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1962

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a dix mois, se sont améliorées au seizième mois. Des photographies de la restauration de plusieurs de ces plantes sont inclues dans ce rapport ainsi qu'une discussion des agents autres que les radiations connus comme étant cause de semblables dégats aux plantes des attols de l'Océan Pacifique.

Zusammenfassung—Eine langfristige Untersuchung am Eniwetok Atoll wurde während der Jahre 1954–57 durchgeführt um die Geschwindigkeit der Erholung der durch Bestrahlung, Schock und Hitzestoss der Nectar Detonation in 1954 beschädigten Landpflanzen festzustellen. Auf der Belle Insel wurden sieben Arten vor der Detonation markiert, gemessen und photographiert. In ungefähr monatlichen Abständen, während der ersten 10 Monate nach der Detonation und danach nach 6 Monaten wurden die Pflanzen wieder beobachtet und photographiert. Das erste Anzeichen der Erholung wurde am achten Tag gefunden, indem Knospen an den Stämmen von *Scaevola* und *Messerschmidia pflanzen* sichtbar wurden. Nach einem Monat hatten die meisten Pflanzen neue Blätter gebildet und einige hatten Blüten und Früchte. Nach 6 Monaten war der generelle Zustand der Vegetation ähnlich dem der vor der Detona-

*Operated by the University of Washington under Contract No. AT(45–1)1385 with the United States Atomic Energy Commission.

tion existierte. Zwei Pflanzen, *Guettarda* und *Portulaca*, die nach 10 Monaten noch ungesund waren, hatten sich nach 16 Monaten gebessert. Photographien einiger der erholten Pflanzen sind diesem Bericht beigefügt, sowie eine Besprechung der Mittel, ausser den Strahlungen, von denen ähnlicher Schaden wir der an den Pflanzen der Korallenattolle des Pazifik berichtet worden ist.

INTRODUCTION

SINCE the summer of 1946, the Laboratory of Radiation Biology of the University of Washington has conducted studies at the Eniwetok Proving Ground to evaluate the distribution of radioactivity in aquatic and terrestrial organisms of the atolls of the western Pacific and adjacent areas. These studies were made either shortly after a nuclear device had been detonated or after intervening periods varying from several to many months. The results of the investigations conducted in 1946,[7] 1947,[1] 1948,[2] 1949,[3] and 1952[5] indicated the need for a study of the reinvasion or regrowth of organisms in an area contaminated by radiation.

A study of this nature was undertaken following the detonation of an atomic device (Nectar) at Eniwetok Atoll in the spring of 1954. Facilities were made available at the Eniwetok Marine Biological Laboratory on Elmer (Parry)

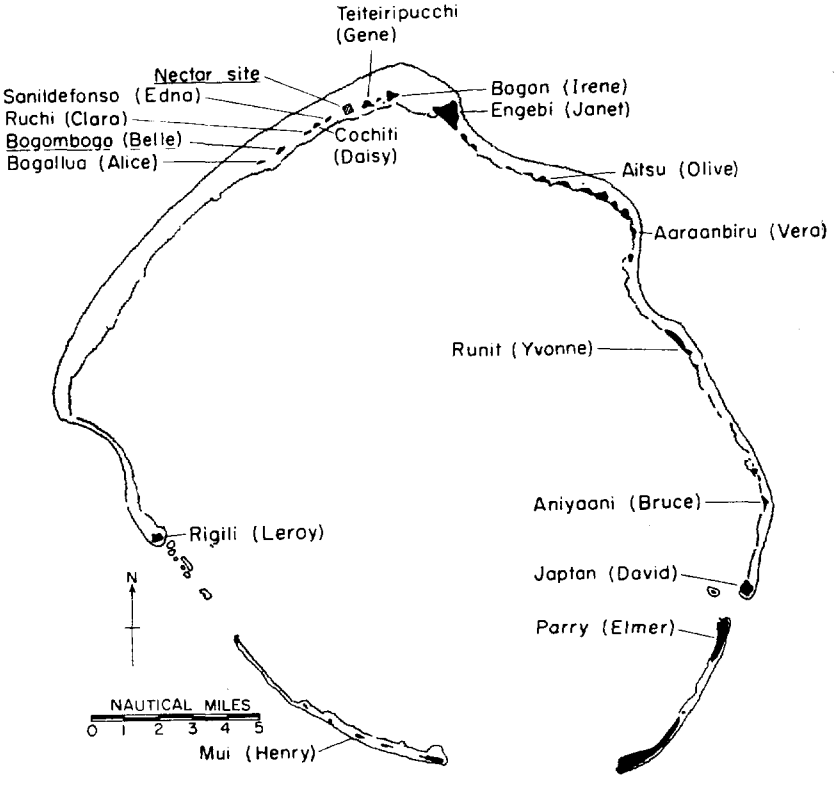

FIG. 1. Eniwetok Atoll.

were generally green and healthy

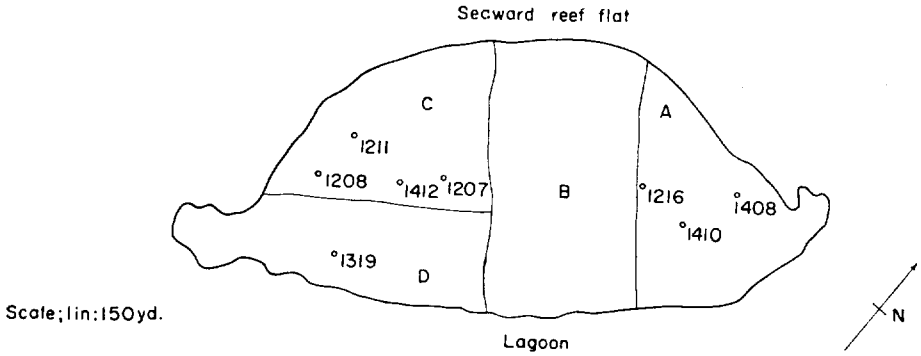

FIG. 2. Diagram of Belle Island, Eniwetok Atoll, showing the location of the land plant stations and the collecting areas.

Area A	Area C	Area D
1216 *Guettarda speciosa*	1207 *Boerhaavia tetrandra*	1319 *Scaevola* sp.
1408 *Messerschmidia argentea*	1208 *Triumfetta procumbens*	
1410 *Lepturus repens*	1211 *Portulaca oleracea*	
	1412 *Cocos nucifera*	

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FIG. 4. General view of land plants at Belle Island, Eniwetok Atoll. (a) On April 15, 1954, before the Nectar detonation. (b) On May 22, 1954, eight days following Nectar, showing a *Scaevola* plant (No. 1319) in the foreground.

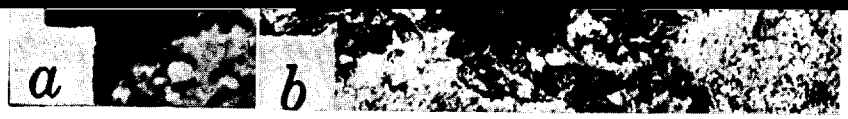

FIG. 5. *Messerschmidia* plant at Belle Island, Eniwetok Atoll. (a) Plant No. 1248 showing adventitious buds on May 22, 1954. (b) Close-up of the same plant on June 18, 1954.

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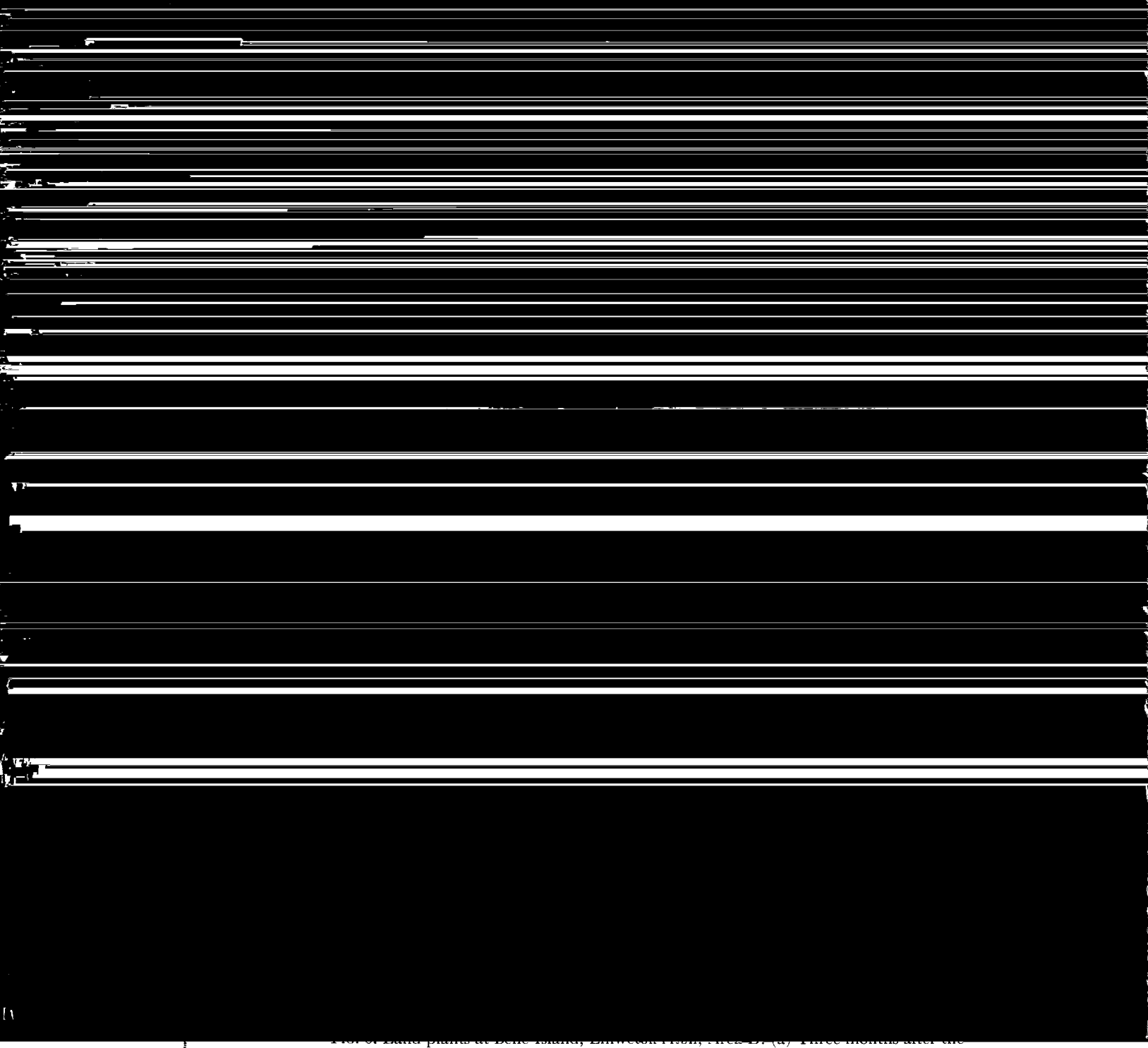

Nectar detonation. (b) Six months after detonation.

FIG. 7. *Guettarda* plant at Belle Island, Eniwetok Atoll. (a) Close-up of unhealthy plant (No. 1216) on March 15, 1955. (b) Close-up of the same plant on November 1, 1955.

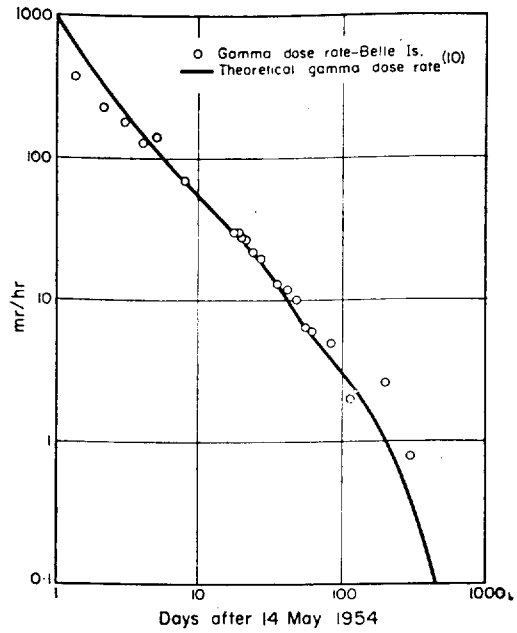

FIG. 3. Gamma dose rates at three feet at Belle Island, Eniwetok Atoll, May 15, 1954 to March 21, 1955, compared with the decay of fission products from the slow neutron fission of U^{235}(10).

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looking. A photograph of the general area taken at this time (Fig. 4a) shows the healthy appearance of the vegetation. In some plants there was yellowing of the leaves and necrosis, especially in *Scaevola* and *Guettarda*, and some reddening of the tops of the grass, *Lepturus repens*. The latter symptom is typical of some species of plants growing in phosphorus-deficient soil, a condition often found on coral atolls and in areas where the top soil has been disturbed or blown away. The Mike detonation of 1952 had removed most of the plants and top soil from Belle Island, resulting in the depletion of some of the elements essential for plant growth. In spite of these deficiencies regrowth of the plants at Belle Island was rapid. In April 1954 some of the *Scaevola* and *Messerschmidia* "trees" were up to five feet in height, with a spread of ten feet, and bore many flowers and fruits. Plants of the other species also were well established.

A photograph of Belle Island taken eight days following the Nectar detonation (Fig. 4b) shows the extent of the damage sustained by the plants. From the air the island looked brown and desolate. On closer inspection it was found that most of the plants had been scorched by the heat wave and many of them had been blown over or broken by the shock blast. Two of the previously tagged plants (*Cocos* and *Portulaca*) had disappeared or had been dislodged from their original positions; other plants of these species were staked and labelled for study. On the tall shrubs, such as *Scaevola*, *Messerschmidia* and *Guettarda*, the leaves were usually gone or scorched, and the scorched branches and a few persistent leaves were all that remained of the plants. Flowers and fruits were found on some plants, especially in the prostrate plants such as *Portulaca*, which was located behind a large fallen coconut trunk. Close-ups of examples of damaged plants eight days post Nectar are shown in the foreground of Figures 4b and 5a.

Recovery of the plants was rapid. Heavy rains occurred on the third day. On the eighth day green buds, 1–3 mm in length, were observed on the stems of *Scaevola* and *Messer-*

plant bore only a few leaves in March 1955, but when observed in November 1955, it had recovered somewhat, bearing abundant flowers and some green leaves.

No other aberrant growth forms were seen in the field observations at Belle Island. At Janet Island, the fasciated stems and the tumorous growths on plants of *Ipomoea tuba* observed in 1949 by BIDDULPH[6] were still present in 1957.

The measurements and observations made on one of the plants, *Scaevola* (No. 1319), during the course of the study are presented in Table 1.

be identified by the appearance of the plant. In coral atolls where the top soil has been removed the retention of rain water in the surface layer of soil would be slight, resulting in the curling, drying, and ultimate death of the shallow-rooted plants. On the basis of these observations it may be concluded that some of the abnormalities observed could have been caused by factors other than radiation. Therefore, it would be impossible to ascertain all of the causes of damage to plants in an area where radiation and nutrient deficiencies both exist. In areas of high radiation levels, much of this damage

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cumulated dose, and some visible damage was observed at doses below 3 r/day.

high (total dose 1,824 r). Other species (*Suriana*, *Cordia subcordata*, *Cocos nucifera* and *Pisonia*

the plants at their worst during the dry period.

Some abnormalities found in the plants on coral atolls have been caused by insects. Taylor reported that the leaves of *Suriana* were clipped as if by insect attack, and Fosberg reported that *Bauhinia* was chlorotic and badly eaten by insects. NIERING[18] reported that on Kapingamarangi Atoll the leaves of *Scaevola* were attacked by a leaf miner and new shoots and buds of *Calophyllum* sp. and *Barringtonia asiatica* were "infested to the point of disrupting the normal growth pattern." On Onotoa Atoll, MOUL[17] observed that several insects were found on *Guettarda* plants. These included wasps, moths, stink bugs, and butterflies. Moul reported also that leaves of *Pisonia* trees were so badly damaged by leaf-cutting bees that he could not find a perfect specimen of foliage. At Rongelap Atoll members of this Laboratory noted infestations of a lepidopteran larva causing deformed leaves on *Guettarda* plants. They also reported that insects caused defoliation and bud damage in plants of *Terminalia* sp. and *Pisonia*.

The bird population also is a factor in the production of unhealthy plants. Niering reported that at Kapingamarangi Atoll the leaves of *Asplenium*, *Nephrolepis*, *Guettarda* and *Pisonia* were turning brown and dying because of the blast damage[12] similar to that observed at Belle Island. Also, from calculations based on data obtained from other nuclear detonations,[12] the initial gamma dose delivered at Belle Island was approximately 30 r, which is much lower than the levels required to cause visible plant damage in laboratory-type experiments. Essentially all of the damage to the land plants, therefore, can be attributed to the heat and blast rather than to the initial nuclear radiation. The excellent recovery of all but three of the plants (*Guettarda*, *Lepturus*, and *Portulaca*) is noteworthy, especially since the plants were subjected continuously to external radiation as well as the internal radiation from absorbed radioisotopes. The abnormal appearance and slow recovery of these plants, among the many observed, would appear to be due to radiation; however, the author feels that the other factors, which were not measured adequately during this investigation, should be evaluated carefully before ascribing the damage to radiation.

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