trum in the lead hemispheres are in agreement with the first assumption. Although controlled laboratory experiments to determine the variation in chromosome aberration frequencies with incident neutron energy must be carried out before *Tradescantia* can function reliably as a neutron dosimeter, the present general agreement in dose determined in the field from biological and physical measurements is impressive. We can also assume that, in a general qualitative way for *Tradescantia,* there are no very great differences in the effects of laboratory-produced fast neutrons and those arising under the burst conditions of a nuclear detonation. Certainly, the relative biological efficiency (RBE) for detonation neutrons compared with fast neutrons from a cyclotron is $1 \pm 25\%$.

Comparing our cyclotron neutron data with the extensive x-ray control data obtained by Conger prior to the early tests, some fairly reliable determinations of the RBE of fast neutrons and x-rays can be made. In the case of predominantly one-hit chromatid aberrations, i.e., chromatid plus isochromatid breaks, an RBE for neutrons to 250 kvp x-rays of 13 was found. For chromatid/chromatid interchanges, as well as chromsome deletions and exchanges, in which a linear relation of aberrations with dose does not exist for x-rays, a definite exact RBE cannot be obtained. By assuming x-ray intensities sufficiently high to give maximum breakage rates and forcing the dose curves to a linear relation, an RBE of approximately 13 for chromatid/chromatid interchanges and 7 and 10 respectively for chromosome deletions and chromosome exchanges can be assigned.

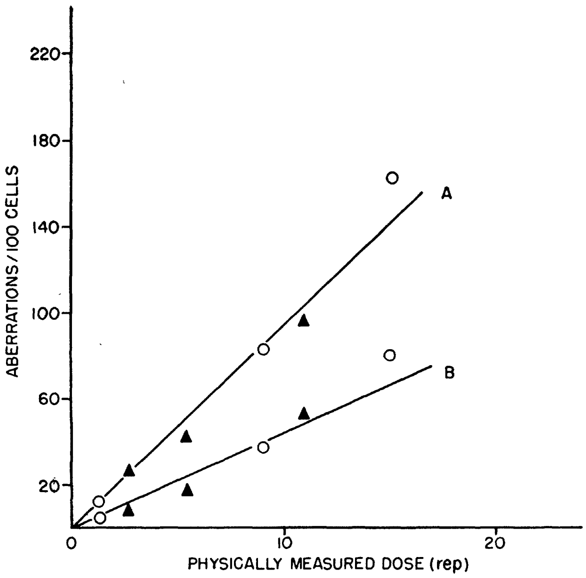

FIG. 2. Chromatid aberrations. Curve A, isochromatid breaks. Curve B, chromatid interchanges. ▲, Cyclotron control data. ○, Field test data.

APPENDIX

Physical Dose Estimates in the Detonation Experiments and Neutron Calibration in the Cyclotron

C. W. Sheppard and E. B. Darden, Jr.

The dose in the ORNL cyclotron was determined with a BF_3 proportional counter calibrated against two Victoreen condenser r-meters. The number of reps/n for the 100-r chamber with thimble of conducting lucite-graphite was 1.7. For the 25-r chamber, which was a conventional Bakelite thimble, the factor was 2.5. These figures were determined by comparing the readings with those of two Rossi-Failla tissue-equivalent ion chambers, one provided by Dr. Rossi and one constructed at ORNL. Comparisons were also made with the readings of an ethylene-filled polyethylene chamber whose walls were coated with a very thin layer of graphite (*3*). This "tissue equivalent chamber" and the Rossi-Failla chambers were themselves calibrated against x- and gamma-ray standards in the laboratory (*4*). Gamma-ray contamination was estimated with a condenser-type ion chamber made of bismuth whose design was similar to that of a beryllium chamber used by us for gamma-ray estimates in the presence of high fluxes of thermal neutrons (*5*). Slow neutrons were determined by gold activation. Approximately one gold neutron was found for every ten total neutrons. The neutrons were made by the Be^9 (p, n) reaction. The energy distribution was estimated by converting the spectrum for a thin target (*6*) to that for a thick one at our different angle of observation and different bombarding energy (22 Mev). Some approximate allowance was also made for the degradation of the neutrons in the 2-in. lead walls of the exposure facility. The result gave a broad distribution with maximum at about 1–2 Mev and tailing off at higher energies to less than 20% total neutrons above the S threshold. Because of the difficulties of physical measurements in the cyclotron, exact control of all variables was not possible and we therefore estimate the uncertainties as about $\pm 20\%$. Attempts to compare our dosimeter readings with those obtained under better physical conditions are now in progress.

In the detonation experiments, the methods of dosimetry were developed as a compromise when it was learned that a well-conceived program of tissue-equivalent chamber development could not be extended to cover our requirements. A total of 19 chambers were completed in time for the experiments. They were built according to the same design as that of the bismuth chambers, but had inner walls of polyethylene coated with thin aquadag.[3] Spacing between the concentric cylindrical electrodes was approximately 0.5 mm. Insulators were of fluorothene and mechanical rigidity was achieved by supporting the inner plastic electrode on a 2S aluminum cylinder and the outer electrode in an enclosing aluminum sleeve. The plastic was thick enough in all cases to stop the beta rays from the activation of aluminum. The chambers were

[3] We wish to acknowledge the assistance of R. K. Abele of the Oak Ridge National Laboratory, Instrumentation and Controls Division, in a portion of the design.

filled with air, relying on the closeness of the electrode spacing to obtain maximal efficiency of ion collection and minimal dependence of the reading on the energy of the neutrons. The sensitivity of a chamber depends on its collecting volume and the latter was varied somewhat by filling a variable amount of air space with insulation. In this way, readings on scale were achieved at almost all of the stations where instruments were placed. Investigation of the calibrations indicated that individual instruments varied considerably but, due to the large number of chambers and the use of statistical methods, the aggregate effect of the individual fluctuations was small. Because lowering the sensitivity by closer electrode spacing introduces serious problems, such as the need for polishing the plastic to a mirror finish, and the electrical difficulties produced by small amounts of particulate matter in the chambers, the highest dose that could be read was about 250 rep. The chambers were calibrated in the cyclotron facility. Because of their design, moderate variations in the neutron spectrum should not affect the calibration. This was tested by introducing paraffin into the neutron beam, with little effect on the calibration factors. In spite of the high voltage gradient on the insulators, leakage was not a serious problem. Soakage of the insulators presented no serious difficulty.

Gamma-ray contamination in several stations was estimated in one detonation experiment by the use of nine chambers in which the collecting electrodes were made of lead. Unfortunately, the accuracy of this method decreases rapidly as the gamma-ray component increases. Lead-lined chambers are quality dependent and the gamma-ray spectrum was not known. The calibration of the chambers against Co^{60} gamma rays was the method of choice. Some confidence can be placed in the allowance for effects which would make the observed neutron dose spuriously high. Effects which would make the readings too low cannot be as easily evaluated. In addition to these difficulties, there is some evidence that the instruments are partially sensitive to slow neutrons even though particular effort was made in the design to minimize this. In general, the readings indicated a considerable gamma ray contamination. The neutron component of the dose recorded by the polyethylene chambers is probably low, because there is some evidence that their ion collection is impaired by the glutting effect of the high momentary ionization density. Since the duration of the exposure was short, the intensity was correspondingly high. Taking all these complicating effects into account, we feel that it is highly unlikely that the ion chambers have overestimated the dose. They may conceivably have underestimated it but not by more than a factor of 2. It is not impossible that they were more accurate than we have supposed. It is anticipated that, as a result of present efforts to refine physical dosimetry of neutrons, future work will be on a much sounder basis.

References

1. CONGER, A. D. *Science* **119**, 36 (1954).
2. RUSSELL, W. L. Private communication.
3. DAINTY, J. Can. Natl. Res. Council Unclassified Rept. CRM-482, Chalk River (1950).
4. DARDEN, E. B., JR., and SHEPPARD, C. W. USAEC Unclassified Rept. ORNL-1002, Office of Tech. Serv., Washington, D. C. (1951).
5. DARDEN, E. B., JR., SHEPPARD, C. W., and EMERSON, L. C. *Rev. Sci. Inst.* **23**, 568 (1952).
6. GUGELOT, P. C. *Phys. Rev.* **81**, 51 (1951).

Manuscript received December 14, 1953.

An Interesting Phenomenon Associated with Irradiation of Dry Maize Seeds[1]

Drew Schwartz[2]

Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee

In the course of experiments conducted to determine the effect of neutron radiation from a nuclear detonation on dry maize seeds, an interesting and completely unexpected phenomenon was observed at the high-dosage levels. This phenomenon is of purely biological interest but serves to emphasize that in the field of biological dosimetry extreme care must be taken to avoid the use of complex biological effects such as growth and survival, which involve a large number of little understood physiological reactions. The observed phenomenon was simply that within a certain dose range there was an unexpected relation between dose and seedling height.

Dry corn seeds were exposed in 7-in.-thick lead hemispheres to the radiation produced by a nuclear detonation. The lead hemispheres were designed to shield the material from the gamma rays so that, in the main, only the effects of fast neutron bombardment were studied. The hemispheres also protected the seeds from temperature and shock effects. One hundred seeds were placed in each hemisphere about 9 hours prior to and recovered approximately 3 hours after the detonation. The recovered seeds were treated with a dust disinfectant, and planted in sand. Ten days after planting the seedlings were removed from the seedling bed and scored. Both the percentage of seeds which germinated and the seedling height were recorded. Germination was found to be unaffected by the radiation. Every lot of treated seeds showed over 90% germination.

The results on seedling height are shown in Fig. 1. Proceeding from the low to the high doses, the seedlings show an initial decrease in height followed by an increase as the high dose levels are approached. There are two possible conclusions which could be drawn

[1] Work performed under Contract No. W-7405-Eng-26 for the Atomic Energy Commission.

[2] The author acknowledges the unselfish cooperation, during the detonation experiments, of Harold H. Plough, at that time Assistant Chief, Biology Branch, Division of Biology and Medicine of the U.S. Atomic Energy Commission.