L.) Juss.

Hirtella rugosa Pers.

?Tetragastris balsasifera (Sv.) Kuntze

Eger etunem 1,

ponoea repanda? Jacq.

Commelina Sp.

Panieun oliviense Hack.

Homaliua racenosun Jacq.

Geotea moschata (Pavon.) Mez.

?olacca icosantra iL.

Digscorea polygonoides ?H.&B.; Willa.

Guettarda laevis Urban.

Sapiun lairocerasus De

Clusia gundlachii Stahl.

Maregravia rectiflora ?Ty. & Pl.

Elephantopts mollis L.

Cordia boringuensis Urban.

Dolioce galinofdes (Eichl.) Gilg.

Henrietella fascicularis (Sw.) Sauville.

Gyrlis racenifiora ?E~

Borreira ocimoides (Burm. £.) De.

Myreia splendens (Sw.) De.

Piper treleaseanum Britton & Wilson,

Gordia? sulcata De.

Daphnopsis philippiana Krug. & Urban,

Rajania cordata 1.

Casearia sylvestris Sw.

Solanum torvum Sy.

Quootea portoricensis Mex.

Desmodium sp.

Solanum sp.

Inga fagifolia (L.) Willd.

Bpermacoe tenuior? L,

Hedychium coronarium Koenig.

Roystonea borinquenia Cook.

Omosia krugii Urban,

Micropholis garcinifolia Pterre,

Meliosma herbertii Rolfe.

Miconia racemosa (Aubl.) De.

Paullinia pinata L,

Heliconia binai L.

Paspalun

Smilax coriacea Spreng.

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Continued Table 6

Sauvagesia erecta Ly

Trora ferrea Jacq; Benth.

Piper amalago 1.

Eupatoriuz odoratun 1.

Ficus laevigata Vahl.

ania cordifolia (L.F.) Willd,

Glidenia strigiliosa (Sv.) De.

fun sp.

Gayaponia anericana (Lam.) Cogn.

piawe rigeeeee. 1

Eugenia janbos 1.

Guatteria caribea Urban.

Cestrun macrophyliun Vent.

Unknown species

Myreia leptoclada De.

Comocledia glabra (Schultes) Spreng.

Spigelia anthelnia 1.

Scleria sp.

BE PPP PPE E REPPE RRR

%

Sprouts, originating after radiation, in the radiation area in the fall of 1967, on the soil showing oxidized conditions.

Species Individuals

Sloanea berteriana Choisy. 163

Palicourea riparia Benth, & Hook, 122

Faychotria berteriana De. 2

Fourea glabra Griseb. 6.

Matayba domingensis (De.) Radlk. 2

Miconia sintenisii Cogn. 20

Eugenia stahlia (Kiaersk) Krug. & Urban. 15

Groton poecilanthus Urban, ak

Dacryodes excelsa Vahl. uy

Hyreia leptoclada De.

nga fagifolia (L.) Willa,

Neliosma herbertit? Rolfe.

Grnosia krugii Urban,

Qeotea moschatia (rev) oF

Heteropteris laurifolia (L.) Juss.

Miconia prasina (Sw.) De,

Casearia arborea (L.C, Rich.) Urban,

Marcgravia rectiflora ?Tr. & Pl,

aareoooob&

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Continued Table 6

Tetragastris balsanifera (Sw.) Kuntze.

Tabebuia pallida Mier

?fragilis Urban,

Cordia boringuensis Urban.

Trichilia pallida Sv.

Alchorneopsis portoricensis Urban.

Drypetes glauca Vahl.

Maniikera bidentate (A.De.) Cher.

Piper aduncun,

Didymopanax morototont, (Aubl.) Dene. & PL.

Gecropia peltata L.

?yrsonina coriacea (Sv.) De.

Solanum rugosum Dinal.

Linociera domingensis (Lam.) Knobl.

rei aplentens (Sv.) De.

Casearta bicolor Urban.

Hrtella rugosa Pers,

Hichornea latifolia ov.

Geotea portoricensie Nez.

Wieropholie garcinifolia Pierre.

isi

ia glauciflora Urban.

Gyathes arborea (E.) J.B. Snith

Dioscorea polygonoides H.B.; Willd,

Schlegelia brachyantha Urban.

Inga vera Willd,

PP PPD DR DORN MRWWUUUW EEE EEN

Vascular plants, at least partly living, originating before
radiation, growing in the radiation area in the fall of 1967, on the
8011 showing oxidized conditions.

Species Individuals

Sloanea berteriana Choisy 6

Bugene stahlii (Rivers) Krug. & Urban, 32

Hourea glabra Griseb. Fs

Palicourea riparia L, aL

Nanilkara bidentate (A.De.) Cher. 5

Heteropteris Inurifolia (i.) Juss. th

?*Inga fagiforta* (L.) Willa. 2

Dacryodes excelsa Vahl. 3

Euterpe globosa Gaertn.

Guettarda laevis Urban. 5

Tetragastris balsanifera (Sv.) Kuntze 3

ia leptoclaia De, ;

Matayba doningensis (De.) Radlk.

?

20

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Continued Table 6

Ormosia krugit Urban.

Wirtella rugosa Pers.

Micropholis garcinifolia Pierre.

Miconia tetrandra Sw.

Inora ferrea Jacq. Benth.

Diypetes glauca Vahl.

Gordia boringuensis Urban.

Neliosna herbertii Rolfe.

Tinociera domingensis (Lam.) Knobl.

Byrsonima coriacea (Sw.) De.

Daphnopsis philippiana Krug. & Urban.

Condia sulcata De.

Miconia prasina (Sw.) De.

Timaliun racenoam Jaca.

?*Qeotea moschata* (Favon.) Nesz.,

Tasearia arborea

Tabebuia pallida Miers.

Didymopariax morototoni (Aubl.) Dene. & Fl.

Gecropia peltata L.

Grills raceniflora? 1.

Geotea Leucoxylon (Sv.) Mec.

Waregravia rectiflora Tr. & Pl.

Groton poeciianthus Urban.

PEPE PPB EEE EE RD DWUWOY FEE

Vascular plants, originating after radiation from seed, in the
radiation area in the fall of 1967, on the soil showing reduced conditions.

Species Individuals

Tabebuia pallida Miers. 88h

Palicourea riparia Benth. & Hook. 383

Tenanthus pallens (Sv.) Munro; Benth. 2ghe

Securidaca virg Sw. 198

Miconia sintenisii Cogn. 126

Psychotria berteriana De. 122

Didymopanax morototoni (Aubl.) Dene. & Pl. 108

Desmodium procumbens (K111.) tena, 106"

Cecropia peltata L. 8

Croton poecilanthus Urban. 2

Mikania' fragilis Urban. 6

Paspalum conjugatum Berg. 58

Tinociera domingensis (Lam.) Knobl. 55

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Continued Table 6

ee

Drypetes glauca Vahl. 2

Nepsera aquatica (Aubl.) Naud. to

Miconia prasina (Sv.) De. My

Ings vers Wilda. 35

Alchorneopsis portoricensis Urban. 35

Alchornea latifolia Sw. 32

Panicum oliviense flack. 30*

Casearia bicolor Urban. ar

ia receniflora? L. 22

Guarea trichilicoides i,

Euterpe globosa Gaertn.

Dacryodes excelsa Vahl. 19

Maregravia rectiflora Tr. & Pl. 19

enia stahlit (Kisersk) Krug. & Urban. iT

Rourea glabra Griseb. It

Piper aduncum 1, ly

Dryopteris deltoidea (Sv.) Kuntze. %

*Fiytolacca icosandra*_ L. u

Byrsonima coriacea (Sw.) De. 16

Matayba domingensis (De.) Radlk. 35

Guettarda laevis Urban

Roney, cymopessis (6¥.) Deaee.# 3

Seotea Teusoxylon (Sv.) Nez B

Casearia arborea (L.C. Rich.) Urban. a

Snilax coriacea Spreng. a

Honaliun racemosum Jacq. 10

Scleria canescens Boeckl. 10*

Rajania condita L. 10

Bauvagesia erecta? 1.

Miconia tetranira Sw.

Heteropteris laurifolia (L.) Juss.

Psychotria brachiata Sv.

Gyathee arborea (E.) JE. Suith,

Borreria ocimoides (Burm. F.) De.

Ixora ferrea Jacq.; Benth.

Casearia arborea (1.C, Rich.) Urban.

Elephantopis mollis L.

Giusia gundlachii Stahl.

Sapiun laurocerasus Desf.

?*Inga fagifolia* (E.) Willd.

Heterotrichm cymosim (Wendl.) Urban

Trichilia pallida Sv.

Pothonorphe unbellata xunth,

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a

Continued Table 6

?

Dryopteris deltoidea (Sw.) Kuntze.

Gordia boringuensis Urban.

?Misophila borinquenia Maxon.

Casearia sylvestris Sw.

Solanun rugosum Dunal.

Hedychium coronariun Koenig.

Heoradolphia volubilis (Willa,) Britton.

4H, & B.; Willa,

a Berteriena Choisy.

Ficus leevigata Vahl.

Bidens pilosa L.

Eupstoriun oforatun L.

Fulrena squarrose Michx.

Fiper treleaseamm Britton & Wilson.

Menilkara bidentata (A. De.) Cher.

Spemmacoce tenvior L.

Nephrolepis rivularis (Vahl.) Mett.

Solanum torvum Sw.

Mikania cordifolia (L.F.) Willd.

Clidemia strigillosa (Sw.) De.

Scotea moschata

Qdontosoria sp.

Unknown grass

Folypodium chnoodes Spreng.

Unknown species

Myreia splendens (Sw.) De.

Gnknown species

Philodendron lingulatum (L.) C, Koch.

Desmodium

Foystonea boringuefia Cook.

Qcotea floribunda (Sw.) Mez.

Guarea raniflora Vent.

Solanum sp.

Gonzalagunia hirsuta (Jacq.) Schum.

Haiantun peticlatun Desv.

Gissampelos pareira L.

Hyreia splentens (Sv.

Ocotea portoricensis Mez.

Gayaponia americana (Lam.) Cogn.

Polypodiun sp.

Ficus trigonata L.

BEBE EE EEE HERD DUM DUUUWOY FREE

PEPE BERR REE

23

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Continued Table 6

Sprouts, originating after radiation, in the radiation area in the fall of 1967, on the soil showing reduced conditions.

Species Individuals

Palicourea riparia Benth. & Hook. 2

Croton poecilanthus Urban. G

Heteropteris laurifolia (L.) Juss.

Rourea glabra Griseb. ir

x

Tabebuia paitida Miers.

Inga fagifolia (L.) Willd,

Gasearia sylvestris Sv.

Eugenia stahlii (Kiersk) Krug. & Urban

Deppetes glauca Vani,

Casearia arborea (L.C, Rich.) Urban.

Matayba domingensis (D.C.) Radlk.

Sloanea berteriana Choisy,

Manilkara bidentata (A,Dc.) Cher.

Dacryodes exselsa Vahl.

Calyeogonion squemlosus Cogn.

Qsotea portericensis. tee,

Qrriits rasenfiofe? L.

Becurldace virgata? Sv.

Piper aduncimt-

Payehotria bertertana De,

Marcgravia rectifioms Tw. & PL,

Manis Tragiits Urban,

Condia boringuensis Urban.

Didymopanwx morototont (Aubl.) Dene. & PL.

Bsychotria brachiota Sv.

HEE RRR ONW FEE EU ADOW

2h

---Page Break---

Continued Table 6

Vascular plants, at least partly living, originating before radiation,
growing in the radiation area in the fall of 1967, on the soil showing
reduced conditions.

Species Individuals

?Palicourea riparia Benth. & Hook. 33

?Bygenta stahlit (Kiacrsk) Krug. & Usben 10

Heteropteris laurifolia (L.) Juss. 10

Fourea glabra Griseb.

Drypetes glauca Vahl,

Manilkara bidentata (A. De.) Cher.

Inga feijofolia (L.) Wiad.

Tora ferrea Jacq. Benth.

Sloanea berteriana Choisy.

Guarea laniflora Vent.

Weinmannia tetrantha Sv,

Calyptegonum squimulosum Cogn.

Contia borinquensis Urban.

Lyreia leptocladia Be.

Bitterpe globosa Goertn.

Hemaliun recenoum Jac.

Casearia arborea (L.C. Rich.) Urban.

Seoronia peltata 1,

morototont (jubl.) Dene. & PL.

eee istifolis Sv.

Gasearia sylvestris Sv.

Natayba domingensis (De.) Radlk.

Inga vera Wild,

Deoten portoricensis Mex.

PEEP EEE RR DW EEA

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OPTICAL MEASURE OF LEAF AREA INDEX

C.F, Jordan

To calculate total fallout burden in the canopy and to calculate quantity of stable elements in the canopy for the biogeochemical eyeing Studies, total biomass of the canopy leaves must be known. Biomass can be calculated by multiplying average leaf biomass per unit by the leaf area. Antex. Average leaf biomass is easy to obtain, but a method is required's

to measure leaf area index over a large portion of the forest. From that leaf area index is proportional to the following ratio of light intensities measured at the forest floor: as . The principle underlying this relationship is that the canopy is relatively transparent to light in the infra-red, while it absorbs relatively large amounts of light in the visible red. Therefore, the more leaves in the canopy, the greater will be the difference in intensity of radiation at these two wavelengths at the forest floor.

On three sunny days, light was measured on every platform of the walk-up tower. The infra-red/red ratio was plotted against height, and leaf area index at the tower site (Fig. 1). Leaf area index was measured by passing a string with a weight on the end off the top of the tower 16 times, and counting the number of leaves touching the string. The slight irregularities in Fig. 1 are probably caused by insufficient light readings at each level. Although total light intensities vary throughout the day, the infra-red/red ratio remains constant when measured above the canopy (Fig. 2).

It appears that after additional calibrations are made on the walk-up tower and on other towers in the forest, infra-red/red ratios may be a suitable method for surveying the leaf area index of the entire forest, continuing effort

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©xX3QNI V3uv 4V37

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RATIO OF LIGHT INTENSITIES, 800mu/675mu

Figure 1, Infra-red/red ratio as a function of leaf area index.

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= 2

a >

q a

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3 @

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g g

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1000 1200 1400 1600

TIME

Figure 2, Light intensities at 800 and 675 m, and the ratio between the two, as a function of time. Measurements taken above canopy, Nov. 16, 1967.

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?RADIONUCLIDE RESIDENCE TIMES IN FOREST COMPARTMENTS

Jerry R. Kine

The measurement of radiomielide residence time in the El Verde forest is now being terminated after 730 days during which time ten samples of plant material per month were collected for measurement of fallout radionuclide content by gama ray spectrometry. Estimates of effective half-life and enviromental half-life were obtained by plotting the monthly data on a semilogarithmic scale as a function of time and fitting a regression line by the method of least squares. The

values for the slopes of the lines obtained in this manner were used to compute half-life. Measurements were also made of environmental half-lives in the vegetation of the Elfin Forest at the top of El Yunque mountain over a similar time interval but with less frequent sampling-

Mean radioactivity, effective half-lives, and correlation coefficients are given in table I for the materials: eg, Lies, SBze, and yin. The average effective half-lives were found from these data to be 228 days for Gaya, 150 days, 120 days, and 250 days, respectively. Environmental half-lives computed from these data were 110 days for lise, 69 days for cs, a doubling time of 1 day for ^{95}Zr , and 177 days for Mtn,

The above data are subject to some restrictions prior to interpretation. First there is small but finite input of nuclides to the system.

Mercury input affects values for ^{95}Zr most seriously. This nuclide is invariably detected in incoming rain water by the use of an ion exchange column. The source of this nuclide is probably from the Chinese nuclear test of May 9, 1966, since this test caused the greatest deposition in Puerto Rico although subsequent tests may contribute also. The effect of input on half-life estimates for the other nuclides is not known but is thought to be small. This is because they are normally not found in the monthly sample of rain water which is processed through the ion exchange column. That there is at least occasional input is shown in Figure 1.

PBF Cohup which collected from 2/29/68 - 1/18/68 shows the presence of Tl, lise, and ^{95}Zr . The most dominant peak in the spectrum is from

the natural fallout include ^{78}e . The column which collected from 1/31/68-2/29/68 shows only ^7Be and This is a typical spectrum and represents what has been found during six months of sampling which went before. It is possible that the forest receives an annual spring input rather than a continuous deposition year around,

A second restriction on the interpretation of the residence time data arises from the function used to compute environmental half-lives. The computation of this quantity is shown by equation 1.

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Where T_{env} = environmental half-life, T_r = radioactive half-life, and t_{eff} = effective half-life. It is apparent from the equation that as the effective half-life approaches the radioactive half-life, the rate of environmental half-life approaches infinity. Figure 2 shows

the relationship between effective half-life and environmental half-life for ^{95}Zr , ^{54}M and ^{137}Cs . A curve for W_{ce} would appear similar to that of S_{liin} since these nuclides have similar radioactive half-lives.

For S_{im} $T_{eff} = 250$ days and $T_r = 291$ days. These are sufficiently close to one another so that a small error in T_{eff} results in a large error in the estimation of T_{env} . This is evident from Figure 2. A similar situation exists in the case of ^{137}Cs where $T_{eff} = 228$ days and $T_r = 285$ days. Thus it is concluded that the computed environmental half-lives for these nuclides have no literal meaning and should not be interpreted. If the effective half-lives had been short, the environmental half-lives could have been accurately computed. It is apparent, therefore, that both nuclides are relatively persistent in the tropical vegetation and that once they enter the biological systems the dominant mode of removal is probably radioactive decay rather than leaching or other dispersal in the environment.

The value of 469 days for the environmental half-life of ^{137}Cs is accurately estimated since the effective half-life (450 d) is short with respect to the radioactive half-life (10950 d). The value of 469 days is, however, an upper estimate because of the uncertainties involved with input. If there was no input whatever the reported value for environmental half-life would be the correct one. With input the true value is shorter than the one indicated.

A lower limit on environmental half-life for ^{137}Cs in vegetation can

be obtained from another experiment in which leaves were, contaminated. by direct application of droplets of solution containing ^{134}Cs , Preliminary data from this experiment are shown in Figure 3. These data are corrected for radioactive decay so that estimates of environmental half-life can be obtained directly. This quantity is estimated roughly from the data to be about 200 days. > This is a lower estimate and not necessarily accurate because in this type of experiment foliar uptake and translocation to other leaves are known to take place. Times the contaminated leaves are reduced in activity due to translocation to uncontaminated leaves as well as by leaching or other mechanisms. In the case of ^{137}Cs foliar uptake also takes place without doubt. Since all leaves have initially the same exposure to atmospheric fallout, however, no net change of ^{137}Cs concentration will occur from this mechanism. The artificial contamination experiment is continuing. It is anticipated that the environmental half-life estimated from this experiment will increase as the foliar absorption mechanism declines in importance. This will ultimately enable an accurate estimate of environmental half-lives to be made through the convergence of upper and lower limits. At present the environmental half-life of ^{137}Cs from atmospheric fallout is estimated to be in the interval from 200 to 469 days in the tropical forest at El Verde.

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Table 1 shows other significant aspects of fallout radionuclide behavior in the tropical forest. It is apparent that understory, vegetation has significantly greater burdens of all nuclides except ^{97}Zr than canopy vegetation. The residence times of the nuclides are not

different between canopy and understory however, Thus the storage capacities of vegetation in the two locations are different but the input-output relationships are the same. This is somewhat paradoxical at this time since it was shown previously that most of the canopy depletion could be accounted for by leaf fall. Data are presented elsewhere in this report which show a more rapid leaf turnover in the canopy than in the understory. Thus We would expect to have a longer effective half-life in the understory than in the canopy. The existing data do not provide a solution to this problem.

Data were also collected from canopy and litter in the Elfin Forest (Table 2). Average values for all slides are higher in this forest than at El Verde but the effective half-lives are approximately the same,

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ber rity, effective half-lives, and correlation coefficients for ice, Tos, 9522,
eves Snprtrts or hein ete at'H Sere hilo.
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Mey Mean activity? 3.0 \pm 0.8 S32
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Table 2

Mean radioagtnvity, effective half-life, and correlation coeffi-

cients for M4ce, 1370s, 95zr, and in canogy and leaf litter
of the Elfin Forest in the Iguillo Mountains of eastern P. Rico.

Meliae Parameter conory leaf Litter

alice Neon activity? 1h + 8.8 11.6 + 5.5

Tp (effective)? 262 480 28T 8

Correlation 0.69%" 0.85%"

Bes Mean activity 10.3 + 2.0 NS

jp (effective) 352 Ze 1S

Correlation o.Tox 18

on Mean activity 1.6 + 0.6 07 + 0.2

307 330

3, jp (effective) 156 05 er 330

Correlation ome 0.93"

Shy Mean activity 1.6 + 0.6 2.6 41.2

gh 257

Ty jp (effective) au 1% ao 7

Correlation 0.69%" 0.820

dvet/g

f times are in days, bracketed by 95% confidence interval

?significant at 996 level (2 tailed test)

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10,000

Zr-Nb

2129168 - 4/8/68

Counts/ 400 Min

W368 - 2129168

Energy, Mev

Figure 1. Gamma ray spectra of ion exchange columns which hea passed the total anount of rainfall from a one square meter area during the time indicated. Levels of fallout are lower than the natural radioisotope Tbe.

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Figure 2. Relationship between estimated environmental half fe and
cttective half Life for sore felloue rellemuclides:

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Time, days

Figure 3. Preliminary curve showing effective half-life of Cs which was artificially placed on leaf surfaces as ¹³⁷Cs,

33

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DIFFERENTIAL LEAF TURNOVER*

C.F. Jordan

Fallout studies at the EL Verde site showed that understory leaves had a higher level of radioactivity than canopy leaves. It was at first suspected that differences might be due to a greater amount of epiphyllae on understory leaves than on canopy leaves, since it is known that epiphyllae-covered leaves have higher radioactivity than leaves with no epiphyllae. However, a study revealed that while there may be a slightly greater amount of epiphyllae in the understory, the difference is not great enough to account for differences in radioactivity. It was then hypothesized that canopy leaves have a faster turnover rate than understory leaves, and therefore do not intercept fallout for as long a time as understory leaves. To determine this, 698 understory leaves, and 600 sun leaves in the canopy were punched on Aug. 10, 1967, and counted on Jan. 7, 1968,

Table 1 shows that canopy leaves may actually have a higher turnover rate. To be sure, leaves must be counted again in Aug. 1968, and perhaps again in Jan. 1969.

Metabolism rates in 12 groups of canopy and shaded leaves of *Mantlaka didymata* were studied in an attempt to shed light on the cause of differential turnover rates. The only conclusion was that canopy leaves photosynthesize much more rapidly than understory leaves, undoubtedly because of more light in the canopy.

ee

Comparison of survival of canopy leaves vs. understory leaves of three species.

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species Year of work taken from year to. of shade for site

Paste, 1968) T. r. n. in 1968 as a paired test

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Dacre excellan we es v9 6

Sonne ertertana 6 os es oe

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?STEM FLOW IN THE TROPICAL RAIN FOREST

carl F. Jordan

In order to determine the stem flow portion of the rain forest water budget, 27 trees of 5 common species, ranging in d.b.h. from 1.6 inches to 30.7 inches, were fitted with stem flow collectors, which rained into collection barrels. After every storm or period of intermittent rain, quantity of water in the barrels was measured with calibrated dip sticks. Measurements on 21 of the trees began in July 1967, and measurements of the remaining trees began in December 1967. Data for this report was collected through February 1968. Calculations for the

purpose of predicting the amount of stem flow in the forest as a whole during a given rainstorm were based on an average of 1k readings for each tree measured from July and 15 for each tree measured from December.

Figure 1 is the final result of these calculations. It shows the amount of water, in inches, reaching the forest floor due to stem flow as a function of the amount of rainfall. Throughout the entire range stem flow is close to 18 percent of rainfall.

The procedure for the calculations is of special interest because the intermediate results give insights as to the factors involved in quantity of stem flow.

The first step was to calculate the regression of quantity of stem flow on amount of rain for each tree. It was assumed that this was a straight line relationship, because after stem flow begins doubling the quantity of rainfall should double the amount of stem flow. Of course it is not a straight line near the origin, as shown in Fig. 2. However, since rainstorms of less than 1/1 inch rarely occur in the study site, and when they do, they contribute very little toward the total water budget, a straight line relationship was assumed.

The regression equations were of the form $Y = ax + b$, where Y is the stem flow in liters, x is rainfall in inches, a is the slope of the regression, and b is the intercept. The slope of each regression was

Gen plotted as a function of the diameter of the tree from which the regression was obtained (Fig. 3). Intermediate size trees collected the greatest amount of water from a given storm, and thus had the greatest slopes in their regression equations (Fig. 3). The data show no relationship between species of tree and amount of runoff.

The $\frac{1}{k}$ intercept was also plotted as a function of diameter (Fig. 4). The values of $\frac{1}{k}$ intercept greater than one are due to the straight line assumption. After the points were plotted, the curves of Figs. 3 and 4 were estimated by eye and drawn in.

From the curves equations were determined for each tree size class (Table 1). Using these equations, quantity of stem flow for .5, 1 and 2 inches of rain was calculated for each size class of tree. This quantity was then multiplied times the number of trees of each size class

35

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per hectare (Table 2). Density data for trees in the 1 inch size class and above were taken from an 6100 sq. meter survey, and for trees in the 2 inch class from a 2000 sq. meter area.

Total amounts of stem flow per size class per hectare for a given

size stom were added together to give total liters of stem flow per
ao Liters per hectare were converted

hectare for the three sizes of stor.

to inches of rain by the factor: 1 inch of water equals 25h,000 liters
per hectare, Stem flov as a function of inches of rain was then plotted
in Fig. 1.

Fig. 1 shows that stem flow is almost a constant percentage of
rainfall as would be expected. With 2 inches of rain, sten flow 1a
+35 inches, or 17.5, and at one inch, it is .18 inches or 18%. At
one quarter inch it ie .055 inches, or 22%. The higher percent nearer
?the origin 1s probably due to the straight Line assumption of the regres-
sion equations.

The correlation coefficient (r) between stem flow and rainfall was
also calculated for all 27 trees. The average r was .76, and one standard
deviation was .15. The lack of higher correlation probably 1s because
quantity of stem flow depends on intensity of storm as well as total anout
of rainfall. However, if ve assume there are equal amounts of heavy and
light rainfall, effects on stenflow due to variations in storm intensity
will cancel themselves out, and average stemflow should be more accurate
?than would-be suggested by a correlation coefficient of .76.

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ost

INCHES OF RAIN

INCHES OF WATER REACHING GROUND DUE To STEM FLOW

Figure 1. Relationship between amount of stem flow and total rainfall,

36

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3°

8

STEM FLOW (LITERS)

v 2

RAIN (INCHES)

Figure 2, Stem flow on one Euterpe globosa as a function of rainfall,

based on field data, 4

© DACRYODES EXCELSA

4 SLOANEA BERTERIANA

x EUTERPA GLOBOSA

© MANILKARA BIDENTATA

+ PALICOUREA RIPARIA

120 °

% 20, 30

DIAMETER OF TREE (INCHES)

Figure 3. Slope of regressions of stem flow in liters on rainfall
in hundredths of an inch, as a function of diameter of tree.

3T

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4& SLOANEA BERTERIANA

EUTERPA GLOBOSA

® MANILKARA BIDENTATA

* PALICOUREA RIPARIA

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DIAMETER OF TREE (INCHES)

Figure 1b, Y intercept of regressions of stem flow in liters on rainfall

* Gn hundredths of an inch, as a function of diameter of tree.

38

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Table 1

Equations for predicting liters of stem flow as a function
of rainfall in inches and hundreds.

Size class inches Form

$$2 y = ix + 0$$

$$\& Y_{slx} + 0$$

$$6 Y_{sealx} + 5$$

$$8 Y = 3é + n$$

$$0 y = hex + 8$$

$$2 Y = Mx + 3$$

Le hex - 1

16 Y=33x - 2

18 Y=2% - 3

20 Yao = h

22 l& - &

2h ex = 4

26 Bx =k

28 sl - &

30 Yeux - 4

39

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SSS

?Table 2

Density of trees in individuals per hectare for 2 inch size classes,

\$s

Size class of tree Tree/hectare

2 4,285

4 355

6 hes

8 118

10 a1.

a 33.3,

a 20.9

16 22.2

18 12.33

20 4.93

3 3.70

2h 2.46

26 2.46

28 3.70

30 1.23

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FLOW OF SOIL WATER IN THE LOWER MONTANE TROPICAL RAIN FOREST*

C.F, Jordan

To construct a stable-element budget of a forest the flow pattern of soil water as well as the volume of soil water and concentration of elements in it must be known. This qualitative study was made to determine the flow pattern of soil water in the tropical rain forest at El Verde.

The terrain near El Verde consists of numerous finger-like ridges, with small valleys between, many of which are occupied by intermittent streams. The study site was located on the side of one of these ridges, where the slope was about 30 degrees.

Although the soil in the area contains a high proportion of clay, the clay is well aggregated with the result that the soil is relatively light in the upper horizons. However, at a certain depth, which depends in part on slope, vegetation, and amount of rain throughfall; the bulk density increases quite sharply (Table 1).

An hypothesis concerning soil water movement based on informal observations was first made. It was: Water infiltrates very quickly into the upper soil and there is virtually no runoff above the surface of the mineral soil. As the water reaches the denser lower soil, it percolates downward. This hypothesis was first made by Serer parallel to the sci? eurtéoe, percolates) Gontlope ahors|this:censer Serer parallel to the sci? eurtéoe,

Fig. 1).

The experimental design to test this hypothesis follows:

1. If there is no surface runoff, a runoff collection pan placed just below the litter of a plot which extends downslope just a few centimeters

should collect just as much runoff during a given amount of rain as a plot a meter or more in length.

2, If runoff infiltrates into the soil in an almost vertical direction until it meets the resistance of the denser soil, at which point the flow parallels the soil surface; then a collection pan placed just above the denser soil in a plot which runs a meter or more downslope should collect more water than a similarly placed pan in a plot only a few centimeters in length.

Downslope cross-sections of the runoff plots showing the positions of the collection pans and hypothesized lines of water flow are shown

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Procedures

Two plots were marked out, one 1 meter on each side, and one 1 meter wide and extending downslope 15 cm. (Fig. 1). The soil was carefully dug away on all four sides of the plots, down to a depth of 5 cm. Collection pans which extended the full width of each plot were

installed on the downslope side of each plot below the litter for the first trials, and at a depth of 30 cm. for the other trials.

Rainfall was applied by siphoning water through a tube to a shower head and passing the head uniformly over the plots. A volume of water that was equivalent to 4 cm of rain falling on that plot was delivered to each plot for each trial.

Results

Trials 1-4 (Table 2) show that the volume of water collected in the pans beneath the litter was approximately the same in both the long and the short plots. This means that if there is any runoff on top of the soil, it does not move downslope more than 15 cm, the length of the small plot.

The water actually collected probably does not represent soil surface runoff for two reasons: 1. The upslope edge of the pan lays underneath the downslope 2 cm of litter, and therefore some of the water collected was moving straight downward through the litter.

2. In places the collection pan was as much as 3-4 cm deep in the mineral soil, because the soil does not form a perfectly straight contour for a distance of one meter. As a result, some of the water collected was subsurface flow.

?Trials 5,6,8, and 9 show that when the pans vere at 30 om, there was more water collected in the longer plot. This could occur only if the water moved downslope at an angle, and not straight down.

?Trial 7 shows that rate of rainfall apparently does not affect the results.

Results of these tests show that the soil vater infiltrates almost vertically, but when it reaches denser soil, it flows downslope.

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Table 2

Dulk densities of soit at different depths at the study
?site in the tropical rain forest near El Verde.

Depth
tea)

0-5

510

35-40

do-is

of

Average bulk One standard

density deviation

(axial velocity in gran)

vel. in eve.

78 08

789 058

Th 095

988 0th

Results of nine experiments

? Trial No, Flot size

(ca)

1 x10

2 35x 100

300 x 200

300 x 200

35 x 100,

35 x 200

35 x 100

300 x 100

100 x 100

Depth of Ant. of water Bgutvalent on Rate of

Of rainfall rainfall

pan

litter

30 em.

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FLOW LINES COLLECTION

Figure 1. Hypothesized lines of water flow, and position of collection pans, in experimental soil blocks.

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KINETICS OF STABLE ELEMENT MOVEMENT IN THE FOREST*

1. WATER BUDGET OF THE FOREST

C.F. Jordan

Part one of the stable element kinetics study was concerned with element concentration in the forest water. This section deals with the quantities of water moving between various compartments of the forest.

?Total rainfall is measured with a standard weather bureau tipping bucket rain gauge located above the canopy. Through-fall is collected

in 12 rain gauges, 5 ft. long x 2 inches wide x 1 ft. deep. Readings are made weekly. Evaporation from the soil surface is not detectable. Stem flow and transpiration studies are sub-projects within themselves and are reported in following sections. Other portions of the water budget are calculated from the following formulas:

$$\text{Evaporation from leaves} = \text{Rain} - (\text{throughfall} + \text{stem flow}).$$
$$\text{Runoff and deep drainage} = (\text{throughfall} + \text{stem flow}) - \text{transpiration}.$$

Total water budget for one year is given in Table 1. Weekly cumulative totals are graphed in Fig. 1. Total amounts of water moving through various portions of the soil are available from the computer print out described in the previous section. To make this data meaningful, the performance of the lysimeters collecting the soil water and the manner in which the soil water moves were studied. These are the subjects of two separate reports included in this volume.

Table 1

Water budget of the rain forest at HI Verde from Feb. 20, 1967 through Feb. 20, 1968.

?Total Rainfall 281.00 cm

Trough fa 195.37 en

?Stem flow 50.56 om

Evap. from leaves 35.00 cm (Rain-throughfall
+ stem flow)

?ranapimation 59.00 en

Fun off & Deep Drainage 186.93 cm (throughfall +

seen flow = trant-

piration)

continuing effort

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---Page Break---

R=RAIN

T = THROUGHFALL

D = DEEP DRAINAGE & RUNOFF

A = TRANSPIRATION

S =STEM FLOW

E = EVAPORATION FROM LEAVES

200

ot

1967 7? 9171 17 1968

Figure 1, Weekly cumulative centimeters of water in various segments of the forest.

46

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KINETICS OF STABLE ELEMENT MOVEMENT IN THE FOREST*

2. CONCENTRATION OF ELEMENTS IN FOREST WATER

C.F, Jordan

The study of stable element kinetics in the tropical rain forest is broken into several parts: 1) Concentration of elements in the forest water. 2) Water budget. 3) Leaf fall and element content of Litter (incorporated into other reports). Concentration of elements in the water moving between compartments multiplied by the amount of water moving between compartments (water budget) will give the rate of element movement between compartments except for that movement that results from leaf fall, This section is concerned with element concentration in forest water:

Collection stations for forest water analyzed for element content

are given in Table 1. Samples are collected weekly. Conductivity of all samples is measured and pH is taken on one complete collection per month. A weighted subsample of each water sample is added to a composite, which is analyzed monthly for Ca, Na, Mg, and Zn.

Conductivity and pH data start in March 1967. A computer program for determining averages and standard deviations of conductivity, pH, and volume for all locations (such as shallow litter) has been completed and de-bugged. Fig. 1 is an example of the data print-out. The minus numbers and zeros in the middle group are caused by the computer clearing. Table 2 is an example of individual element concentrations. Manganese is barely detectable in most samples. Cobalt, strontium and cesium were not detectable by atomic absorption methods. Other elements will be determined in the future depending upon equipment availability.

Element concentration in the stem flow of one large *Sloanea berteriana* was somewhat higher than other trees and concentration in several large trees of the species *Dacryodes excelsa* was substantially higher than in the rest of the trees. Therefore, these trees are treated separately.

In the soil waters of New Jersey, in a previous study I found that

a considerable proportion of the total elements being moved were adsorbed or incorporated in suspended material, mostly of organic nature. Two different treatments of the tropical rain forest soil water failed to show a measureable amount of elements associated with organic or inorganic matter suspended in the water.

*continuing effort

Mr

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?Table 1

Collection stations for forest water that is analyzed for stable element content.

Number of collectors

Location

Above canopy 2

Below canopy (through-fall) 20

Stem flow et

Shallow litter 8

Deep litter 6

A horizon (soil) aerobic conditions 9

?A horizon (sot1) anaerobic conditions 4

B horizon (sot) 4

Atver (nomal flow) 4

River (high stage) 2

Brook 4

Littert 2

A horizon (soil)* 2

B horizon (soil)* 2

2

Sapprolite*

hese collectors eventually to be used for tritium microsystem

analysis.

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GROUP 2

6 / 26 / 67

vou

TOTAL 17640400

AVERs 2940400

Sede 2528052

GROUP 1

Ov 07 67

vou.

TOTAL 0.00

AVER® 0400

SeDe 0600

GROUP 3

6 / 26 / 67

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TOTAL 13844600

AVERe = 1977671

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OND

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COND

4480

4680

0400

COND

213089

30055

Figure 1. Data print out of computer program for average and standard deviation of volume, pH, and conductivity of forest water

samples.

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each station were weighted

proportion for all stations in each location

Table 2

Location

Above canopy

Below canopy

Stem flow

Individual element concentrations in the forest waters for Jan., 1968,

Five weekly sub-samples from each collection

and pooled, then average concentration

was determined.

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*At site to be used for tritium,

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CHEMISTRY OF SUCCESSIONAL VEGETATIONAL*

C.F, Jordan

The stable element concentration of the plants appearing in the radiation damaged area is being determined for two reasons: 1, To see if Part of the overall biogeochemical study of the montane tropical ecosystem, 2, To see if it is a part of the radiation recovery story.

Leaves of the most common seedlings, saplings, and sprouts, and stems and roots of several species were collected, and plant parts of the same species were pooled (i.e. all roots of *Miconia racemosa*).

Samples were then dried, ground, ashed, dissolved in 0.1 M HCL, and analyzed on the atomic absorption spectrophotometer.

Leaves of species common in the irradiated area generally are much higher in calcium, somewhat higher in magnesium, and at about the same level of manganese, strontium, and cobalt, as leaves of mature forest species (compare Table 1 with data in section on chemistry of climax vegetation). However, leaves of the sprouts which formed from pre-irradiation trees have almost the same element content as the canopy leaves of the same species in the undisturbed forest (Table 2). Calcium and magnesium content of leaves appears higher than that of stem, and stem than that of roots (Table 3).

More extensive sampling will be undertaken to confirm these indications.

OO

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ELEMENTAL COMPOSITION OF CLIMAX VEGETATION*

Jerry R. Kline

Previous measurements of fallout radionuclides in rain forest vege-

\$a)son fhgved that there was a consistent difference in the amounts of

cs, ~~*¥¥~~ce, and 5% contained in leaves between canopy and understory.

Understory plants were contaminated to a greater extent than canopy plants.

Analyses for stable elements were therefore begun to determine whether

they had the same type of distribution.

Analyses Were carried out for Ca, Sr, Mg, Mn, and Co in the leaves

of 10 different species in the canopy and understory from one location

at the El Verde Field Station. Results are given in Table 1. With three

species, Manilkara, Sloanea, and Dacryodes, pairs of canopy ~ understory

samples were obtained. These show no consistent tendency for understory

plants to be enriched in elemental content. In the case of Bugenis and

Micropholis, the elemental composition is similar to that of the other trees

which have the potential to reach the canopy. These two species are found in the canopy although in this case the individuals involved were, immature and were sampled in the understory. These results indicate that elemental content of leaves is not related to forest structure. a .

Plants which are adapted to survival in the understory do seem to be enriched in Ca and Sr however. This is illustrated by the Ca and Sr contents of *Calycogonium* and *Palicourea* which have average mature heights of 12 and 3 meters respectively. The pattern for the other elements measured is less consistent. Both understory species are relatively enriched in Co. *Calycogonium* has considerably higher Mn levels than the other plants but its Fe levels are not particularly high. The situation is reversed in the case of *Palicourea* which has high Mg levels and ordinary Zn levels.

Within the canopy species group, each individual seems to have its own distinctive complement of elements. The *Dacryodes* for instance has considerably lower levels of Ca, Sr, and Mg than *Manilkara*, but it has from 3 to 10 times higher concentrations of Mn. It is apparent, however, that there is no general difference between canopy and understory in elemental content.

Table 2 shows computed specific activity of ^{137}Cs for canopy and under-

story, the canopy has 9.7 pCi/ng while the understory has, 22.2 Bq/g.

Mie indicates that there is partitioning of the fallout in which is quite independent of the cycling of stable Mn through normal biological

Toutes. It has been previously suggested that this partitioning might be due to the fact that the radionuclide is injected into the system through aerial deposition rather than through root uptake. The deposited nuclide is probably intercepted on leaf surfaces and retained there through the action of epiphyllae. Thus specific activity on any particular leaf is more a function of the interception ability of the leaf than it is of mineral cycling. If mineral cycling were the dominant mode of entry of radionuclides into the leaves we would of course expect that the specific activities would be everywhere the same. The fact that they are not

*continuing effort

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Several years after major production of Shin indicates that there must be a rather slow turnover of minerals in tropical vegetation by mineral

cycling. This supports the environmental half time measurements which appear elsewhere in this report and which indicate the same thing.

Attempts were made to measure stable Cs in plants to permit the computation of specific activity but the levels of the stable element were too low to be detected by atomic absorption. ¹³⁷Cs shows the same kind of canopy-understory distribution as Dln and it is concluded that it also is transported independently of mineral cycles involving root uptake. This conclusion is drawn by analogy with the Mn situation and

from the fact that none of the stable elements measured so far have exhibited understory enrichment which is related to the fact that understory leaves live longer than canopy or sun leaves and thus have a longer period in which to intercept miclides. Understory leaves probably also Teintercept mclides which have been lost from canopy leaves by leaching and thus have a sonevhat greater exposure to contamination than canopy leaves,

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ate 2

Rlesental contents of canopy ant understory leaves at HI Verde

species tecatton

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naerstory 27100 + 2780 58.2 23.5 wapTt woe YET UeT.5_ 3.0, o.bT

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Understory 10les + WL 12.9 8.0 STALE 10 e604 526 224 0.95

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Sprcttic activity of Thin in canopy ant understory leaves in the forest at HL Verde

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?TRANSPIRATION*

To estimate the loss of chemical elements from the ecosystem, the quantity of water going into deep drainage and runoff must be known, as well as the element concentration in this water. The only presently feasible way to estimate the proportion of rainfall that goes into deep drainage and into runoff is to calculate it from the forms given in the water budget section. A transpiration measurement is required for this estimate.

Transpiration has been estimated by several methods. By placing an evaporation pan above the canopy and assuming that the vapor pressure deficit there governs the transpiration of the canopy, Odum estimated transpiration to be 1.8 m/aay.

A second estimate of transpiration is derived from the data on tritium movement in soil of a tropical rain forest" by Kline and Jordan in this volume. In that report, the lysimeter was 18 cm deep. It took 21 cm of rain to move the tritium peak down to the lysimeter. The 21 cm of rain fell over a period of 20 days, Therefore, 3 cm of rain were lost by transpiration over 20 day period, or 1.50 m/aay. It was assumed that there was no evaporation from the soil surface,

A third estimate of transpiration was obtained by determining change in moisture content of the soil during dry periods. This was done by measuring the amount of artificially applied rain required to obtain freely flowing water in small soil plots. Freely flowing water

was collected in lysimeters, the performance of which are described in another section of this report. Transpiration, estimated by this method, was 1.55 mm/day.

These three independent estimates of transpiration all were very similar. If a value of 1.5 mm/day for transpiration is used, and assuming that water moves equally through all the xylem, it should take a pulse of tritium approximately 6 days to reach the top of a canopy tree. Preliminary results from an experiment in which tritium was injected into a canopy tree on Mar. 6, 1968, indicate that this estimate may be valid.

*continuing effort

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RADIONUCLIDE BEHAVIOR IN TROPICAL SOIL*

Jerry R. Kline

A tracer experiment described in a previous report was terminated with the conclusion that very little cycling of radionuclides from Tall to understory vegetation took place through roots (See PRNC-102, p. 1k). After termination of the vegetative phases of the experiment, Posi and litter measurements were continued to determine, if possible whether radionuclide reactions in these compartments could explain the

Yul amount of cycling by plants.

Ahigg was leached from the organic surface litter of the soil with an effective half-Life of approximately 15 days. Upon reaching WEN Sins however, the miclide movenent Decane extrenclly slow. Figure {Mnows the penetration of the melide into the aoil after 18 ronths deteaching. The relationship is exponential and shovs that the ok igitly 48 reduced by about 1/2 in the sotl for every inch of depth. Suis behavior io unexpected for highly weathered soils in a high rain« wee thea, Tt indicates that the tropical soils have rather effective binding mechanienis hich restrict movenent.

the existence of such binding mechanisms in soil is shown in Figure 2. ?Three soils were extracted in duplicate with neutral nomal ium acetate solution five times in succession. ?The amount, of ics remaining in the soil after each extraction was measured. | The yesults show that the first extraction removed approximately 30-HO® Of the mclide but that subsequent extractions were very, ineffective Sn renoving 13§cs, Similar results vere obtained with 4m (Figure 3). the results for both muclides indicate that significant reversion to pelatively insoluble chemical forms took place in the soil during the period of 18 months in the field.

In effort was made to characterize the chemical forns of the nuclide ia the soils, Samples were extracted with amoniun acetate maetione to measure exchangeable forms. A second group of samples

see treated with H₂O₂ to decompose the organic matter and then extracted with methanolic (HA) solution to determine the quantity of Organically bound microlides. A third group was extracted with 0.2 M HI to determine the precipitation in acid soluble forms in the soil had occurred.

Results of these extractions are given in Figure 1.

Of the total microlides was retained by the soil regardless of whether

the soil was treated with H₂O₂ or HI solution. On the other hand was released in significant amounts by the destruction of

Organic matter with H₂O₂ and was almost completely extracted by the Gigante microlide behavior indicates that, the two microlides are in equilibrium in the soil. From 30 to 100% of microlides are exchangeable, but undetectable amounts are associated with organic matter or precipitated acid soluble compounds, Only about, 18% of the total is exchange-

continuing effort

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able while possibly over 30% of it became associated with organic matter, and most of the remainder was in some acid soluble chemical form.

The behavior of ^{134}Cs could be explained if the soils contain expanding lattice clay minerals since fixation of alkali metals by clays is a well established phenomenon. At present it is not known whether these soils have this type of mineral. X-ray diffraction studies of these soils are planned to determine if these minerals are present. ^{134}Cs is accounted for almost entirely within the exchangeable, organic, and acid soluble forms.

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DEPTH INCHES

Figure 1. Penetration of ^{134}Cs into the soil of the tropical rain forest at El Verde, Puerto Rico, 18 months after application.

100

age

% RETAINED

EXTRACTION

Figure 2, Retention of 34os in aot against successive extractions with neutral nomal amoniun acetate solutions. Sotls were collected from the El Verde Field Station 18 months after the miclide vas applied.

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sss

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Retained

Bsgess

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Figure 3. Retention of S4vin in soil against successive extractions with neutral normal enmonium acetate solutions. Soils were collected from the El Verde Field Station 18 months after the nuclide was applied.

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ry
10
2 a
3 50
* ao
0

to

3 a5

Extraction

Figure 4. Retention of ^{134}Cs and ^{137}Cs after various treatments.

60

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FALLOUT RADIONUCLIDE DISTRIBUTION IN VEGETATION OF PUERTO RICO

Jerry R. Kline

The objective of this investigation was a systematic determination of fallout radionuclides contained in vegetation on the island of Puerto Rico. Five north-south transects of the island were made for the purpose of gathering plant and soil material. Along each transect 6 to 12 samples of plant leaves, litter, and soil were collected at each of 5 to 7 sampling sites. The sampling sites were selected according to elevation above sea level and each transect included sites at 50, 500, and 1000 meters above sea level on the north and 500 and 50 meters elevation on the south. This sampling pattern conforms to the geographical structure of the island which has a central mountain

range surrounded by low level coastal plains. In some cases the elevation in the center of the transect was significantly greater than 1000 meters, when this was encountered the point of maximum elevation was sampled as well as a 1000 meter location both to the north and to the south of the peak. When this was done the transect has a total of 7 sites. Elevations were preselected on a contour map and were then verified on-site using a barometric type automobile altimeter. The altimeter was calibrated every day at sea level.

When collected the samples were oven-dried and counted in bulk by gamma scintillation spectrometry. Data were corrected by computer solution of simultaneous equations. Averages were calculated for all species at each site except those which are epiphytes. These were averaged separately. Data for ^{67}Ge , ^{137}Cs , ^{95}Zr , and ^{54}Mn are given in Table 1 for all leaves collected in each transect. Samples collected on the eastern end of the island are generally higher in radionuclide content. There is little tendency, however, for longitudinal gradients to occur in transects 2, 3, 4, and 5 which were taken progressively towards the west. Altitudinal gradients were present however in all five transects with highest levels of radioactivity present at highest elevations. In general there was less radioactivity in vegetation of the south coast than on the north coast. This is consistent with lower rainfall which normally occurs in this area.

Samples of epiphytic plants were also collected wherever possible
4m all transects. These were averaged separately and the data are given
in Table 2, These samples consisted of bromeliads, ferns, and mosses.

The levels of radioactivity are considerably higher in these plants than
for leaves taken from the same locations. The role of epiphytes as
accumulators of airborne radioactivity which was first observed at the

HI Verde Field Station seems to be general wherever such plants are found.

Single samples of litter were also collected at each sampling site.
Results for these samples are shown in Table 3. These results indicate
that there is no detectable east-west gradient of radioactivity. Altitudinal
sequences are present however. The litter is enriched in radioactivity
relative to fresh leaves at each site. This suggests that the

*continuing effort

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not being recycled

fuclides are accumulating in the litter and are not

Biologically or leached by rainfall at rates comparable to leaf turn-
over in the system,

Preliminary conclusions from this study are 1) There are no east west gradient of contamination in vegetation on the island, 2) The role of epiphytic plants such as bromeliads, ferns and mosses as accumulators of airborne radioactivity is general. These plants should be included in any environmental surveys where radioactive contamination is suspected 3) Radionuclides appear to be accumulating in the litter at all sites sampled. The behavior of radionuclides in this variety of environments is therefore similar to El Verde where extensive evidence indicates the loss from the litter by either biological recycling or leaching is low,

table 2

Distribution of fallout radionuclides in vegetation
for the Island of Puerto Rico.

Elevation Transect

meters Muclide 65'45 G6'00" 6630" 66N5' GT" 00t

wort Mee 1.58 0.73 0.20 0.87 1.21,

Toe ott 0.49 0.29 OTT Onh9

Mer 0.79 Ohh 0.13 0.12 0.13

Ym 0.12 0.07 0.05 0.06 0.07

500

North Mee OTL 1.55 0.10 0.99 1.00

Teg 28h 0.92 0.750463 0.78

Roe 0N3 0.52 0.19 oe 0.55

Fm 0.18 0.08 0.05 0.13 0.09

Mee has 3,850.50 hag 0.98

Tos 75h 2.93 0.8766 LoL

Str 0.89 1.24 038 0.20 0.8

hn

North

0.95 0.70 0.2 0M 0,10

a

62

---Page Break---

SaaS

Continued Table 1

Elevation ?Transect

meters Muclide 65°45" 66700" 66°30" 667U5' 67'00"

500

North Mee 0.80 1.08 0.27 «0.0.13,

Tos 1.65 1.01 OM 0.35 0.25;

Wer 0,38 0.59 0.29 -0.0T 0.06

Fh 0.13 0.09 0.18 0.05 0.08

50

South Mee 0.26 0.67 0.52 120.67

3%os 0.51 0.2T «0.280.203

Mee 0.18 0.78 0120.00.19

Dh 0.12 O.1T 0.06043 0.22

Greater than 444

1000 meters* Ce 2.81 0.43,

3Tos 6.20 3.4

Poe 0.49 0.32

ara 0.56 0.24

2000

south Mice 0.70 1.40

33Tos 0.9h 0.21

on 0.72 0.K8

Mn 0.23 (0.2L

63

---Page Break---

Elevation

meters Muclides.

50

Yorth ae

Toe

gy

7

500

orth ice

Tes

Bop

en

1000

orth tice

13Tq

Bay.

Pita

500

South thee

35

zy,

Distribution of fallout radionuclides in epiphytic
plants on the Island of Puerto Rico.

Table 2

?Transect

65°45" 66"00" _66"30" _ 667454 67"00"

0.36

3.21

0.81

0.06

0.94

7.56

0.86

0.33

16.81

34.8

2.38

1.88

0.05

0.5.

0.32

0.05

0.05

1.29

onda.

0.05

33.18

34.38

5.90

2.37

0.37

2.95

0.4

0.28

1.78

3.25

onda.

0.20

4,60

148

12.08

0.55

0.45

3.08

0.29

o.th

0.85

2.14

0.19

0.20

LAT

L5T

0.15

0.19

2.30

12h

0.2

0.09

0.9%

2.78

0.35

0.15

4B

2.38

0.05

0.24

2.18

2.83

0.29

0.18

0.5

5.28

O42

0.02.

1.58

TAT

0.36

0.19

3.20

0.05

0.36

0.32

6h

---Page Break---

EE

Continued Table 2

Elevation ?Transect

neters Muclides 65°15" 66'00' 6630" 66S" E700!

south Mee 9.07 aig 1.02

13Teg 2.23 3.31 2.22

Mer 0.12 0.32 0.24

Phin 0.06 0.19 0,06

?ooo meters gg 12.80 3.76

los 15.63 1.23

on 2.00 0.25 a

Ph 0.32 0.2

Bouth Meg aay a8

1395 1.99 9.72

on on 0.92

aal o.1 0.N6

65

---Page Break---

?Table 3

Distribution of fallout radionuclides in ground

Litter on the Island of Puerto Rico.

oe

Elevation ?Transect,
meters Muclides 65°45" 66°00" _66"30" _ 66*N5" 67°00"

worth Moe 2.25 0.6 0.05 0.63.

Tes 1.22 0.96 0.050.750, 86

ir 0.05 0.2L 0.2h 0,33 On

Pin 0.03 0.230.050. 0.05

North Mee 3.98 2.28 Lak 1.80

. les 3,20 0.78 1.59 1.36

Poe om Ok 017 0,50

Pha ov 0.05 0.20 0.20

forth Mee 15.66 10.50 1.02 ake 3.28

los a7.00 132k 20 a

Mir 2.00 2.58 0.20 0.09 0.32

sevth Mee 0.05 1100.46 3.20

Mog Ms ag oat 0.79

Moe 0,050.12 0.20 1b

Fhm 0.5 0.12 0.08 0.06

---Page Break---

rr

Continued Table 3

Elevation Transect

meters. Muclide 65°45' 66°00' 66°00" 66°45" 67°00"

50

South Mee aol 0.01 0.058

137,

Flea 1.02 0.05 0.15.8

%zr 0.19 0.09019 oO.

Thm 0.03 0.05 0.05 0.05

Greater than

1000 meters Mice 5.84 5.25

B3Tq 9.93 16.59

ae 0.26 0.25

ar OWT 0.96

1000

South We. 482 (0.99

Tos 2.97 1.52

Moe 0.49 0,20

yn 0.33 (0.38

61

---Page Break---

Sioe-Septs A98T

Figure 1. Distribution of ^{137}Cs in vegetation on the island of Puerto Rico. Sampling sites are shown by X. Values to the left of each site are elevations in meters and to the right are pCi/

a.

oreo esas

tetri 1

Figure 2. Distribution of $\delta^{13}C$ in vegetation on the island of Puerto

Rico. Sampling sites are shown by X, Values to the left of

each site are elevations in meters and to the right are $\delta^{13}C$

a.

6

---Page Break---

Source

Figure 3. Distribution of $\delta^{15}N$ - 951m in vegetation on the island of

Puerto Rico. Sampling sites are shown by X. Values to the

left of each site are elevations in meters and to the right

are pCi/en.

ample cottetat

Sa eepes 1907

Distribution of ^{14}C in vegetation on the island of Puerto Rico. Sampling sites are shown by X. Values to the left of each site are elevations in meters and to the right are pCi/

a.

Figure 4.

9

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REACTIONS OF NUCLIDES WITH EPIPHYLLAE*

Raymond Henzlik and Jerry R. Kine

Epiphyllae are mixtures of organisms which grow on the surfaces of leaves in the rain forest. Their populations may include algae, fungi, lichens, liverworts, mosses or bacteria. These organisms have been suspected of playing a role in the nutrient cycling mechanisms of the forest because they were found to contain large amounts of fallout radionuclides. Experiments were carried out in cooperation with Dr. Raymond Henzlik, an Oak Ridge Research Participant from Ball State University, to examine some reactions of these organisms with radionuclides.

Leaves from four species of tree were contaminated with radioactive solutions containing ^{137}Cs and ^{89}Sr for a period of 20 minutes after which the leaves were washed in tap water for 6 minutes. ALL

species had leaves which had epiphytic growth and those which did not.

The results are shown in Table 1. Epiphyllae were from 4 to 7 times more efficient in retaining radionuclides than were leaves which had

no surface growth. This indicates that these organisms may be adapted to deriving their mineral nutrient requirements by interception of rain water or canopy leachate,

Minerals which are intercepted by epiphyllous leaves may be transferred to the leaves by foliar uptake. If this happened it could be an important source of nutrients for the higher plants of the area. An experiment was done to determine whether leaves received nutrients from labeled epiphyllae. Excised leaf sections containing labeled epiphyllae were placed firmly against the surfaces of leaves in the field and held there for 24 hours. Leaves in the field were matched for those having surface growth and for those which did not. After up to 10 days, the leaves were harvested sectioned, and counted.

The results (Table 2) show that epiphyllae took up more radioactivity from the labeled overlays than did clean leaf surfaces. The activity in the tip portions of the leaves probably indicates surface translocation since the leaves are adapted to shedding water in this direction. The activity in the basal portion of the leaves may indicate some uptake and translocation by the leaf. It is apparent, however, that most of the activity remained in the region of the leaf which was originally

contaminated. It is concluded that epiphytes of this type are not efficiently adapted to furnishing their higher plant hosts with minerals through foliar uptake. The strong binding -adaptation exhibited by these organisms for mineral elements suggests that the opposite may be true. Minerals leached from leaves by rain water may be the source of nutrients for the epiphyllae.

*continuing effort

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a

?Table 1

Absorption of ^{34}S and ^{87}Sr on epiphyllous and non-epiphyllous leaves of the tropical rain forest.

Leaf surface 23% Cr^{3+} /sect 855p Ce^{3+} /sect

Epiphyllous gah 5363

Ton-eptphyllous hos 1269

Table 2

Uptake of radionuclides by epiphyllous and non-epiphyllous leaves
and translocation of the nuclides within the leaves.

Leaf surface ?Region, 3Tes cru/sect Sen crt/sect

Epiphyllous tp am 98

overlay 1062 2604

base ko 180

Non-epiphyllous tip 26 3h

overlay nz 332

base 1 8

Rn

---Page Break---

NEUTRON ACTIVATION OF TROPICAL SOILS AND PLANTS*

Jerry R, Kine

The objective of this investigation was to measure the characteristics of thermal neutron irradiated soils and plants of the tropics, and to determine those elements which can be feasibly determined by non-destructive neutron activation. Eleven soils of Puerto Rico and 5 from Panama are included in the study. Two samples of ashed plant material were also included,

One hundred milligram samples of oven dried, crushed soils were weighed into specially constructed polyethylene packets in preparation for the irradiation. Six such packets along with chemical standards were then placed in a screw top polyethylene capsule and the capsule was irradiated in the PRIC research reactor for one hour at a flux of 2×10^{11} n/cm²/sec. After a one to 3 day period of cooling the samples were counted

by gamma scintillation spectrometry using a shielded 3 x 3 NaI(TL) crystal connected to a 400 channel spectrometer. Three types of measurements were made for each sample. These were 1) Gross gamma decay rates, 2) Observation of gamma-ray spectra to determine which nuclides were present, 3) Quantitative analysis of prominent elements in the spectra.

Figure 1 shows gross gamma decay patterns for 6 of the soils of this study. The others are omitted for clarity since similar decay curves were obtained. Regardless of the origin of the sample the curves are characterized by initial rapid decay rates for the first 100 hours after irradiation. Half-lives for samples in this portion of the curve are 15-20 hours which implies that the dominant radioactivity is ²⁴Na. This was verified

by observation of the spectra and is consistent with what has been found previously by the author for temperate zone soils. As ^{232}Th decays away the curves go through a sharp bend lasting from 100 to 300 hours and then show a half-life of approximately 1400 hours or 58 days. The portion of the decay curve is dominated by radioactivity from ^{59}Fe ($T_{1/2} = 45 \text{ d}$) and ^{46}Sc ($T_{1/2} = 84 \text{ d}$) with probably minor contributions from other nuclides. This is also consistent with what has been found for temperate zone soils. It is concluded from these studies that neutron irradiated tropical soils have essentially the same complement of elements undergoing neutron capture as temperate zone soils in spite of the fact that they are subject to much more intense weathering.

*completed

**Kline, J.R., J.P. Foss, and R. Brar. Lanthanum and Scandium distribution in three glacial soils of Western Wisconsin. In preparation, Preprints: available.

2

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Gamma ray spectra of several of the soils in this study are shown in Figures 2-8. Two spectra are shown for each soil. The first of each pair was taken from 7 days after irradiation and is therefore in a Stage of decay corresponding to the rapidly curving portion of the decay curves. The second spectrum was taken 56 days after irradiation and

corresponds to the slowly decaying portion of the decay curves.

The nuclides not prominently present in many of the early spectra are Sr, C2br, M50, 59Fe and Zr. None of the spectra show traces of W or V. Most of the soils seen to have below detection limits of these elements. All of these elements have been observed previously in a variety of temperate zone soils. One of the differences between geothermal soils and temperate soils seems to be the apparent paucity of U in the tropical soils. This is consistent with the conclusion of Kline et al. who suggested that U is probably easily leached from soils. ~

The older gamma ray spectra are dominated by Sr, Mn, and 59Fe.

In this respect they are very similar to temperate soils. Further analyses will be done on the data to determine whether these soils contain the rare earth elements Ba and Sm. These elements have been found in many temperate soils. Their presence or absence in tropical soils will give some indication of rare earth weathering behavior.

Quantitative analyses were made for Cr, Sc and Fe. Results are shown in Table 1. Fe values range from 3.5 to over 17% with the majority of samples having Fe contents between 7 and 10%. These are reasonable levels for tropical soils which have undergone selective removal of silica during the process of laterization. Temperate zone soils by contrast have Fe contents which may range from 0.5 to 3%. Se values range from 7.3 to over 60 ppm. These values are generally higher than have been found in the temperate zone. The author has for instance found a range of 1-10

ppm Sc in a group of soils from Minnesota. Kline and Brar* have showed
?a general association between Fe and Sc in a world wide collection of
soils. High Fe soils are almost always found to be high in Sc also. The
results from the tropical soils are consistent with this relationship
which was established by independent measurement previously.

Cr levels ranged from 37 to 175 ppm. These amounts are about in
the sane range as has been found in other groups of soils. No relationships
have thus far been found between Cr and other elenents of soils.

*Kline, J.R., and §.S, Brar. Instrumental analysis of neutron irradiated
soils. In preparation. Preprint copy avail.

---Page Break---

Table 1

Amounts of Fe, Sc, and

cr in

some tropical soils

Depth

inches

Sotie

EL Verde (Contral Center)

El Verde (Control Center)

EL Verde (Rad, Center)

EL Verde (Rad. Center)

EL Verde (Rad. Center)

Elfin forest (FR)

Elfin forest (PR)

Elfin forest (PR)

Limestone (Bayamén, PR)

Caibalache (Manat{, PR)

Guajataca gorge (quebradillas, PR)

Chepo, Panama

ong

12-2

os

51

12-24

ong

12-24

2h-36

0-6

0-6

0-6

0-6

&

9-7

9.3

5.0

TS

19

9.3

9.5

10.4

1.8

T1

3.5

19

Se

mm

47.0

55.1

13

ad

18.4

22.8

60.5

had

26.2

33.4

10.6

28.8

cr

70.0

37.2

197.2

17h.

120.3

59.2

TH

---Page Break---

Figure 1. Gross gamma decay curves for some neutron irradiated soils of Puerto Rico and Panama. Soils were irradiated for 1 hour at a flux of 2×10^{10} n/cm²/sec. No. 1, Bayanén, P.R. 2, El Yunque peak P.R.; 3, Quebradillas, P.R.; 4, El Yunque peak subsoil, P.R. 5, Chepo Panama; 6, Vanatú, P.R.

om

is °

Lim

os

Ps

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=

THHODODHOM HHH OMM mm

ows,

Figure 2, Gamma ray spectra of neutron irradiated surface soil from FI

Verde, Puerto Rico. Upper curve taken 100 hours after irradiation;
lower after 450 hours.

B

---Page Break---

gE855

SEBEBBEES ES

Counts! 10 Min

0 2% % © 50 © 70 WH 9 WO No 12> G0 WO 150 Ko 170 1m

Energy MEV

Figure 3. Ganma rey spectra of neutron irradiated soil taken from the

5-12 inch depth at El Verde Puerto Rico. Upper curve 100
hours after irradiation; lover after 450 houre.

10,000

B86

#

¢

=

counts! 10 tin

aye:

gee

ne

88

0 10 2 3 © 50 @ 70 H %0 100 10 120 10 10 150 100 170

Energy, Mev

Figure 4, Gamma ray spectra of neutron irradiated soil taken from the
12-2 inch depth at El Verde Puerto Rico. Upper curve 100
hours after irradiation; lower after 450 hours.

6

---Page Break---

cant in

Figure 5.

Countin

Figure 6.

sea

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ea

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THVSDG DH DMM w HMM me

era. Mev

Gama ray spectra of neutron irradiated surface soll taken
fron the Elfin forest on El Yunque peak, Puerto Rico. Upper
curve 100 hours after irradiation; lover after 450 hours.

vs

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ww

a

4

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a

5

4

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2

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d

THHSDOVH Owwowww wi ww

egy, Me

Cama rey spectrun of neutron irradiated surface soil taken
from Darien Province Panama. 100 hours after irradiation.

---Page Break---

Ccountsi10 Min

0 0 2 3% 4 50 6 70 9 % 100 110 120 130 140 150 160 170 180

coy, ey

Figure 7. Guana ray spectrum of neutron Ssradiated surface solt taken
frou Darien Province Panana,? 1500 hours after irradiation,

=

S 7.00

= 8

5 coe ee

3 san :

4,00

3,000

200

wo Me

0 10 2 30 4 50 6 7 8 90 NiO 120 130 140 150 160 170 180 190

Energy, Mev

Gamma ray spectrum of neutron irradiated surface soil taken

Figure 8.

from a mangrove swamp in Darien Province Panama. 1500 hours

after irradiation. Early spectra dominated by ^{24}Na not shown.

8

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?TERMITE NESTS AND TUNNELS IN THE RADIATION CENTER AT EL VERDE*

Elizabeth NoMahan**

Richard Wiegert and the forest work crew in May 1966, mapped the

Radiation and Control Center to a radius of 60 m and located 2h nests

of *Nasutitermes costalis*. All were active except #22 and #23 in the

Radiation Center and fai in the Control Center. P. Murphy had noted in

1964 that Wiegert's #23 nest had been active prior to irradiation. Nests

Hee and #2k probably had been abandoned prior to irradiation, (See Fig. 1).

in the summer of 1966 Wetzel studied the contents of both centers, examining Wiegert's nests and locating a new one (#25) about 35 feet

Giant tree, the only tree nest discovered in the forest areas

Special attention was given nests #19, #20, and #11 which lay within 33 m of the Cs source. Their accumulated doses of radiation were 6000 r, 1000 r, and 500 r respectively. All three were still active in 1966, but #19 and #20 were in a deteriorated condition. McMahan failed to find nymphal stages in these two nests and only a few in #11 and concluded that irradiation had sterilized the primary reproductives as well as any potential supplementary reproductives.

On March 28, 1967, McMahan re-examined these nests and found that all three had been abandoned. Other nests were not systematically checked at this time.

In July 1967, she examined 11 nests previously mapped (plus a new one, #26, which she found in the Control Center)... This time #15 (at 50 m) and (at 60 m) in the Radiation Center were found to be abandoned. Out of 11 nests known to have been active in this Center in May 1966, 5 had been abandoned by July 1967. All of the 10 known active nests in the Control Center (plus nest #26) were still active. (See Fig. 1 for map of nests).

ests at 50-80 m received accumulated doses of only about, 100-200 r, but this may have been sufficient to sterilize reproductives. A nest in which no brood is developing must necessarily deteriorate as natural mortality decimates the population. (A nest usually represents the offspring of a single reproductive pair).

A study is under way to compare ratios of nymphs and mature workers present in the remaining nests, both in the Radiation and in the Control Centers. Results may help to indicate whether or not sterility has been the chief factor in nest abandonment.

continuing effort

**University of North Carolina

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?Tunnels

?Tunnels of wood carton connect nests with dead branches or other food sources. McMahan in the summer of 1966, surveyed these tunnels on the trees of the Radiation, Control, and North Cut Centers. Every upright trunk with a diameter above 1/2 inch, dead or alive, was examined for the presence of tunnels. When a tunnel was found, it was examined for occupants, which might be either *Nasutitermes costalis* or *Parvitermes giscolor*, (*P. discolor* is another species common in the centers, but is not a nest-builder).

Approximately 10% of the trees in each center exhibited tunnels.

Only 12% of the tunnels in the Radiation Center were occupied (usually by *Parvitermes*), while 526 of those in the Control Center, an 36% of those in the North Cut Center were occupied.

The tunnels in the three Centers were recensused in the summer of 1967. This time only 8% of the Radiation Center tunnels were occupied, while 19% of the Control Center tunnels and 12% of the North Cut Center tunnels were occupied, Table 1 summarizes the tunnel data,

These data indicate that the termite population in the Radiation Center continues to decrease, Since there are now fewer *Nasutitermes* nests in this center, the decrease in *Nasutitermes*-occupied tunnels should be expected. It is interesting to note, however, that *Parvitermes* occupation is also low, as compared with the North Cut Center. The latter also has no *Nasutitermes* nests within 30 m of point zero but does have a large number of *Parvitermes*-occupied tunnels.

The data may indicate that recolonization of a rain forest area in which the termite populations have been wiped out is a slow process. It will be interesting to continue this study for another year.

+ carck to ely 20m rats

tio of trutstemes to Pevitorce scewption (not ext)

reno. de motly 0 flntng of old tmee

es

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SOIL RESPIRATION*

C.F, Jordan

Sci respiration in the mature forest and the irradiated area was

measured by putting a relatively large box (250 liter capacity, covering

625 n® of soil) over the soll surface, and mearuring COp build up insite

the box. An objection to this approach for measuring soil metabolism is that the build up of CO₂ in the box inhibits further respiration. However, Fig. 1 shows that in a large box inhibition began only after about 20 minutes, when air inside the box was not circulated. When a small fan inside the box circulated the air, inhibition began sooner. Only changes during the first 10 minutes of each trial were used in calculations

Table 1 summarizes the results for the three sampling dates. Soil in the irradiated area was respiring at a considerably higher level than soil in the mature forest. In two of the irradiated area plots. The higher respiration was partially due to grass, but in the third irradiated area no grass was present, yet respiration still was high. On Feb. 14, respiration was lower in all areas, especially the well drained soil in the mature forest. This could be due to the fact that previous to Feb. 14, there were 11 rainless days, a relative drought in the rain forest.

se

soil respiration in the main forest.

SSS

soil respiration in the main forest.

soil respiration in the main forest.

Nature forest, well drained 4012 06 008

ature forest, poorly drained soft a on ?

Irradiated area, 1004 grass covered,

?well drafeed aot

Trradiated area, 50 grass covered,

"poorly Grated soit ° or

Trradtated area, beneath aecontary

?vegetation, well arateed soll

*continuing effort

---Page Break---

NO FAN

600

FAN

500

z

2400}

SS

oO

300

Lo,

Oo 20 40

TIME (MINUTES)

Figure 1, Buildup of CO, inside the soil metabolism box, with and
Without a fan circulating air inside the box.

83

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pe GIANT CYLINDER EXPERIMENT#

C.F, Jordan

Ch TY 18, 1967, the giant cyl with the fan

2 2967, cylinder was operated

Ee ret 30% more air than on previous runs in an attempt to

1988 of air through the top of the cylinder by diffusion or
turbulente. The fan flow was increased from 588,557 to 865,100 liters/
min by decreasing the size of the pulley on the fan. In order to
differentiate the metabolism of the canopy from that of the soil, air

was sampled sequentially at four heights; 20 ft. above the canopy, mid-
canopy, below canopy, and 4 ft. above the ground. The sampling system
consisted of a timer mechanism operating four solenoid valves.

The most meaningful data was the difference in CO_2 concentration
between the above-canopy and below-canopy intakes for the first night.
The chart data from this night was transferred to graph paper and the
scale expanded (Fig. 1) to facilitate computations. From midnight to
0600, July 19, 1967, respiration of the canopy alone was $.443 \text{ } \mu\text{C}/\text{m}^2/\text{hr}$.
This value is close to the value Odun obtained for the whole forest
prism, on previous cylinder runs. The higher respiration rate on July
19 could be a result of the more rapid passage of air through the cylinder
in this experiment.

The concentration of CO_2 in the air taken in by the intake nearest
the ground increased when the intake was lowered toward the ground, and
decreased when the intake was raised, indicating that CO_2 diffusion from
the soil, especially near the fan, can confound results, at least with
a high rate of air movement through the cylinder.

The morning of July 20, the timing mechanism became erratic, making interpretation of results impossible. Smoke bomb tests of the draw of the cylinder failed even though the bombs failed to ignite. Pulses of CO₂ were released at various levels on the tower by means of a fire extinguisher, while the analyzer intake was in front of the fan, Table 1 gives time for pulse to travel from release to recording on chart.

On July 21, wind tore the sides of the cylinder, and the experiment was terminated.

I do not recommend continuation of the giant cylinder work as it now exists. However, these experiments have been valuable in that they have provided experience that will be useful in any future ecosystem metabolism

studies,

completed

8h

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The following are my recommendations for any future giant cylinder work: -

2, Walls of the cylinder (or hexagon) should be of rigid material such as plexiglass, because one of the most serious problems with the polyethylene walls was billowing. The rigid walls should be in panels that can be).

tilted like venetian blinds, so that during windy days the panels may be opened. With solid valve for the cylinder and because an almost, constant temperature inversion exists in the forest; build-up and decrease? of CO₂

at various levels can be converted to forest metabolism in the same manner as G. Woodwell did at Brookhaven National Laboratory. The difference between the Brookhaven situation and El Verde situation is that Woodwell: measured respiration during inversions on calm nights when there was an assumption of no horizontal air movement while at El Verde, even in no-wind situations, there is air drainage down the mountain, With air drainage there is no build-up at the various levels.

2. The top of the cylinder should be fitted with some sort of turbulence causing device, so that wind passing across the top of the cylinder does not suck air up out of the cylinder (Bernoulli effect).

3, At other locations where there is no inversion and a fan must be used, the fan or fans should be large enough, and spaced in such a manner, that there is a uniform flow throughout the cylinder, yet moving air slowly enough so that metabolism rate is not a function of fan speed.

4, A whole battery of CO₂ intakes should be spaced throughout the cylinder

to determine intra-cylinder variations.

Table 1

Time for COp pulse to travel through the cylinder from
release elevation to fan at the bottom,

Release elevation Time,

feet Minutes

4

5

36 5

48 T

85

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ONE CHART UNIT EQUALS

25 PPM CO

BELOW CANOPY

' ABOVE CANOPY

CHART UNITS

2400 0600

TIME

Figure 1. Expansion of chart read-out for the giant cylinder experiment, the night of July 19-20, 1967.

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PERFORMANCE OF THE ZERO-TENSION LYSINETER*

Carl F, Jordan

INTRODUCTION

4m "Boemmayer" (Kohnke et al. 1940) type of lysineter was recently described (Jordan 1968) which collects water moving through undisturbed

soil (Fig. 1), and which apparently eliminates the surface tension that occurs at the soil-air interface in this type of lysimeter. This lysimeter, called the Zero-Tension lysimeter, is a 2x 12 inch stainless steel trough, inside of which are two parallel bars which run the length of the trough. The film of water at the soil-air interface flows over and down the bars, and the capillary force between the bars pulls the water into the collection tube (see Jordan 1968, for a detailed description of lysimeter). The objective of this investigation was to determine the "effective collection area" of this lysimeter under various conditions, so that results of studies utilizing this lysimeter can be quantitative.

"Effective collection area" of a lysimeter is a theoretical area

of the soil surface above the lysimeter from which all entering water moves in a straight line toward the lysimeter and outside of which, no water moves into the lysimeter. It is calculated by multiplying the area of the top of the lysimeter (154.8 cm² in the case of the Zero Tension lysimeter) times the effective collection area factor, E_c . Factor E_c is defined as:

$$E_c = \frac{\text{volume of water collected}}{\text{area of top of lysimeter} \times \text{volume of infiltrating rainfall}}$$

volume of infiltrating rainfall

when the soil moisture is at field capacity or above.

Although several types of "Ebermayer" lysimeters have been described (Joffe 1929, Shilova 1955, Cole 1958), no tests have been reported on the performance of these lysimeters. Cole, Gessel, and Hela (1961), and Cole (1963) apparently assume that by setting suction on their lysimeter to a pressure equivalent to the soil moisture tension at field capacity, they collect soil water only from directly above the lysimeter.

MATERIAL AND METHODS

A Zero-Tension lysimeter, as described by Jordan (1968), was tested under field conditions, and in a test box under closely controlled conditions.

*Lysimeters are being used to study radioactive and stable isotope movement in the soil. To quantify these studies, certain characteristics of the lysimeters must be understood, such as, from what volume of soil does the lysimeter collect. The following report concerns performance characteristics of the lysimeters used at the El Verde site.

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Soils

The field tests were made in a lower montane tropical rain forest near El Verde, Puerto Rico, on a soil belonging to the Los Quineor Clay Series (Roberts 1942). No recent mapping has been done in the area. The soil at the test site was described in 1966 by the U.S. Soil Conservation Service. The upper soil horizon, where the lysimeters were located, is a strongly acid, slightly plastic clay, with a weak, fine subangular blocky structure, brown in color (7.5 YR 5/6), and with organic matter from above in worm channels. There is an abrupt boundary above lower horizons.

For the test box experiments, two soil types were used: 1. Los Quineos clay from a site similar to that of the field test; 2. An undescribed alluvial soil from the flood plain of the Rio Grande River, one mile south of the town of the Rio Grande, Puerto Rico.

As a basis for comparison of the soils used in the tests bulk densities were measured (Table 1) by the core method (Blake 1965), and particle size distribution was determined (Table 2) by the pipette method (Day 1965).

LITTER

LYSIMETERS:

COLLECTION

TUBE

COLLECTION

BOTTLE

Figure 1. Cross section of a pit and tunnel, showing en installation of Zero-Tension lysimeters.

Table 1

Bulk densities of soils in which lysimeter was tested.

Wo. of Average bulk One standard
ot. senples density deviation

10s Guineos clay,

field sample,

0-5 in. depth 4 48 048

Tos Guineos clay,

test box y +708 054

muviun,

test box ?732 +099

Table 2

Particle size distribution of soils used in lysimeter tests.

Mumbers in parenthesis are size of particles, in millimeters.

Soil Sana

los Guineos clay 25 (.05)

Alluviun 4g (.02)

posit

38 (? .05-.002)

30 (| .02-.002)

foley

37 (.002)

Famisten, 1965

using hydrometer

method)

ai (? .002)

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?Test Box

The bottom of the test box was 1/2 inch plywood, 79 cm on each side. The sides of the box were made of 1/2 inch plexiglass, 50 cm high. From a 3/4 inch hole in the center of the bottom of the box,

a polyethylene tube led to a four liter trap, which was connected to a vacuum pump. The hole in the box was covered with screening and glass wool. The bottom of the box was lined with approximately 4 cm of coarse sand, to allow water which drained from the soil above to flow easily toward the hole in the center. The sand was covered with 20 cm of soil, and 4 cm of partially decomposed litter.

A lysimeter was buried approximately 12 cm below the mineral soil surface in the test box. A collection tube ran from the lysimeter through a hole in the side of the box to a collection bottle. Artificial rain was applied through a siphon tube to an ordinary shower head which was passed over the box in a systematic manner.

For all tests, 20 liters of water were applied, an amount equivalent

to 3.2 cm of rain over the area of the test box and field plots.

The rate of application for most tests was 27 mm/hr for a seven minute

period, a rate and duration similar to the numerous summer showers which

occur at the test site. All the artificially applied rainfall infiltrated

into the soil, and there was no surface accumulation or runoff, even

when rainfall application was 51 mm/hr.

To ensure that all the trials in the test box were comparable, it

was necessary to make sure that the moisture content of the soil at the

beginning of each trial was the same. The most convenient soil moisture

level to start each trial was field capacity. Field capacity was attained

by applying rainfall to the soil box until a water table began to build

up in the bottom of the box (visible through the plexiglass walls), and

then removing this free water with the pump, which sucked the free water

from the bottom of the box. At the point when all free water was removed

and the pump was sucking mostly air, field capacity was assumed,

The pump was operated continually during all trials.

Field Tests

Two lysimeters were installed as for field use (Jordan 1968) at a depth of 12 cm on a flat ridge top in the Los Guineos clay. String was laid out in a square, 79 cm on a side, on top of the soil surface, so that each lysimeter would be underneath the center of a square. Artificial rain was applied in exactly the same manner as for the test box. Artificial, rather than natural rain was used, because point to point variations in rainfall through vegetation are large, and these variations make accurate rainfall input measurements impossible,

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Before the test runs were made in the field, rain was applied until the lysimeter just began to collect water. Then the application was halted until drainage stopped, at which time a test run was started. This procedure ensured that an amount of water, equivalent to that applied to the soil surface, percolated through the level of the lysimeter.

RESULTS AND DISCUSSION

Experimentally obtained values of the effective collection area factor f are given in Table 3. Values of f for tests 1-20 are very close to one, indicating that the effective collection area of the lysimeter is equal to the actual top area of the lysimeter, for the soils and conditions tested.

Tests 1-10, made in the test box filled with Los Guineos clay,

show that varying the rates of rainfall does not change the effective collection area. Tests 11 and 12 in Los Quineos clay show that changing lysimeters does not change results. Tests 13-16, made with alluvium as a test soil, show that the effective collection area may be the same in various soil types. In the field tests with Los Quineos clay (17-20),

f varies more than in the test box, but still appears to be close to one.

Tests 21-24 were made to determine the effect rocks and roots would have on the amount of water collected in the lysimeter. In test 21, a rock, 30 cm in diameter placed on the soil surface, reduced the collection by almost half. For test 22, a piece of flat plastic was carefully placed in the soil so that it was 1/2 inch above the lysimeter, and covered half the length of the lysimeter. The fact that the f value was very close to 0.5 indicates that volume of lysimeter collections which are less than expected may be directly proportional to areas above the lysimeter blocked by rocks or other solid materials. For trial 23, a 1/2 inch dowel was placed so it ran downward at about a 30 degree angle and ended just above the lysimeter. For trial 24, the dowel was removed, but the channels remained. The effect of simulated roots and root channels under these conditions was to reduce the volume of water collected in the lysimeter. However, root channels in the test box, decreased the amount of water collected, in heavy, compact soils root channels running above one lysimeter might cause the volume collected to be greater than the volume collected from another lysimeter without a root channel above it.

Since the effective collection area of the lysimeter is equivalent to the actual top area of the lysimeter under conditions of vertical @rainage, the lysimeter must be a tension free collector, neither resisting downward flow (in which case effective collection area would be smaller than top area of the lysimeter) nor increasing suction of the Soil interface (in which case the effective collection area would be greater than the top area of the lysimeter).

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SUIMARY

The Zero-Tension Lysimeter was tested under laboratory conditions and in the field, and was found to be a passive collector of gravitational soil water. It neither resisted nor increased downward movement of this Water, and, effectively, collected water only from the soil directly above the lysimeter. It appears to be a suitable device for the quantitative measure of water flux in soils under field conditions,

References

Blake, G.R. 1965. Bulk density. In Methods of Soil Analysis, Part 1. No. 9 in the series, Agronomy. Am Soc Agr Inc., Madison, Wis. pp. 374-390.

Cole, D.W. 1958. Alundum tension lysimeter. Soil Science 85: 293-296.

Cole, D.W. 1963. Release of elements from the forest floor and migration through associated soil profiles. Ph.D. thesis, Univ. of Wash. Univ. Microfilms Inc., Ann Arbor, Mich.

Cole, D.W., Gessel, 8.P., and Held, EE, 1961. ?Tension lysineter studies of ion and moisture movement in glacial till and coral atoll soils. Soil Sct. Soc. Am. Proc., 25: 321-325.

Dey, P.R. 1965. Particles fractionation and particle-size analysis. 4n Methods of Soil Analysis, Fart 1, lo. 9 in the series, agronomy. Am Soc Agr Inc., Madison, Wis. pp. 545-567.

Bamisten, JE. 1965. Soils. In the Rain Forest Project Annual Report FY-65. PRIC 61. Puerto Rico Nuclear Center, Rlo Piedras, Puerto Rico, pp. 136-137.

Joffe, J.8. 1929. A new type of lysimeter at the New Jerscy Agricultural Experiment Station. Science 70: 147-148.

Jordan, C.F. 1968, A simple, tension-free lysimeter. Soil Science 105: 81-86,

Kohnke, H., Dredbelbis, F.R. and Davidson, J.M. 1940. A survey

and discussion of lysimeters and a bibliography on their construction and performance. U.S. Dept. Agr. Misc. Pub. No. 372.

Roberts, R.C. 1942. Soil Survey of Puerto Rico. U.S.D.A. Soil Survey Series, 1936, No. 8, 503 p.

Shilova, E.L, 1955. A method for obtaining soil solution under natural conditions. Pedology (Russian) 11: 86-9

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Table 3

Wohannes of soil water collected in Zero-Tension lysimeters under various test conditions and effective

collection area factor f calculated from these values

?Volume of water applied in all tests was 10 liters,

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BIOELIMINATION OF an?

George E, Drewry

IN THE SNAIL CARACOLUS CARACOLLAY

The primary objective of this study is to establish the form, slope, and variability in the curve of elimination of tracer Zinc by the snail *Caracollus caracolla*. The standardized live gamma counting methods and high recapture probabilities established for this species make it feasible to follow the course of tracer bielimination by individual animals in both the field and the laboratory. A secondary objective is to discover, by dissection and gamma counting, the relative deposition of tracer zinc in various organs. The preliminary data to be presented here is drawn from three data sources. A field population of snails in the vicinity of three Zinc⁶⁵ labeled trees has been marked and sampled regularly as described elsewhere. Bioelimination in these snails is available directly from the data; in addition their gross behavior patterns, ranges etc. are under study. In general, however, their bioelimination curves do not stand alone because they have access to an additional supply of tracer, and continuing uptake could introduce subtle distortions in the bielimination curve as well as sharp disruptions of the baseline. To complement these data, therefore, a second field population, whose members had established ranges in a part of the forest remote from the tracer area, was labeled by moving it for one night into the tracer area, then marked and released overnight on Dec. 7, 1967. ALL were recovered and twenty-nine exhibited sufficient uptake to be useful. A third population of laboratory animals was labeled by the same method on Dec, 6, 1967. In this case thirty animals were released, twenty-nine recovered and twenty-six exhibited

high-level uptake.

The overnight uptake by the fifty-six members of these two populations is interesting by itself and is summarized in Table 1. Means are presented in counts per minute per snail rather than by weight for two reasons. One is that there was no correlation of uptake level with snail weight, and since the counts could not be reduced by washing in water it was concluded that the bulk of the uptake was by ingestion of labeled bryophytes and lichens. The counts presented were taken 24 hours after release, 12 hours after recapture and followed the first defecation by each animal. Fecal material was removed before counting and counted separately for several animals, it was radioactive in approximate but not perfect proportion to the snail producing it. If the primary route of uptake was by ingestion it follows that either the food was not labeled uniformly or the meals were not proportional to the weights of the animals, both of which are probably true. The second reason for leaving weight out of the calculation is a fact that has been overlooked in some published bioelimination studies, that weight changes subsequent to uptake represent dilution changes in counts per unit weight that are not bioelimination per se. An insoluble pellet of a long-lived isotope implanted in a growing animal would appear to become eliminated if activity were expressed as a function of weight. The variation of count rate in Table 1 is great and the standard deviation exceeds the mean in individuals from one tree. In actuality the distribution is more nearly Poisson than normal, as illustrated by separating the

oh

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ve and negative component,

posts nts of the standard deviation. ?Tree C, which

is much more frequently utilized than the other two by the resident? snail population, contributed less variation and a lower count rate. Whether these were the result of six months of utilization prior to these uptakes

and three samples from the overnight labeled free population, tear curves are presented in Figure 1. ALL data is corrected for Tasloustine nec of ZincO>. The ordinate in this Figure ts a log scale end tay cee that these curves are either not exponential decay or that they here two OF ore compartments. The Points could be fitted by two lines with a mee near 17 days, unfortunately the need vas not detected for counts at thie critical time and the experiment mst be repeated. Sone of the data in subsequent figures suggests such a break, but decay ia pictured as a curve in all of the Tfigures in acconiance with the snoothest fit for

igure 1. ?The slope is exponential after 30 days in all data. Fi fiso indicates that tree snatls elinimats zine were sapiaiy than fae caged snails. This could be due to differences in activity or to recy cling within the cage, but the latter hypothesis 1e discredited by a failure of the absolute count rates of the caged snails to converge, in fact they tended to diverge with time, Figure 2 presenta data from counts of 12 snails that were introduced to the Zinc6S study area around the fine of initial contamination. one of these snails established ranges in

the area and they were recaptured at distances of up to 100 meters from the area. They left again immediately on release and some were recaptured several times in this manner. Although snails of this category were prone to climb trees and experience secondary high level uptakes before they move away, they were relatively immune to low-level uptake so that the times of uptake and unbroken periods of elimination are relatively dependable. Only such elimination periods are plotted in Figure 2. A curve for the time following day 20 has been fitted using the method of least squares. It has a half-life slope of 64 days.

Figure 3 is a similar curve plotted for the recapture counts of the six wide-ranging snails showing the longest periods between high-level uptakes. Low-level uptake is not ruled out for these animals but their ranges are mostly outside of the contaminated area and the minor fluctuations in their individual curves are well within the range of routine counting error. Therefore, if they experienced low level uptake it was continuous, which is not true for many of the narrow ranging snails that remain much closer to the source of uptake. The point scatter in Figure 3 is due to individual differences rather than to counting variation, as demonstrated in Figure 4, which gives individual curves for two of the animals in Figure 3 with the fitted curve of Figure 3 for reference, (dotted line). These two animals exhibit the maximum and minimum half-life slopes included in the composite of Figure 3, differing by more than a factor of 10. Both snails are adults with similar weights.

They had slight weight gains during the period of observations, but

the one with the more rapid elimination seems to be the more active
snail having a range about three times the area of the other, which 1t

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mole 1

Summary of overnight Zinc uptake by 6 months on Dec. 5.8.6, 1967

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5 ato Th Th hg woot

6 2 Th kg ?6 a oem

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from 5 indoor cayed snails

Figure 1. Bicelimination of Zinc during the first 63 days after initial uptake.

Te ~ 64 days (0 points)

Time in days

Figure 2. Bioelimination of Zinc in involuntary transient snails
(snails initially stocked in experimental area) which
voluntarily moved far away from the contaminated areas.

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Tw in days

Figure 3. Bioelimination of Zinc® in wide ranging snails that do not
show clear evidence of additional uptake after their first
uptake.

Time in days

Figure 4, Individual bicelimination curves for the two extreme individuals of Figure 3 to illustrate that point scatter in Figure 3 is due to Individual variation rather than counting artifacts.

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crossed and recrossed at frequent intervals. With the added note that the range of the more sedentary individual had a greater percentage of its area within the contaminated area, increasing the likelihood of continuous low-level uptake and that the composite slope of Figure 3 would be similar to the 64 days of Figure 2 without the contribution

of this individual; I consider that 64 days is the best current estimate of the biological half-life of Zinc 9 in this species.

Table 2 presents preliminary data from the dissection of six snails at listed times after tracer uptake. Although these data must be supplemented considerably before conclusions are validated, the trend exhibited is noteworthy. Zinc⁶⁵ seems to be either concentrated or selectively retained in the liver, Unfortunately separation of gut

and liver, which is an extremely tedious operation owing to the enclosure of much of the former in the latter, was not attempted in the first animals examined. Additional dissections planned for this series were postponed until another experiment, because of an apparent disease developing among the caged snails that reduced the samples for the bioelimination studies. Eventually more than half of the caged population was lost.

In summary, results in this study are preliminary but encouraging.

Bioelimination has been followed in individuals as well as in populations and holds the promise of being correlated with activity levels, other behavior patterns, and environmental variables. It is not a simple exponential decay, but has a minimum of two compartments. After a rapid post-uptake decline lasting almost twenty days it levels into a smooth half-life slope in the vicinity of 70 days, which appears to differ somewhat from one individual to another. During the first 10 days following uptake there seems to be an increase in the relative concentration of this isotope in the liver at the expense of other organs and tissues.

References

Brungs, W.A. Jr. 1963. Distribution of Cobalt 60, Zinc 65, Strontium 85 and Cesium 137 in a fresh water pond.

U.S. Public Health Service, Environmental Health

Series.

Morton, J-E. 1958. Mollusks, an introduction to their
Hutchinson and Co. Ltd. London.

form and function.

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BEHAVIOR AND NATURAL HISTORY OF THE SWATL CARACOLUS
CARACOLLA IN A TRACER-LABELED ENVIRONMENT. *

George E. Drewry

In the process of following the movement of ^{65}Zn from tree trunk
epiphyte communities through the food chain, 151 *Caracolus caracolla*
snails were painted with fluorescent paint and given numbers to facilitate
collection and rapid identification. Objectives of the study were
to ascertain approximate population density, extent of utilization of
three tagged tree trunks in foraging by the population, the level of
tracer that would be maintained in the population, and enough background
information on the natural history of the species to provide understanding
of the energetics and dynamics of the forage patterns observed.

An additional objective was developed as the study progressed: an attempt

to explain observed differences between individuals in their ranges and susceptibility to tracer uptake. Toward these ends all snails observed within five meters of a triangle formed by three trees were collected, numbered, live-counted, painted, and released at a central point to be resampled on a regular schedule, if they remained in the area and accessible for collection. In most cases animals were counted on the evening

of the day they were collected and released the following day. The location of each animal collected was recorded at the time of capture

to within about one meter in the study zone and with less accuracy as distance from the central point increased. Collection effort was standardized with one hour each collection day being spent within the 200 m of the central study zone and a second hour walking in a widening spiral outward from it. Collections were made about every other day for the first month after tracer application, once a week for the next three months, and twice monthly thereafter.

The snails studied have been divided into several categories for purpose of comparison. Snails captured three or more times without the location of capture giving evidence that they are moving out of the study area and whose apparent range (from the location data) remained partly or wholly within the study zone, were considered to be resident snails. Of

the 151 marked animals, 76 have received this classification. Three other residents have ranges well outside of the study area, At the beginning of the study 24 snails were collected at another location and carried into the study area. None of these animals established ranges there and all were gone in a few weeks. These snails were called involuntary transients. Similar to them in behavior; but entering the study area of their own volition, were 13 snails labeled voluntary transients.

The remaining 35 snails are ones about which insufficient information was available for classification. Most have been recently marked and may represent immigrants. All snails were divided provisionally into juvenile and adult classes on the basis of shell morphology and a correlation between shell features and the onset of testicular sperm formation in ten dissected individuals was made. Puberty occurs between the weights of 18 and 23 and is marked externally by the development of a lip on the shell opening and a little later by extension of the lip to close ventrally the cavity within the shell spiral. Individuals are oviparous and structurally

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Figure 1.

Figure 2,

Method of determining range for an individual snail. Dark circles (A,B, & C) are Zinc6? labelled trees. Dark square (RP) is release point. Dotted line is 5 meter Limit of study zone. X's are individual collection points.

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ATG in meters

Correlation of shell lip thickness (with a size correction)

versus size of observed range (as Wérea), all adult snails.

Points are snails classified as narrow-ranging, open circles wide-ranging, and large symbols are means.

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Figure 3. Observed ranges of }2 resident snails that exhibited no measure-
able uptake of Zinc®>, Dark circles (A,B, & C) are tagged trees.
Dotted line is 5 meter limit, lumber of days spanned by observa-
?tions on each snail is written in the range for that snail.

Figure 4, Observed ranges of 7 resident snails that exhibited o:
low-level uptakes of Zinc65 without any high-level vptake
Reference points same as in Figure 3.

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bisexual; functional bisexuality 1s assumed on the basis of testicular
activity in all adults dissected end observations of copulation in which
intromission vas accomplished by both members of the pair. Egg produc-
?tion has not been studied, however, and it 1s not impossible that
protandry or other temporal separation of sexual function could occur.

Sexual behavior was of particular interest since it was first

invoked as a possible explanation for the marked disparities observed

in size of the range of individual snails. The range of areas for 8

or more captures is from 4.6 me to 237 ne and these extremes also

encompass the ranges of all individuals captured 3 times or more.

Observed ranges were plotted to scale for each of the 79 resident snails

and their extent estimated by sketching a rounded boundary around the

point (see in Figure 1), cutting out and weighing the figure so obtained,

and multiplying the weight by a scaling factor. This procedure was found

to expedite area determinations for many of the ranges which were clearly

not circular. On the basis of the areas obtained the resident snails were

divided into wide-ranging and narrow-ranging categories with a break point

near 56.2. Some overlap was permitted because a few snails with ranges

smaller than 56 m² exhibited rapid range crossing behavior similar to that

of the wider-ranging individuals and it is now believed that the distinction

is a real one, although its meaning remains obscure. It is clear that the

size of the snail is not a factor. Each category included a full selection

of sizes from the smallest juveniles to the largest adults and the size of

the range is not at all correlated with the size of the snail. The presence

of juvenile wide-ranging snails does not support the hypothesis that range

size is related to sexual behavior. An effort was made to find morphologi-

cal characteristics correlated with range size and Figure 2 shows a slight

negative correlation between the thickness of the shell lip and territory

size in a sample of 24 adults. This sample will be expanded as additional

individuals are recaptured, It was necessary to use a lip thickness index

(correcting for size) as the lip in both groups continues to thicken after formation as the animal grows. The index chosen was: $I = 100 \times .16$ ($y = 1.8$) where T is the index value, x the lip thickness in inches, y the shell diameter in inches and 1.8 a chosen zero intercept below the diameter at which the lip actually begins to form. The formula is based on the actual regression of lip thickness on shell diameter in wide-ranging snails and an index value of 43 is average for them. It is noteworthy that there is large variation in all shell parameters in adults of snail and also in the relationship of shell diameter to weight. It appears that the shell is large enough at maturity for considerable expansion of the soft parts without shell growth and that additions to the shell are made in irregular snouts and only at intervals.

The breakdown of resident snails into range classes and age classes is as follows: of the 76 resident snails, 54 are narrow-ranging and 22 wide-ranging; there are 24 narrow-ranging juveniles and 30 adults; and a wide-ranging Juvenile and 13 adults. Of these, 7 juvenile and 4 adult narrow-ranging snails and 1 juvenile wide-ranging snail have not been captured in the last 100 days of the study and are presumed to have left the area or died and 2 snails are known to have died: one juvenile narrow-ranging and 1 adult wide-ranging snail. The remaining 62 snails constitute the resident population of the area together with immigrants which have not

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Summary of tracer uptate by resident sail population, with separation of narrove
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Summary of weight changes in the resident snail population

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Total ants 22 100 22 100 36 100 B10

et change ose 1.54 ose 1,24 Ome 2K vetgnted

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yet been recognized as having established range

parked since day 100 (the date is analyzed to be on 25th, emails

the 13 voluntary transients and the disappearing verona ett

Jon ave ae sggeet that the population te mete equine St betien

Jop enatie Which, taking into sesount the full exten

of the residents ranges, measures about 300 a2, ie ie yee ten

hiding? places and the conspicuous eatination ancy

ination such aa mark ant recapture

inapplicable, Algo the collector's knovledge ef the favorite bates

places of the long term resident narrov-ranging snalie inerosices se

isost tmavoldable bias in their favor,

?vo other behavioral characteristics should be mentioned in pas-

sing on to a discussion of tracer uptake. One 48 the considerable

homing sbility of snails renoved fron their accustomed ranges. The

three snails classified as outside residents have ranges actually center-

ød about 15 m fron the central release point while two of the voluntary

transients have established (or retuned to) ranges nore than 50 m fran

?the release point. The latter tvo enails have been brought in twice fron

the sone small areas, vvhich are rocky ani extrenely difficult to search,

returning thus twice each. The three 15 residents go regularly to their

ranges after cach release, arriving usually in two or three days, and have

done so an average of 11 tines each, The compass directions Involved are

different, and whether navigation is accomplished by direction finding or knowledge of the terrain is not clearly established. The latter is suggested, however, by the fact that the involuntary transients, which were released over 600 m from their collection point, left the release point

in all directions and frequently chose another direction if recaptured

and released again. Another outstanding characteristic is the tendency

of transient snails to climb trees. A group of 60 snails tagged for bio-
mineralization studies, reported in another paper, were carried into the
study area, released on the ground within 1 foot of the labeled tree trunk,
and collected the next day. Of 59 recovered, 58 or 98% had climbed in one day.
The 2k involuntary transients introduced into the area were released in a
similar manner and 23 or 96% of them had fed on the tagged trunks before
the first recapture. In 63 additional recaptures of members of this group
following releases at the central release point, there was evidence of
feeding on a labeled trunk 10 times or .16 zinc uptakes per capture. The
voluntary transients had an even higher rate of utilization, having 23
uptakes per capture as a group even though this activity was confined to
1 foot of the 13 or 16% of the members,

In contrast to transients, the resident community was less active in
climbing and foraging on the ^{65}Zn labeled tree trunks. The more than 150

individuals of various groups actually collected from the trunks established
2 fm base-line for deducing whether a snail had actually been on a trunk
or was carrying Zn that had been removed from the trunks by another
agent, Several snails which had ranges including the bases of the Labeled
trees, but which never climbed the trees, exhibited base-lines of low-level

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Figure 5. Observed ranges of 10 resident snails that exhibited more
or less continuous low-level uptake of Zinc⁶⁵ without any
high-level uptake, Reference points same as in Figure 3.

Figure 6, Observed ranges of 19 resident snails that exhibited high-
level uptakes of Zinc⁶⁵, Reference points same as in Fig. 3.

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a spectrum from 1.01

uptake that never exceeded 100 counts/min in the gamma Spectrometers)

to 1.21 Nyr for one inter-capture interval. In contrast, the initial

directly from the trunk exhibited a sharp increase in uptake

>than 100 counts/in, this level or greater is called uptake

and is taken to indicate foraging on the trunk itself. Of 22

snails, 17 (77%) utilized the tagged tree trunks, of these 9 (2008) of

Juveniles but only 8 (62) of the adults are represented. The

Utilization was 21 uptakes in 176 captures or .12 uptakes per capture.

Of narrow-ranging snails 19 (35%) utilized the tagged trunks, Juveniles

and adults were more similar in this category having 10 (42%) and 9 (30%)

individuals respectively represented. The rate of utilization was 2)

uptakes per 347 captures or .08 uptakes per capture. Juveniles in both

groups exceeded adults in rate of utilization, the juvenile rate in narrow-

Foraging snails being 155% of the adult rate and 185% in the wide-ranging

group. See Table 1 for a more complete breakdown of these categories.

Of the snails in both range classes that did not directly utilize

>the tagged trunks, some exhibited no uptake of ^{65}Zn while others had

either continuous or intermittent low-level uptake. The sample ($n = 5$)

in this category in wide-ranging snails is too small for analysis, but in

narrow-ranging snails it is interesting that about half of both adults and

juveniles had no uptake and the other half exhibited low level uptake.

Figures 3, 4, 5, and 6 suggest that micro-geography played a part in this

phenomenon. The tagged trees are represented as dark circles and labeled

A, B, and C. The ground between them is level and low. The lower four

ranges in Figure 2 are on the tops of very large boulders while the ones

in the vicinity of tree B are in the highest ground in the study zone.

The snail that spent 72 days within 3 meters of tree B without detectable uptake also provides evidence that this tree, which is a palm with long nooses as epiphytes, was not releasing much of its tracer burden to the surrounding soil. Figure 5 suggests that three-fourths of the resident snails utilizing labeled trunks did so on tree C, whose epiphytes are mainly leafy liverworts and lichens. All of the ranges depicted in Figures 2-5 are those of narrow-ranging snails. Figure 6 presents ranges of 11 wide-ranging snails for comparison. Those ranges of snails exhibiting high-level uptake are marked with an asterisk, low-level is marked

©, and no uptake marked 00.

An important question that must be considered in a study of this type is the effect that the experimental treatment had on the parameters under study. Indeed the overall weight of the 79 resident snails that received the most holding, declined by a factor of 1.4% per snail. This figure conceals both increases and decreases of up to 25% in some individuals. Gross figures are about equal percentage wise in adults and juveniles. There is no evidence of a correlation, however, between weight loss and number of captures, as one would expect if there were a causal relationship. There is likewise no evidence that the isotope levels had any effect on weight, the gross figures (Table 2) being 1.5% loss in snails with no uptake, 1.26% loss for low-level uptake and 1.1% loss for high level uptake. The snails with high-level burdens of 652n had hitherto rare percentages of both gain and loss and there exists the very remote possibility that the levels of tracer involved had a stimulating effect on activity level or

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Figure 8.

Observed ranges of 11 wide-ranging snails within the study zone.

Reference points same as in Figure 3. Ranges of snails having

high-level uptake marked *, low-level uptake marked Q, and no uptake marked 90.

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number of snails at each recapture as a function of number of recaptures.

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some similar parameter. Fleatvold (in press), who had worked over a longer period with these snails, states that most of the growth occurs in the months from March to July, while this study has covered so far the remaining months from August to February. There is also no evidence of positive or negative behavioral response to handling in a plot of sample size versus recapture number (Figure 6). One would expect a break in the curve if there were a tolerance level whose transgression resulted in death or departure. An inconsistent mean interval between recapture of about 13 days or 2 sample periods for recaptures 1 through 15 likewise indicates that the snails

do not become more evasive or leave after multiple handlings. The plot of apparent range area versus number of recaptures indicates a slight increase in both narrow and wide-ranging snail ranges that can easily be ascribed to improved information,

In summary the population of *Caracolus caracolla* in an area of rain forest has been found to consist of about one resident snail for every 3 to 5 m² with residence times for some extending at least 220 days. There is a continual flux of transient snails moving through and the loss of about .17% of the resident population per day from death and/or emigration is made up by newly established residents. Two extremes with intermediate types apparently exist with respect to the size of the area over which a resident snail ranges and these behavior patterns seem to be correlated with shell morphology and the tendency to forage on tree trunks. Wide-ranging snails have, on the average, thinner lips on their shells and a 50% higher probability of foraging on trunks. Transient snails, whose ranging characteristics cannot be established in a study of this magnitude, have an even higher probability of utilizing tree trunks, and a snail moved far from familiar territory has a near certainty of climbing the nearest tree before moving away. Snails experimentally moved into an area seem to have a very low probability of establishing themselves near where they are released. Juvenile snails are very similar to adults in size of range and general behavior, but seem to have a slightly greater tendency to forage on tree trunks. The particular trees chosen for tagging in this experiment probably do not provide a reliable estimate of overall trunk utilization in feeding, as only one of them appears to have been used to an appreciable extent. Finally there is no evidence that the snails respond adversely to the large amount of handling involved in this study as there have been no noticeable changes in either their behavior or general health.

The remaining objective of the study, that of determining the level

of tracer maintained in the population, could be derived in estimate form from crude analysis of the raw data. It is desired, however, to submit the data to careful analysis utilizing bicelimination rates as well as corrections for radioactive decay, and these rate constants are only now being established within acceptable confidence limits. The dynamics and equilibrium constants in ⁵Zn uptake and bicelimination by snails will be the subject of a subsequent report. A deficiency in this study as an indicator of the absolute extent of tree trunk foraging in *Caracolus caragolla* has also appeared in the fact that utilization of the three trunks tagged is obviously unequal, so a sample of three cannot be deemed representative. It is also clear from the recapture location data that the snails utilized the trunk of a tree adjacent to tree C up to 5 times as often as they did of C, which was the most heavily used of the three in the sample.

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References

Brungs, W.A. Jr. 1967. Distribution of Cobalt 60, Zinc 65, Strontium 85, and Cesium 137 in a freshwater pond.
U.S. Public Health Service, Environmental Health
Series Pub. No. 999eRH-21: 1-52.

Heatwole, H., A. Rosey, I. Colorado, R. Amadeo (in press) Effects
Of Defoliation of @ population of the Puerto Rican tree

A Tropical Rain Forest.

Stiven, Alan E, (in press) Respiration in the snail *Ceracolus*
caracolla and an estimate of the relative density and
Biomass of litter snail A. Tropical Rain Forest. H.T.
Odum et al.

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?PHENOLOGY

JR, Kline and C.F, Jordan

Leaf fall and fruit fall collections continue to be made in order
to study possible long term variations, and as an index of recovery in
the irradiated center. Leaf fall data for May 1967 through April 1968
are given for the radiation center and the control center in Figure 1.
Fruit fall for the same time interval is given in Table 1. Both leaf
fall and fruit fall are intended to form a continuous record with
previous annual reports. Longer term behavior can be determined by

consultation of these paper.

Pruite of various species collected fran May 2967 through March 1968,

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?Lea? fall in the control area of the rain forest at EL Verde Puerto Rico.

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May, 967 July

Figure 1.

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Figure 2, leat fall in the irradiated area of the rain forest at
Gus 8 Gh Verde Puerto Rico, Teradiarton? wt: ?terminated after
92 days in April 1965.

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Continued Table 1

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Yontn Week Rainfall inches

January, 1967 LT 0.49

85 3.08

16-23 3:00

abo32 iy

February, 1967 at 1.03

a5 2g

1623 aa

2-30 3:20

March, 1967 7 2.26

85 0:32

16-25 0130

23 1150

?April, 1967 Lt 5.38

a5 ores

16-23 0:02

2h-30 0.95

+ 1967 Lt 4.98

Yer 298 85 3:21

16-23 3.62

2-31 016

June, 1967 Fe 1.9

16-23, 2125

24-30 Ash

July, 1967 Lt 1.ge

8-15 5.59

16-23 2.16

2-31 66

August, 1967 7 2.21

85 187

16-23 3:15

2h-31 itt

September, 1967 7 1.55

eas 3:22

16-23 125

24-31 2.6r

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INSECT IDENTIFICATIONS*

George EB. Drewry

The following identifications for insects collected at El Verde

Were made by Dr. Ronald Hodges of the U.S. National Museum and are

Submitted as an addendum to the checklist reported in the 1967 Rain
Forest Project Annual Report.

Petty Subfamily Mader of Genus ant species where known
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Family

Pyralidae

Thyrididee

Subfamily Number of Genus and species where known

?species

Pyraustinae

Pyralinas 1

Epipaschiinae 5

Cranbinae

Chrysauginae 3

Schoenobiinse 3

a

Lineodes metagrammalis Moschler

Argyractis serapionalis Schaus

Aegyractis sp.a

Argyractis sp.>

Gataclysta sumptiosalie Yoochler

Gataclyte miralie Voucher

Seetome

Condolorrhiza?sp. a

Condolorrhiza sp. b

Undulanbia sp.

Byralis manthotalis

gemmae feartmusalin Tempeck

Socare,

etralopha scabridella Ragonot

Tetralopha sp.

Pococera atramentalis (Lederer)

Argyrin lacteata (Febr.)

Diatraea saccharalis Fabr.

Guenee

Pachymorphus subductellus Moschler

Gaphys bilinea Walker

Parachna sp.

Rhodoncure leuconotule Pagenstecher

Rhodoneura thiastralis (Walker)

Rhodoneura nyrsusalis (Walker)

née

bee

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STAFF

Project! Of 10 full-time employees in the Terrestrial Ecology

project: 3 scientists, 3 technicians, 3 field workers, and 1 secre-

On addition the Project has one part-time technician and coopera-

working arrangements with 4 scientists from other organizations
are conducting research at El Verde. A staff list follows.

SCIENTIFIC

A. Resident

Jerry R. Kline, Ph.D., Project Director

Garl F. Jordan, Ph.D., Associate Scientist I, Plant Ecologist

George E. Drevry, Ph.D., Associate Scientist I, Animal Ecologist

B. Visiting

Raymond E. Henzlik, Ph.D., Oak Ridge Research Participant

from Ball State University, June-August, 1967. Worked

on radionuclide behavior in epiphyllae.

Elizabeth McMahan, Ph.D., University of North Carolina.

Worked on radiosensitivity of termites during summer

1967. Will continue field studies of termites in the

irradiated center at El Verde during 1968.

Joe, A. Himelstein, Ph.D., Botanist, University of Georgia.

Worked on nitrogen fixation in epiphyllae.

John Koranda, Ph.D., Lawrence Radiation Laboratory. Worked

on tritium behavior in tropical ecosystems.

TECHNICAL

Douglas Kron, Electronics Technician I, Weather Station Operator

Alejo Estrada Pinto, Research Assistant I, Field Botanist

Paul Rossy, Research Technician, Gamma Ray Spectroscopist

José Colén, Research Technician (1/2 time), Atomic Absorption

operator

?FIELD WORKERS

Moisés Parrille Rosario, Maintenance Foreman

Doroteo Martinez Garcia, Field Worker

Juan Martinez Maisonet, Field Worker

SECRETARIAL

?Ana Josefina Correa Lépe2, Administrative Secretary II

ut

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PAPERS PRESENTED AT SCIENTIFIC MEETINGS

?AND PUBLICATIONS

Papers Presented

?The following papers were presented at society or symposium meetings.

2) Kline, J.R.,J.E, Foss, and §.8. Brar. La and Se distribution in

?three glacial soils of western Wisconsin. Presented to

Soil Science Society of America, November 5-10, 1967.

Washington D.C. (Manuscript submitted).

Publications

The following manuscripts have been submitted for publication in addition to those listed above.

1) Einisten, Joe, and J.R, Kline, Mitrogen fixation by epiphyllae.

Submitted to Ecology.

2) Jordan, C.F, Vegetative sprouting following irradiation of a tropical rain forest. Submitted for inclusion in the book

A Tropical Rain Forest. H.T. Odun ed.

3) Kline, J.R., and C.F. Jordan. Tritium movement in soil of a tropical rain forest. Science, 160: 550-551 (1968).

4) Kline, J.R., and S. Brar. Instrumental analysis of neutron irradiated soils. Submitted to Soil Science Society of America Proceedings.

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APPENDIX

MANUSCRIPTS WHICH HAVE BEEN PREPARED AND

lig

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?TRITIUM MOVEMENT IN SOIL OF TROPICAL RAIN FOREST

J.R. Kine and C.F. Jordan

ABSTRACT

?Tritiated water applied to the surface of soil in a tropical rain forest was found in free water of the litter and top 18 cm of soil as even in the high

long as 7 months after the application. Plant roots in the rainfall environment of a tropical rain forest, therefore are exposed

to tritiated water for a considerable time after release.

?Tritium might be released to the tropical environment through military or peaceful thermo-nuclear detonations. The behavior of such release in the tropical ecosystem is not well known although Koranda (1) found tritium in soils and plants of Eniwetok 12 years after testing of thermonuclear weapons had ceased there. We now report on the residence half-times of tritium in clay soils of the tropical rain forest in the

Taguillo Mountains of Eastern Puerto Rico.

A soil plot, 0.94 m² in area, was prepared by installing a lysimeter (2) 18 cm below the soil surface, from a horizontal tunnel originating outside the plot, without disturbing the soil above it.

Free water percolating through the soil was collected in the lysimeter, drained into a plastic collection vessel, and sampled after every rain for three weeks and weekly thereafter. The downslope terminus of the plot was fitted with a metal tray placed as nearly as possible at the Litter-soil interface to collect and sample surface run-off water.

Two rain gauges (3) were placed at the sides of the plot to measure rainfall at the forest floor. Above, canopy rainfall was measured by a standard tipping bucket rain gauge on a tower. From a garden sprinkling can, one liter of tritiated water (concentration, 20 nCi/liter) was applied to the plot. The sampling program lasted 210 days after the tritium was applied. Tritium was determined by standard methods of liquid-scintillation counting in 1-ml water samples. We did not convert results to absolute activities because all we required was the variation of count rates to time.

Tritium activity in soil water collected 18 cm below the surface reached a peak in approximately 16 days and declined exponentially during the rest of the experiment. (Fig. 1). The effective half-life after reaching the peak (uncorrected for tritium decay) in this soil (found by least-squares analysis) was 16.3 days. The curve represents the spatial distribution in soils and was obtained in the soil profile with a fixed-point collector which measures the shape of the distribution. Thus, the time distribution is interpreted as a mirror image of the moving spatial distribution (at peak) passing through the lysimeter. Tritium therefore moved through the soil profile with a sharp leading edge, followed by a long exponentially declining tail.

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The first phase of tritium release in soil-surface water has an effective half-life of approximately 2.9 days; the second phase has a half-life of 35.6 days. The first phase of tritium loss in the surface probably reflects penetration of the moving front of tritium into the profile and dilution and equilibration with the incoming waters which saturate the surface litter. The second longer lived phase may represent partial release of tritium trapped as immobile water, in tortuous pore spaces of the soil near the surface. The fact that the effective half-life of this phase is longer than in the soil profile means that, in the soil surface or surface litter, there is some compartment which has less complete equilibration with incoming fresh

Water than indicated by the soil profile. Such compartments could include the water used in metabolism by soil and litter organisms.

Cumulative rainfall during the experiment was 184 cm above the forest canopy and 137 cm at the forest floor (Fig. 2). Although the rainfall pattern had many highs and lows of input, tritium loss occurred as a more-or-less smooth function of time.

A theoretical model for the behavior of tritium in soils (3 or 4) contends that tritiated water applied as a unit pulse to a soil surface will move downward in the soil profile as a front or peak which separates pre-existing water from water entering the system after the tritium input. According to the model, the peeling phenomenon occurs because of the rapid rate of self diffusion in soils, as compared to the slow rate of bulk water movement. The rapid exchange prevents the tritium pulse from overtaking old water in the soil, and from being overtaken by new inputs of water, and can be used (6) to measure evapotranspiration. Vertical diffusion causes the natural peak to broaden during downward movement in the soil, but we expect concentrations of tritium in the free soil water after the peak to approach zero if all phases of immobile water are equally rapidly exchanged with the freely moving water (5).

Clay soil has many tortuous pore spaces, however, which may inhibit free molecular diffusion of tritiated water. In clay soils there are other sites (such as clay water films and exchangeable Epincgen) which could have a restricted molecular exchange with the water moving bulk water. Such diffusion-restricted compartments would result in exponential decay curves since the process of renewal would be essentially successive dilution in an infinite series.

The two-phase-release curve in the soil litter and mineral surface supports the view that there are in soil somewhat isolated compartments of immobile tritium which do not have complete, rapid exchange with the freely-moving bulk water.

We conclude that the basic model proposed by Zimmerman et al. (3), for tritium movement in soils must be modified to allow for the existence in clay soils of isolated compartments of immobile water which do not have completely free molecular exchange with the more

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Figure 1,

Figure 2.

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SPECIFIC ACTIVITY (PM/mL)

4080120160200

Time (oavs)

Loss rates of tritium from soil and from surface litter in
@ tropical rain forest. (A) tritium in free soil water
collected 18 cm below the surface; (B) tritium in free
surface water,

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RAINFALL (CM/WEEK)

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ol

040 80 12060 200

TIME (ays)

Rainfall input to the tropical rain forest during the experimental period. Fluctuations in tritium activity in free soil water and surface water are independent of rainfall fluctuations.

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rapidly moving phases. Even in clay soils of the tropical rain forest, most of the tritium pulse passed through the profile in the form of a peak or front in a manner similar to that shown by Zimmerman et al. After the peak however, the profile remained labeled. This behavior must be considered in predicting the biocumulative effects of thermonuclear detonations. If tritium moved in soils as a peak analogous to the movement on a chromatographic column, it would be carried out of the major rooting zone of most plants in high rainfall areas relatively quickly. The residual labelling of the soil profile as shown here, however, implies that plant roots would be exposed to tritium long after the input, and that food products grown on these soils would be correspondingly contaminated,

References

Corey, J.C., D.R. Neilsen, and J.W. Bigger, 1963. Soil Sci. Soc. Amer. Proc., 27 (3).

Jordan, C.F. 1968, A Simple Tension-Free lysimeter. Accepted publication by Soil Science.

Koranda, J.J. 1965. Health Physics 17, 115.

Zimmerman, U., K.O. Munnich, W. Roether, W. Kruetz, K. Schubach, and O. Siegel, 1965. In Proc. 6th Int. Conf. Radio-carbon and Tritium Dating Pullman, Wash. June 7-11, 1965, ST.

, W. Kruetz, K. Schubach, O. Siegel, 1966. Science asl.

» K.O. Munnich, and W. Roether, 1967a, in Isotope

Techniques in the Hydrologic Cycle, Geophysical Monograph Series, No. 11.

» P. Ehler, K.O. Munnich, 1967, In Proceedings of The Symposium on Isotopes in Hydrology. IAEA Conf. Vienna, Nov. 14-16, 1966, 567.

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EFFECTS OF IONIZING RADIATION ON THREE NEOTROPICAL TERMITES SPECIES (ISOPTERA, TERMITIDAE)

Elizabeth A. McMahan

ABSTRACT

Adult workers and soldiers of three termite species from a montane rain forest in Puerto Rico (*Nasutitermes costalis*, *N. nigriceps*, and *Parvitermes discolor*) were irradiated with a cobalt-60 source in two series of tests. Two dose rates (615 rads/min and 42 rads/min) and three accumulated doses (3000r, 6000r, 12,000r) were used. Primary data consisted of L_{50} values. Significant differences in radiation sensitivity between *N. costalis* and *P. discolor* (Series I) but not between *N. costalis* and *N. nigriceps* (Series II) were found. For all species, workers were more radiosensitive than soldiers. Mortality was positively correlated with dose rate and with dose magnitude, as expected. There is evidence that these rain forest termites may be more radiosensitive than adult insects have generally been found to be. Such a result might be correlated with their habitual lack of exposure to harsh environmental conditions.

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Introduction

Most studies of the effects of ionizing radiation on insects have indicated that adults are at least 100 times less sensitive to the lethal effects of such radiation than are vertebrates (See O'Brien and Wolfe, 1964, for summaries). Insect resistivity has been attributed to the relatively low rate of cell division in adults, except for cells of the gonads. Doses of 60,000 r and up have usually been required for killing adult insects, and lower doses result in sterility (Lindquist, 1958; O'Brien and Wolfe, 1964). Effects vary with age of insect, developmental stage, oxygen tension, temperature, and nutritional status. This paper reports results of experimental irradiation of adult termite

In the summers of 1966 and 1967 field and laboratory studies were made of termite populations in a Puerto Rican montane rain forest, a portion of which had been experimentally exposed to a cesium-137 gamma emitting source for 92 days in the early spring of 1965 (Odum, in press).

Most of the termites represented two species, *Nasutitermes costalis* and *Parvitermes discolor*, both members of family Termitidae. *N. costalis* builds nests of wood carton, a material produced by the termites themselves, while *P. discolor* lives in decaying logs and dead tree trunks. Both species build carton tunnels to food sources outside their living

quarters. Life span for members of these species is not certain, but

it is assumed to be similar to that of other termite species: five years

or more for workers and soldiers (Harris and Sands 1965).

In the summer of 1966, fifteen months after cessation of irradiation, tunnel occupation within a 30 meter radius of the irradiated center was compared with that of comparable areas in two control centers. In one control center the trees had been topped by machete to simulate radiation damage to the canopy, while the other control center was left undisturbed. Only 13% of the tunnels in the irradiated center were found to be occupied, while 36% and 19%, respectively, were occupied in the two control centers,

In addition, the nest population of *N. costalis* in the irradiated area appeared to differ from those outside in containing fewer inhabitants, and especially fewer immature colony members. All nests within 60 meters of point 0 in the three centers were examined periodically. In the summer of 1966, the irradiated center contained 11 nests, the disturbed control center had none, and the undisturbed control center had 12.

Of the 11 still-active nests in the irradiated center, one had received a total dose of 6000 r, one 1000 x, another 500 r, and the eight others had received accumulated doses of 200 r or less. These doses are relatively low, yet by July, 1967, five of these 11 irradiated nests had become abandoned, as opposed to only one (very small) of the 12 non-irradiated nests present in the comparable area of the undisturbed control center. Minnel occupation had decreased further in the irradiated center while remaining approximately the same in the control centers.

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These comparisons of tunnel ant nest occupancy indicated that the irradiation, although relatively low, had affected adversely the termites in the cesium center. A logical hypothesis seemed to be that the irradiation had resulted in sterilization of reproductives and potential reproductives, with consequent failure of adult and soldier replacement by developing brood. A further supposition was made that perhaps termites are more sensitive to ionizing radiation than most insects have been found to be.

Preliminary tests, 1

In the summer of 1966 a preliminary laboratory test of radiation sensitivity was carried out on a population of *I. costalis*, all termites

taken from a single nest in an unirradiated portion of the rain forest.

Four experimental groups, each composed of 20 adult workers, 20 soldiers, and 10 young nymphs were taken from a population that had been given a dose of 6000 r at a rate of 67 rads/min. from a cobalt-60 source. These four groups were matched with similar but unirradiated groups from the initial nest population. All irradiated termites were dead in 6 days, while 60% of the controls were still active at that time. Nymphs were more sensitive than adults, and adult soldiers appeared to be slightly more resistant than adult workers.

Experiments, 1967

A more extensive test of radiation sensitivity was planned for the summer of 1967, comparing different termite species and utilizing several radiation dosages. The first series compared the two termite species most common in the rain forest, *N. costalis* and *P. discolor*. Series I also included testing of a species of homopteran found to be very prevalent in the irradiated center, but extremely poor survival of both control and experimental leafhoppers showed that holding Conditions during the test were too poor for conclusions to be reached. These homopteran results, therefore, are mentioned only briefly in this report. The second series compared *N. costalis* with yet another termite species, *N. nigriceps*.

Experimental Animal

Reticulitermes flavipes, *H. niger* and *Parvitermes*

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Workers and soldiers were used in the present experiment. Since,

are smaller than workers; Table 1 gives arenes. Table 1 gives arenes. Table 1 gives arenes.

castes for the three species,

ALL termites in each test population were taken from

and all colonies were from outside the experimental centers, the diet?

individuals for both experimental series were taken from the same

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The *N. costalis* termites in Series T were collected by breaking the

nest? a large plastic sheet and transferring appropriate individuals to

Plastic containers using camel's hair brushes. The large nest fragments

with most of the remaining colony, were then placed at the base of &

free, shielded from rain, and left undisturbed until the beginning of

Series IZ, 10 days later. Again, termites were shaken from the nest

fragments and transferred to plastic containers. *Parvitermes* indi-

viduals were collected by breaking open a large infested rotten log and

brushing the termites into dishes from which they were transferred to

the experimental containers. *N. nigriceps* individuals were taken

similarly from a large tunnel on @ rotting tree trunk, because no

nest was found. Ordinarily *N. nigriceps* is not found at altitudes

much above 500 feet but the species had invaded an area adjoining a forestry road in the experimental area at about 1000 feet. Members

of this population were used in Series 2.

?The homopterans were leafhoppers in all stages of nymphal development, plus adults. They were selected for testing because of their great prevalence in the area, Average adult weight was .90 mg.

?They were collected within 15 meters of the cesium site on leaves

of *Ichnauthus pallens* (Sv) Minro, a grass typical of open spaces in this rain forest.

?The *Ichnauthus* had invaded the center following defoliation. of

?the trees after irradiation. It was heavily infested with the leaf-

hoppers, most of which were Juveniles feeding on the under sides of

leaves and on stems. Many winged adults were also present, and both

nymphs and adults were very active, Collecting consisted in finding

fairly-infested leaf, detaching it gently by a scissor-cut and quickly

placing the entire leaf inside a small plastic experimental Jar. An

?attempt was made to put at least 10 leafhoppers in each container, but no exact count was attempted at the time of collecting.

ALL populations compared in a given series were collected on the same day. It took approximately two hours to collect each species and to segregate the individuals appropriately in the small experimental containers. Irradiation was on the succeeding day.

Experimental Containers

?The plastic Jars in which the experimental animals were held and tested were 4 cm high and 4 cm in diameter. Each had a screw-top lid, and a circular floor of dampened paper toweling.

The termite Jars also contained a 2 cm x 1 cm chunk of damp, decaying wood and a 3 cm length of dampened Cecropia petiole, 1 cm in diameter. Both of these food sources had been found previously to be acceptable to termites as food. All the wood chunks used in the containers had been taken from the same piece of decaying wood.

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The homopterans were placed in similar containers but with only the damp circle of paper towel as a "floor", and no wood. Their food source consisted of the leaves of *Ichnautia* to which they were attached when collected. Fresh (uninfected) leaves were added every other day to these containers. Container Lids were loosely secured in place,

Irradiation

Three radiation doses (3000 r, 6000 r, and 12,000 r) were used, with two dose rates for each: 615 rads/min. and 42 rads/min. Irradiation was carried out in the Puerto Rico Nuclear Center in Rio Piedras, using a cobalt-60 source. All containers in a given series were irradiated simultaneously, dose rate being controlled by distance from the source, and dose magnitude by time of exposure. Control containers received exactly the same treatment as experimental containers except that they were not irradiated,

Procedures

Series 1 compared the radiation sensitivity of *Nasutitermes gustalis*, *Parvitermes discolor*, and the homopteran, Table 2 indicates the overall experimental set up: Six experimental conditions and one control per species, with replicates of each, making a total of 8 containers. At the start of the experiment, the termite containers

each held 20 workers and 5 soldiers. The homoptera containers each held an average of 10 leafhoppers.

Following appropriate irradiation of the experimental containers all were kept at ambient temperatures (approx. 26°C) and humidity at the El Verde rain forest station. Each morning all containers were opened in a constant sequence and the inhabitants were removed gently for examination. Number of survivors was recorded and dead individuals were discarded.

Because of their strong tendency to hop, the leafhoppers were gently transferred into a closable plastic bag for counting. The termites usually remained clinging to the wood chunks or Cecropia petioles and were transferred for examination to a bowl lined with a pliable plastic sheet. Every individual was accounted for before survivors were returned gently to their containers.

Series II was carried out ten days later in exactly the same way as Series I except that workers and soldiers of *N. costalis* and *N.*

nigriceps were tested.

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Results

Holding conditions for termites during

apparently not as bad as those? for the isopods Terie nino Poors

as shown by high control mortality rates, Table 3 gives survival percentages on the eighth day following treatment for both, control

and irradiated termites and leafhoppers. Total accumulated dose and dose rate are disregarded. The eighth day was chosen for the comparison because it was the maximum point of survival for experimental individuals of *H. nigriceps*, the termite species first reaching 100% mortality. In subsequent analyses, the experimental data have been corrected for control mortality. Results for Series I and Series II have been kept separate in all analyses because the large differences in mortality for control individuals (see *N. costalis*, Table 1) indicate that conditions in the two series were too different to permit pooling.

Time, in days, at which 50 percent of experimental termites were dead (L_{50}) was calculated for each experimental condition for each termite species and used as the primary datum in analyses.

Comparison of Worker and Soldier. The result supported those of the preliminary tests of 1966 in showing that soldiers are more radio-resistant than adult workers. Figures 1 and 2 give soldier and worker mortality curves for Series I and II, respectively, when data for irradiation conditions (dose rate & total accumulated dose) are pooled.

In Series I, the average U5 values for lig soldiers and workers are 4.1 and 2.7 days; comparable figures for *P. discolor* are 9.7 and 8.5. In Series II for *N. costalis*, they are 1.45 and 1.40; and for *N. nigriceps*, they are 3.55 and 2.90. In all cases, soldier survival exceeded worker survival.

Effects of Accumulated Dose and Dose Rate. As expected, there was a positive correlation both between mortality rate and size of accumulated dose and between mortality rate and dose rate. These effects are shown in Table 4 and 5, in terms of mean of U50 values, with data for Soldiers and workers pooled. In order to evaluate the significance of the U50 mean values and the interaction between levels of dose size and dose rate for different species, analyses of variance, using a factorial arrangement of the treatments taken two sets at a time, were applied to the data shown in Tables 4 and 5. The results are given in Tables 6-13. They show that size of total dose affected significantly the time of death for *N. costalis* and *N. nigriceps* but not for *P. discolor* (Tables 6, 7, 8, 9), and that the differences resulted only at the higher, not at the lower, dose rate (Tables 10, 11, 12, 13).

Species differences, The average time of death following irradiation

tion atseses-Significantiy for N. costalie and P. discolor (Series T, Table 10 and 11, Figure 1) ab doth high and lov dose rates. On the other hand, N, gostalis end N. nigriceps aia not show such differences Mt elther rate. (series 11, bles 12 and 13, Figure 2),

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Figure 1.

Figure 2.

Comparison of soldier and worker survival rates after irradiation for P. discolor and N. costalis in Series I, Percentage figures go. above 100 because all data are corrected for control mortality. Dose rate and dose magnitude data are pooled.

Comparison of soldier and worker survival rates after

irradiation for *N. nigriceps* and *N. costalis* in Series II.

Percentage figures go above 100 because all-data axe
corrected for control mortality. Dose rate ant dese

magnitute data are pooled.

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?Table 1

Average Weights of Workers and
Soldiers for Three Termite Species

Parvitemmes Naguti termes Nasutitermes

caste discolor costalis ?nigriceps

Soldier 0.82 mg 2.54 mg, 2.44 ng

Worker 2.03 mg 4.64 mg, 6.99 mg

Table 2 a

Experimental Plan for Series I

contro Irradiated Containers Irradiated Containers

Species Containere (6150/min) (i2e/min)

3000r 6000r_12,000r 3000r_6000r_12,000r

Nasutitermes 4 4 4 4 4 4 4

Parvitermes 4 4 4 4 4 4 4

Homoptera, 4 4 4 4 4 4 4

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Table 3

Fer Cent Survival of Termites and Leafhoppers on
Eight Day Folloving Irradiation®

Series I

Termite Nasutitermes costalis Parvitermes discolor

? ?Control Experimental, ?Control Experimental

Soldier 93.33, 19.83 15.00 5.10

Worker 83.33 9.79 85.00 49.38

a _

Series IT

?Termite Nagutitermes costal! Hasutitermes nigriceps

Control Experimental, ?Control Experimental,

Soldier 70.00 15.00 25.00 6.68

Worker 43.75 8.13 15.00 0.00

Series I

Control Experimental,

Leafhopper 0.00 1.85

a

?ALL dose rate and total accumulated dose data pooled,

132

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?Table 4

Average Tae. Values (+ 95 Per Cent Confidence Limits) of N. costalis
and P. discolor for Levels of Total dose and Dose Rate (Series I).

?Total Dose (r) Dose Rate H, costalis P, aiseolor

3000 High (615 rads/min) 8.61 days 12.38 days

Low (42 rads/min) 7.50 7.06

6000 High 2.65 7.78

low 429 10.90

12,000 Bigh 0.99 4.65

low 1.61 85h

Table 5

Average Lf50 (+ 95 Per Cent Confidence Linits) of N. costalis and

?N. nigrigeps for Levels of Total Dose and Dose Rate. (Series II).

?Total Dose (r) Dose Rate A. nigriceps

3000 High (615 rads/min) 6.05 days .~ 2.59 days

Low (42 rads/min) 9.65 9.35

6000 High 1.31 2.87

low 3.57 3.46

12000 High 0.89 3.53

Low 1. 3.97

133

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?Table 6

Analysis of Variance of Total Accumlated Dose and Dose Rate Affecting Tine of
Death of N. costalis, with Treatnents Arranged in Factorial Design (Series I),

Degrees of Sum of Mean

Source of Variation Freedom Squares Square F

?Treatments 5 198.88

A, Total dose 2 190.26

B. Dose rate 1 0.89

AB Interaction 2 TB

Error 18 31.11

?Total 23 229.99

Table 7

Analysis of Variance of Total Accumulated Dose and Dose Rate Affecting Time of
Death of *P. discolor*, with Treatments Arranged in Factorial Design (Series I).

Source of Variation Degrees of Sm of. Mean

Freedom Squares Square F

?Treatments 5 125.05

A, Total dose 2 36.32

B, Dose rate 1 4.73 [3

AB Interaction 2 82.00 00

Error 18 alior 217

Total 23 23642 eee

234

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?Table 8

Analysis of Variance of Total Accumulated Dose and Dose Rate Affecting Time
of Death of *N. costalis*, with Treatments Arranged in Factorial Design (Series II).

Degrees of Sum of Mean

Source of Variation Freedom Squares «= ?Squares. F

?Treatments 5 2s8 il i yrsessessasse

A, Total dose 2 pork 100.70

B. Dose rate 1 eT. er.

4B Interaction 2 9.33, 4.67 c

Error 18 129.18 6.68

?Total 23 358.320 ws

Table 9

Analysis of Variance of Total Accumulated Dose and Dose Rate Affecting Time
of Death of *N. nigriceps*, with Treatments Arranged in Factorial Design (Series II).

Degrees of Sum of Mean

Source of Variation Freedom © Squares Square F

?Treatments 5 127.58 . mace -°

A. Total dose 2 35-17 17.59

B. Dose rate 1 40.43 40.83

AB Interaction 2 51.98 25.99

Error 18 28.21 157

?Total 23 155.79

135

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?Table 10

Analysis of Variance of Total Accumulated Dose and Species Differences

Affecting Time of Death of *N. costalis* and *P. discolor*, with Treatments

Aranged in Factorial Design (Series I).

615 rads /nin

Degrees at = Stm of Mean

Source of Variation Freedom Squares Squares F

Treatments 5 308.05

A. Total dose 2 213.38

B. Species 1 89.01

AB Interaction 2 5.66

Error 8 32.23

Total 3 3h0.28

Table 12

Analysis of Variance of Total Accumulated Dose and Species Differences
 Affecting Time of Death of *N. costalis* and *P. discolor*, with Treatments
 Arranged in Factorial (Series T.

Tow Dose Rate: 2 rads/nin.

Degrees of Sum of Mean

Source of Variation Freedom Squares Squares F

?Treatments 5 213.11

A. Total dose 2 30.08

B, Species 1 113.84

AB Interaction 2 6.19

Srror 18 109.96

Total 23 323.06

Table 12

Analysis of Variance of Total Accumulated Dose and Species Differences
Affecting Time of Death of *N. costalis*

costalis and *N. nigriceps*, with Treatments
Arranged in Factorial Design (Series II).
High Dose Rate: 615 rads/min

Degrees of Freedom

Source of Variation Freedom Squares Squares F

Treatments 5 67.86

A, Total dose 2 25.23 12.61

B, Species 1 0.37 0.37

4B Interaction 2 4226 21.13

Error 18 28.51 1.58

Total 23 96.36 panes

?Table 13

Analysis of Variance of Total Accumulated Dose and Species Differences

?Affecting Time of Death of *N. costalis* and *N. nigriceps* with Treatments

torial Design (Series II).

42 rads/min

Degrees of Sun of Mean

Source of Variation Freedom Squares Square F

?Treatments 5 hol .59 saeteee ee

A. Total dose 2 255.82 227.91 1.50 n.

B. Species 1 85.65 85.65 1.00 n,

AB Interaction 2 153.11 6.56 0:90 ni

Error 18 1537-29 85.41 seeeee

?Total 23 2031.86 :

3

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Interaction effects. In addition to the significant main efecta,

Significant interactions were shomn for various sets of treatments (See

Teble 7,9, 11, and 12), Inspection of the data reveals that these

Significant interactions are the result of wide cifferences in mortality

between replicates within single treataents, Although N. costalts date

are consistent in showing positive correlations between mortality and both total dose and dose rate, *P. discolor* and *N. nigriceps* data are not always consistent. In almost every case the inconsistency is due to high mortality in some containers and low in others for the same experimental condition. Factors responsible for these wide differences between replicates are not known.

Discussion

Menhinick and Dodson have pointed out that no general principle for predicting radiosensitivity of insects, similar to the nuclear volume method for higher plants, has so far been elaborated. Their studies, in which 12 species of insect (none in order Isctopera) were irradiated in a Cobalt-60 source at doses ranging between 1000 and 312,000 rad at two dose rates (3000 r/min or 30,000 r/min), indicated that there seemed to be little relation of sensitivity to taxonomic grouping. Their studies did show, however, that within each order, radiosensitivity appeared to be correlated with weight. Other investigators testing the radiosensitivity of other organisms, have obtained similar results.

These termite data support the apparent positive correlation between weight and radiosensitivity, although not entirely consistently. One should expect, on this basis, to find an increase in sensitivity in going from soldier to worker (see Table 1) and from *P. discolor* to *N. nigriceps*. The only departure from the expected trend is the lack of evidence for greater sensitivity of *N. nigriceps* over *N. coarctatus*,

Both the high (615 r/min) and the low (42 r/min) dose rates resulted in increased mortality for all species. Size of total dose was significantly effective in producing differential mortality only when dose rate was high. The reason for this result probably lies in the

The original question pertaining to a supposed heightened radiosensitivity of termites over most other insects has not been answered unequivocally by these studies. High mortality among control termites indicated that holding conditions were poor. The results obtained were comparable, however, with those of the preliminary tests conducted in 1966. At that time the *R. costalis* nest was broken up into three groups, two-thirds of which were divided equally between two closed rearing containers. One container, with its thousands of inhabitants, was given a total of 6000 r at the rate of 67 r/min. The other population was not irradiated. From each of these two populations, four replicates

groups were selected and placed in small plastic jars, each group consisting of

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ting of ten adult workers, ten soldiers, and five nymphs, a total of 25 individuals. The jars were examined daily. Mortality was high for both control and experimental (irradiated) termites, but after six days all termites in the four experimental jars were dead while 67 of those in

the four control jars still survived. Even more striking was the comparison between the two original populations in the two waste-basket containers. All of the thousands of inhabitants of the irradiated basket were dead as compared with virtually none of the termites in the nonirradiated basket. It appeared that holding conditions in the large basket containers were considerably better than those in the small plastic jars, and more closely approximated conditions in nature. Nevertheless 100% mortality

had occurred among the irradiated termites six days after they had received only 6000 r, given at a rate of 67 rai/min.

When the data for 1966 and 1967 are viewed together they appear to suggest that these termites are more radiosensitive than most other adult insects that have been studied. Male cockroaches (*Periplaneta americana*)

were found to have Psp values of 1h days gt, 10,000 (Wharton and Wharton 1959); the boll weevil (*Anthonomus grandis*) had? Usg values of 6 days for males and 7 days for females at a dose of 15,000 r (Davich and Lindquist 1962); both male and female plum curculios (*Gonotrachelus nenughar*) had values in excess of 10 days at 10,000 r (Lippold, Canbrell and Nassey 1968) and Female adult large milkweed bugs (*Oncopeltus fasciatus*) had an Usg of 28 days at 10,000 r. These values should be compared with the LD50 values for the three termite species, given in Tables 4 and 5.

Woodwell (1967) had suggested that organisms which are adapted to harsh environmental conditions tend to be radioresistant. The converse would be that organisms which have not had to adapt to stringent conditions might be more sensitive to ionizing radiation. These rainforest termites, by virtue of their colonial habits and geographical distribution, are protected against environmental extremes. It will be interesting to see how termites living in other, more demanding, environments compare in radiosensitivity with these rainforest termites.

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References

Davich, L.B. and D.A. Lindquist, 1962. Exploratory studies on

gamma radiation for the sterilization of the boll weevil,

J. Econ. Entomol. 55: 164-7.

Harris, W.V. and W.A. Sands, 1965. The social organization of termite colonies. Symp. 2001. Soc. Long. No. 14, 113-131,

Lindquist, A.W. 1958. Entomological uses of radioisotopes. In Radiation Biology and Medicine, W.D. Claus, Ed. Reading Mass.: Addison = Wesley Publ. Co.

Lippold, P.C., F.L. Ganbrell, and I.M. Nagsey, Jr. 1968. Effects of ionizing radiation on the European Chafer, the plum curculio, and the large milkweed bug. Ann. Entomol. Soc. Amer. 61: 151-158.

Menhinick, B.F. and G.J. Dodson, 1964. Radiation sensitivity of insects.

O'Brien, R.D. and L.S. Wolfe, 1964, Radiation, Radioactivity and Insects. Academic Press, N.Y. 211 pp.

Odum, H.T., Ed. A. Tropical Rainforest. Atomic Energy Commission,
In Press.

Wharton, D.R.A. and M.L Wharton, 1959. The effects of radiation

on the longevity of the cockroach. *Periplaneta americana*,
as affected ty dose, age, sex, and food intake. Radiation

Res. 11: 600-9.

Woodwell, G.M, 1967. Radiation and the patterns of nature. *Science*
156, 461-470.

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insects. Dr. A.E. Stiven gave statistical aid.

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NITROGEN FIXATION BY EPIPHYLLAE*

Joe A. Binisten and Jerry R, Kline

University of Georgia ani Puerto Rico Nuclear Center

Preliminary studies on nitrogen fixation in the lower montane rain forest of eastern Puerto Rico indicated nitrogen levels of 2 to 3% in leaves of leguminous plants and in the leaf nodulated *Psychotria* (1). Leaves from non leguminous plants normally had less than 1 N although several cases were found where the levels were over 3%. Leaves with the largest visible growth of epiphyllae appeared to have the highest content of N. This suggested that some components of the mixed epiphyllae communities could fix atmospheric N,

Ruinen (3) reported that epiphyllae fixed nitrogen in vitro and suggested that the bacteria *Azotobacter* and *Beijerinckia* might be responsible. Stewart's review (4) suggested that nitrogen fixation occurs in the phyllosphere. We now report the results of a preliminary experiment which was carried out using N_2^{15} to determine qualitatively whether N fixation occurs in the phyllosphere under field conditions in the tropical rain forest.

Methods

Shade leaves of a grapefruit tree (*Citrus paradisi*) at the edge of

a salic clearing in the lower montane rainforest were selected for the experiment since their epiphyllae populations appeared similar to those in the forest. Five undisturbed leaves were enclosed in plastic bags which were sealed by taping securely to the stems. Hypodermic needles with rubber tube connections were used for removal of the normal atmosphere and subsequent replacement by an atmosphere consisting of 75% Argon, 20% oxygen and 5% CO_2 . Metal pinchcocks on the rubber tube connections to the needles were used to prevent the loss of the artificial atmosphere during a 48-hour exposure period. During the period of exposure, the bags remained inflated. Verifying that the systems were well-sealed.

At the end of 2 days of exposure to ^{15}N the leaves were cut from the tree and the epiphyllae were scraped from the leaves. It was planned to measure the amount of NIS in the epiphyllae from each leaf, but the amounts available were too small for Kjeldahl conversion to ammonia. The epiphyllae from the 5 leaves were therefore pooled as one sample and were sent along with the scraped leaves to a commercial laboratory (Leonet Corp., Palisades Park, N.J.) for analysis,

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for Rico for the U.S. Atomic Energy Commission under contract AT(0-1)-

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Results

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The results of this experiment are given in Table 1. The po

sample of epiphyllae scraped from five leaves had taken up 9.676 of their total nitrogen from the gaseous N_2 during the 48-hour exposure period.

The other samples analyzed were leaves from which the epiphyllae had been scraped. Leaf #1 was a young leaf with about 50% of its upper surface covered by black fungal and bacterial matter which resisted removal by the scraping technique used. As a result most of the black material was left on the leaf. Leaves 2,3, and 4 were older leaves with large amounts of lichens and liverworts. Most of the material classified as "pooled epiphyllae" in Table 1 came from these three leaves. The results show that nitrogen fixation occurred in the organisms on leaf surface and implies that some transference to the host leaf took place since these leaves are enriched by a factor of 2 or more over the natural isotopic abundance of N^{15} which is 0.37% (2). Some of the enrichment of N^{15} in the leaves could be due to the inability to remove all of the epiphyllae by scraping. It is doubtful that the total enrichment is accounted for in this way however since in the case of leaves 2,3, and 4 the surfaces were visually free of colonies after scraping.

Total nitrogen in the samples was 5% for the epiphyllae and averaged 1.6 for the leaves from which the epiphyllae were taken. This is supporting evidence that nitrogen is fixed by some members of these mixed communities.

The occurrence of nitrogen fixation by epiphyllae suggests the possibility of a symbiotic relationship between these organisms and the higher plants. Nitrogen might be furnished to the leaves by the micro-organisms through foliar uptake while they in turn receive inorganic nutrients from the trees. Whether or not the relationship is truly symbiotic, these organisms must add to the pool of available nitrogen in the rain forest through leaf fall and cell turnover.

At this stage it is not known which components of the mixed communities are active nitrogen fixers, Attempts are being made to isolate and culture the responsible organisms, however at this point it is apparent that a potentially important source of biologically available nitrogen in the tropical rain forest has been demonstrated under field conditions.

5 of 95% isotopic purity was obtained from Nuclear Equipment Chemical Corp., Farmingdale, N.Y.

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Table 1

Amounts of total nitrogen in leaves and epiphyllae and percent

of total Nas NI? after 48-hours exposure to 1

saaple We, of Materiel total ny

Pooled epiphyllise 0.2059 0.0 9.6T

Scraped leaf #1 2.1703 0.023! 5.65

"8 te 1.7533 0.0085 0.99

"8 gg 1.29h0 0.0280 0.70

"om my 1ags1 0.0220 0.81

Banisten, Joe A, 1966.

Irradiation,

Koch, B.C. 1960.

Ruinen, Jakoba. 1965.

in the phyllosphere.

393.

Stewart, W.D.P. 1967.

Literature Cited

Activation ?sis Handbook.

New York and london. 219 p.

1426-1432.

143

?The Phyllosphere IIT.

lWitrogen-fixing plants.

Changes in tropical forest soils after

?The ASB Bulletin, 13, (no. 2): 33.

Academic Press,

Nitrogen fixation

Plant and Soil XXII, lo. 3, p. 375-

Science, 158:

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WATER OF A TROPICAL RAIN FOREST

carl F, Jordan

Introduction

The dynamic of radionuclide movement in tropical soils were studied by analyzing soil water collected weekly at various depths, after the mclides were applied to the soil surface.

Methods

A study plot was prepared by inserting aluminum garden edging around a 96 x 120 cm plot to a depth of about 3 cm on three sides. The fourth side was dug away, and two 2 x 12 inch zero-tension lysimeters (Serdan, 1968) were installed beneath the litter, and two at 5 inches in the manner shown in Fig. 1, On Aug. 10, 1967, 1 me of 85gr and noi of 130s in 2500 ml of water were applied evenly to the plot with a garden sprinkling can, lysimeter water collections were made weekly, boiled to dryness, taken up in 5 ml. of 1M HCl, and 3 ml were counted on @ single channel gamma analyzer. Results were corrected for physical decay and background, and activity per ml collected was calculated. Then the two litter samples for each week were averaged and plotted. The results of these calculations are referred to as "activity" in the remainder of this paper.

Activity of each sample was multiplied by volume collected from each lysimeter for each date, and total radioactivity that moved through

the litter and 5 inch level was calculated as of Jan. 2, 1968 (145 days

after start of experiment).

Rainfall above the canopy was measured with a standard tipping bucket rain gauge, and below the canopy with twelve $\frac{1}{8}$ ft. x 2 in rain gauges. Data was not treated statistically, because data from 1968, not included in this report, could influence results. Lines on graphs were drawn in simply as an aid to interpreting data,

Results

activity of 13hcs in the litter water decreased at a rapid rate for the first two weeks following application, and from then on rate of decrease of activity was lower (Fig. 2). At 5 inches, activity increased to a peak at 3 weeks, after which activity at first dropped off sharply, then after 7 weeks, it dropped off more slowly (Fig. 2)+

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COLLECTION TUBE

COLLECTION BOTTLE

Figure 1. Cross section of lysimeter pit, showing manner of installation of zero-tension lysimeters. Tunnels are packed with soil after installation. For litter layer lysimeters, Litter layer is peeled back, lysimeter is installed, and litter is then replaced.

100

100, 150, 200

ool

TIME (DAYS)

Figure 2. Activity of icq in the aot vater, collected tn lysimeters beneath the litter (A), and at 5 inches (B).

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100

50 100 150 200

OI TIME (DAYS)

Figure 3. Activity of sr in the soll vater, collected in lysineters

?beneath the litter (A), and at 5 inches (B),

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Activity of 85sr in the litter water aro

a er dropped off sharply for about

weeks, after which it stayed relatively constant (Fig. 3). At 5 inches,

there vas slight peak in activity, folloved ty an almost constant level

after 10 weeks (Fig. 3). y ost. constant

As of Jan. 2, 1968, 33% of the 85sr applied to the entire surface

had moved out of the litter, and .57% had moved through the 5 inch level.

Twenty seven % of the ^{137}Cs had moved out of the Litter, and .32% had moved through 5 inch level.

Total rainfall from 8/10/67 to 1/2/68 was 103 in above the canopy and 76 in below the canopy. a

Discussion

The very low total amounts of ^{137}Cs and ^{85}Sr in the soil water indicate that most of these radionuclides have become bound in the litter and upper few cm of soil. This is in agreement with Kline's data (1968) which shows that half the activity of ^{137}Cs and ^{85}Sr applied in a similar manner was in the upper 2.5 cm of soil after 18 months.

Presumably, ^{134}Cs and ^{85}Sr were adsorbed by the litter when the solution was sprinkled on the plot. Following adsorption, there were two or three different release rates into the soil water. The rapid decrease in activity in the first few weeks following application could be due to rapid removal of ions adsorbed to the surface of living or non-living organic matter, and soil. The later, more gradual release rate could be due to ions initially incorporated into living organisms, and then gradually released, or, to replacement of adsorbed ions by other ions moving downward.

At the 5 inch depth, there is a rapid increase in activity in the

first few weeks followed by a gradual decrease in ^{85}Sr activity and a sharper first few weeks. The peak of activity and first decrease of each nuclide suggest that water reflects the initial injection spike which had broadened out to a peak of activity at the 5 inch level. The following almost uniform release of ^{85}Sr probably is due to phenomenon mentioned in the above paragraph, while the declining release rate of ^{134}Cs could be caused by the ^{137}Cs gradually being incorporated into the crystal lattice of the clay soil.

When fixation is completed, rate of ^{134}Cs release should be steady.

Before the final portion of the regression lines can be treated statistically, and final conclusions reached, about a year's more data are required.

Time concentrations of ^{137}Cs and ^{85}Sr in the soil water apparently depend on the amount of rain in an interval since weekly rainfall totals ranged from 0 to 14 cm. Concentration rather appears to be a function of the total amount of water that has moved through the soil.

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