*Summary.*—Paired-feeding experiments showed an increase of both riboflavin and protein content of liver and carcass on a diet containing 7 μg. of riboflavin per gram when the protein content of the diet was increased from 12 to 32 per cent.

Increasing the riboflavin content of a 12 per cent protein diet from 1 to 9 μg. per gram resulted in slight increase in weight, in fat and in total protein stored. The riboflavin in liver and carcass was also increased.

The same increase, from 1 to 9 μg. of riboflavin per gram of air-dry food, on a 20 per cent protein diet had only slight influence upon growth or nitrogen stored, but increased the storage of riboflavin.

When food was allowed *ad libitum*, increasing the riboflavin in a 20 per cent protein diet from 1 to 9 μg. per gram resulted in increased appetite, growth and retention of protein and riboflavin, though the percentages of protein were less because of the greater gain in body weight.

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## *ON THE FREQUENCY AND TRANSMITTED CHROMOSOME ALTERATIONS AND GENE MUTATIONS INDUCED BY ATOMIC BOMB RADIATIONS IN MAIZE**

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Samples of maize seed of the single cross L289 × I205 were placed on some of the ships within the target area at Bikini at the time of the atomic

bomb test of July 1, 1946. At about the same time Dr. L. F. Randolph exposed duplicate samples to x-rays at Cornell University. Plantings were made at the California Institute of Technology of both series together with untreated controls. From these plants, sporocyte samples were collected by Dr. Randolph for studies at Cornell University on the visible chromosomal changes induced by the radiations (Randolph, Longley and Li *in press*). Studies on hereditary effects have been carried on at the California Institute of Technology in coöperation with the United States Department of Agriculture and the Naval Medical Research Section of Operation Crossroads.

Seedling comparisons supplemented later by pollen sector frequencies indicated one lot of seed exposed to atomic bomb radiations has received a dosage equivalent in biological effects to slightly below 15,000 r units of x-ray. Most of the studies have been made on this lot and on the comparable lot exposed to 15,000 r units x-ray.

In maize, chromosomal alterations can be detected readily by partial pollen sterility, unless the alteration involves only a very small portion of a chromosome. Examination of 751 plants of the unexposed controls showed only normal pollen.

Plants from irradiated seeds are mosaics of various sectors, each of which is assumed to be the progeny of a single meristematic cell of the multicellular growing tip of the embryo. Observations on the pollen indicated that about 90 per cent of the tassels of the Bikini lot had one or more sectors showing chromosome alterations.

Three plants were outcrossed to normals or to plants of low dosage when normal plants were not available. The outcross plants were derived from one normal gamete and one from the irradiated source, and should thus give a direct frequency of such transmissible effects as could be detected or recognized by the techniques employed.

In order to obtain a large number of chromosomal alterations for cytological study, ten seeds of each outcross were planted. The number of partial-sterile plants obtained was expected to be a little higher than random, since

1. Pollen was taken only from plants known to have at least one sector of partial sterility,

2. The majority of these pollinations were made on low dosage lots rather than on normal controls,

3. In the outcrosses of the Bikini or x-ray lots as female parents, seed was selected from poorly filled portions of the ear. Such parts are most likely to be partial-sterile sectors.

The observed frequencies were

| | TOTAL PLANTS | PER CENT PARTIAL-STERILE |
|---|---|---|
| Normal or low dosage × Bikini pollen | 3176 | 4.7 |
| Normal or low dosage × 15,000 r x-ray | 2582 | 6.0 |
| Bikini × normal pollen | 5456 | 6.4 |
| 15,000 r x-ray × normal pollen | 3248 | 7.8 |

An unselected sample should give a somewhat lower frequency of transmitted partial-sterile plants, probably 4.5 or 5.0 per cent.

All partial-sterile plants were outcrossed to standard stocks to establish lines for cytogenetic study.

Some of the normal plants were self-pollinated to obtain mutant characters for other studies. In all, 1231 self-pollinated ears were harvested from the Bikini lot, and 655 from the corresponding 15,000 r x-ray lot. Of these 26 per cent of the ears from the Bikini lot and 23 per cent of those from x-ray were tabulated as segregating for endosperm characters such as white endosperm, sugary, brittle, opaque, shrunken, many types of defective endosperm and also several viviparous types. No doubt many defective types were overlooked.

Seedling tests are in progress and a test for mature plant characters will be made. Conspicuous seedling characters have been found to be even more frequent than the endosperm defects. The seedling characters include chlorophyll deficiencies such as white (albino), pale yellow and yellow lethals, pale green and yellow-green seedlings, virescents, piebald, zebra, striate and striped seedlings. Some appear to be mutable. A wide range of other characters such as glossies, dwarfs and a host of morphologically aberrant types have also appeared, many of which are unlike any described in the maize literature.

Because of the difficulty of establishing any objective standards for detecting and classifying miscellaneous mutations, no plans had been made for studies on mutation frequency and accordingly no controls were self-pollinated to test for the presence of recessive gene defects in the stock used. Some recessives could be carried in the commercial inbred lines, L289 and I205, used in making up the single cross, but not in such frequencies as were obtained. A number of control plants were used as pollen parents in a series of outcrosses with no clear evidence of any recessive having been carried in the control parent. Whenever the source could be determined the recessive came from the irradiated parent. It is possible that a minor portion of the gene defects may have been present in the stock, but at most it could have been only a small fraction. Additional tests will be made the coming summer including a study of the lower dosages and a checkup of the controls.

From data thus far obtained, it appears that most of the outcross plants carried one or more recessive mutations from the irradiated parent. Thus more than 50 per cent of the functioning gametes of plants from seed exposed to 15,000 r units x-ray or to the nearly equivalent atomic radiation exposure carry one or more gene mutations caused by the radiations.

The dormant seeds in these tests were exposed to much greater irradiation than the lethal dose for most animals or for actively growing plant tissue. But roughly similar frequencies obtained from 15,000 r x-ray and the nearly equivalent Bikini lot support the expectation that atomic bomb radiations have about the same heritable effects as comparable doses of x-rays.

*Summary.*—Maize seed receiving atomic bomb radiations equivalent to nearly 15,000 r units x-ray were tested for hereditary chromosomal alterations and gene mutations.

The frequency of chromosomal alterations as indicated by partial pollen sterility was 4.7–6.4 per cent in progenies which were not entirely random. It is estimated that a random frequency would be between 4.5 and 5.0 per cent.

The frequency of gene mutation was extremely high. Probably more than 50 per cent of the gametes of the exposed generation carried one or more gene mutations.

The frequencies of chromosomal alterations and gene mutations in a lot exposed to 15,000 r units x-ray were roughly equivalent to the frequencies obtained in the Bikini lot.

* Coöperative investigations of the Kerckhoff Laboratories of Biology, California Institute of Technology, and the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

This is a brief report based on a coöperative program carried on at the California Institute of Technology by a group of investigators including Dr. A. E. Longley of the United States Department of Agriculture, Prof. E. F. Frolik of the University of Nebraska, Dr. E. E. Dale of Union College and the following graduate student assistants: C. H. Li, K. L. Retherford, Earl P. Patterson, Wayne F. Keim and Don Robertson.

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## *THE RELATION BETWEEN NICOTINIC ACID AND CARBOHYDRATES IN A SERIES OF MAIZE ENDOSPERM GENOTYPES**

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It has been shown by Burkholder, McVeigh and Moyer,[1] by Barton-Wright,[2] and by Mather and Barton-Wright[3] that kernels of surgary maize