IRRADIATION EXPERIMENTS ON DIPLOID YEAST WITH HEAVY PARTICLES

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Abstract

Survival curves for diploid yeast after irradiation with different particles have been plotted and fitted to a model, developed by KATZ et.al.

I. Introduction

Irradiation effects on biological cell systems are of great interest in radiation therapy.We have studied the radiation damage in diploid yeast (Saccharomyces cerevisiae, wild type) by particles of different LET.The experimental results have been interpreted with a model given by KATZ et. al. [1]).

II. Materials and Methods

The experiments were performed at the Compact-Cyclotron of the Deutsches Krebsforschungszentrum Heidelberg.The fixed energy machine accelerates protons to 22 MeV,deuterons to 11 MeV, He^3 to 28 MeV and He^4 -ions to 22 MeV. Up to now only protons and deuterons have been used in our experiments. Aluminium foils were used as stopping material to vary the particle energy. The particle energy has been determined by the energy-range relation [11]). The experimental set-up is shown in a diagrammatic drawing (Fig.1). The extracted beam of the cyclotron (1) is deflected by an analyzer magnet (3) to ensure homogeneity of particle momenta and focussed on the target position (8) by magnetic quadrupole lenses (2) and a beamsteerer (5) for horizontal and vertical direction [10]). Beam monitoring is performed by a transmissiontype of ionization chamber (6) with 5µm thick electrodes coated with aluminium and graphite (HYDROCOLLAG),placed about 50 mm before the cell samples. For the monitor calibration a parallel plate ionization chamber can be placed at the irradiation position.The dose measurements have also been checked by a ferrous sulphate dosimeter system [9]),using a G-value of 14.4 $(100\ eV)^{-1}$ for 20 MeV protons [2]).The dose rates employed, varied between 20 and 100krd per minute in various runs.For dose rates above 1 krd per minute there is no

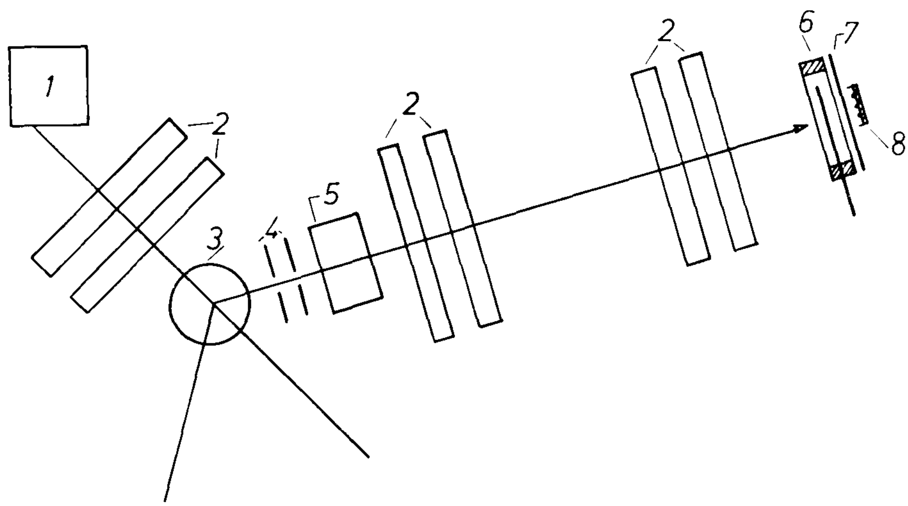

Fig.1 Schematic drawing of the experimental setup for irradiation with heavy particles.

(1) fixed energy cyclotron (2) quadrupole lenses (3) analyzing magnet (4) beam aperture (5) beamsteerer (6) transmission-type-ionization-chamber for beam monitoring (7) aluminium absorber (8) remote controlled sample changer

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influence on the shape of the survival curves as shown in [3]).The mass stopping power $1/\rho$ (dE/dx) for yeast cells has been calculated from [11]) and was about 3% less than for water. The particle beam was homogeneous over a diameter of at least 2 cm.Since the range of the particles is much greater than the monolayer of the cells, all the cells were irradiated with the same dose and the same particle energy. Cultures of the diploid strain 211 of the yeast Saccharomyces cerevisiae were used, which where grown on nutrient agar to stationary phase. To ensure a certain homogeneity of the cell population for the single runs we checked the cell size spectrum by a Coulter-counter [4]).The cells were suspended in phosphate buffer solution. Aliquots (50 µl) of this suspension (concentration: $5x10^6$ cells/ml) were placed on sterile 13 mm Millipore filters (type AAWP 04750),which were on a Difco agar plate to supply the cells with water during the irradiation. This filter technique has been applied because of the low particle range.The cells have been irradiated under aerobic conditions at room temperature (25°C). After irradiation the cells were resuspended from the filters by stirring them in phosphate buffer solution for one minute.The samples were plated on YED agar (2% dextrose, 0,5% yeast extract, 2% agar), and kept at a constant temperature of 30°C for 3 days (immediate plating). For repair experiments we plated samples on Difco agar and added nutrient agar after 50 hours of time (agar holding repair). We used this AHR-technique because of its good reproducibility; no cells died over this period as control experiments have shown.

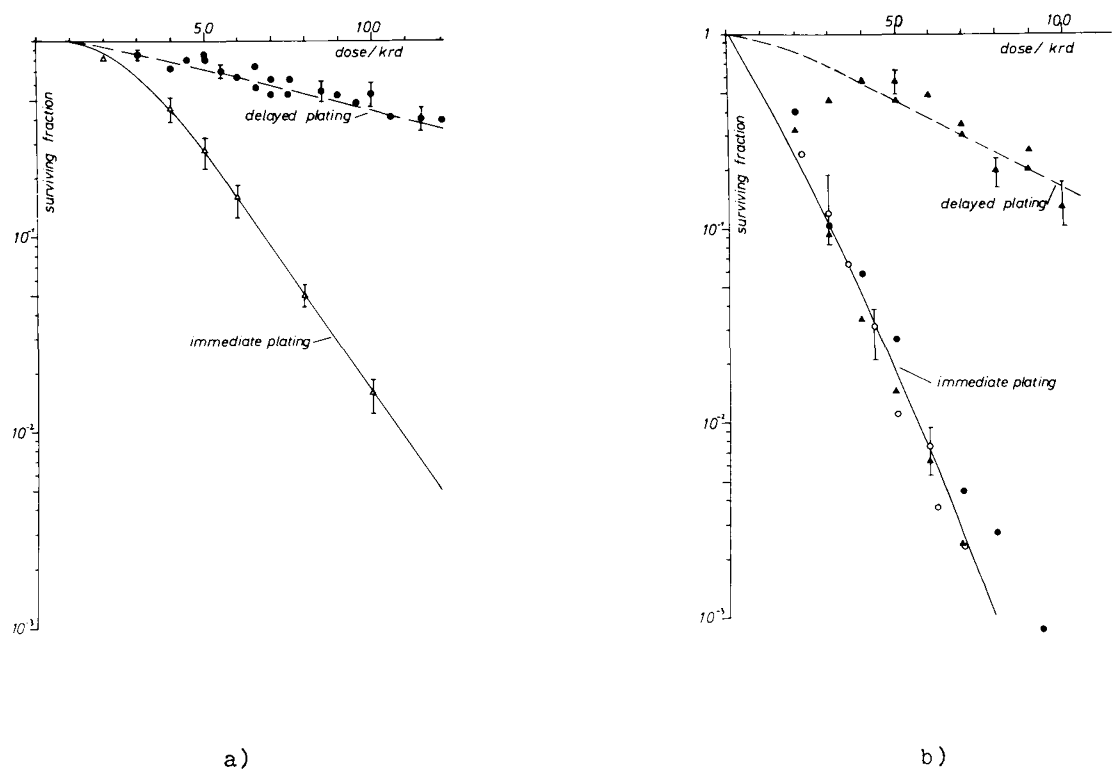

Fig.2 Survival curves for diploid yeast (strain 211) irradiated with a) 70 kV X - rays, filtered with 0.7mm of Aluminium Dose-rate: 7 krd/minute. LET_∞ = 29 MeV cm^2 g^{-1} b) 3.5 MeV α-particles. Dose-rate 7 krd/minute [8]). LET_∞ = 1170 MeV cm^2 g^{-1} . ●, ▲ own measurements (different runs), ○ after Schäfer [8])

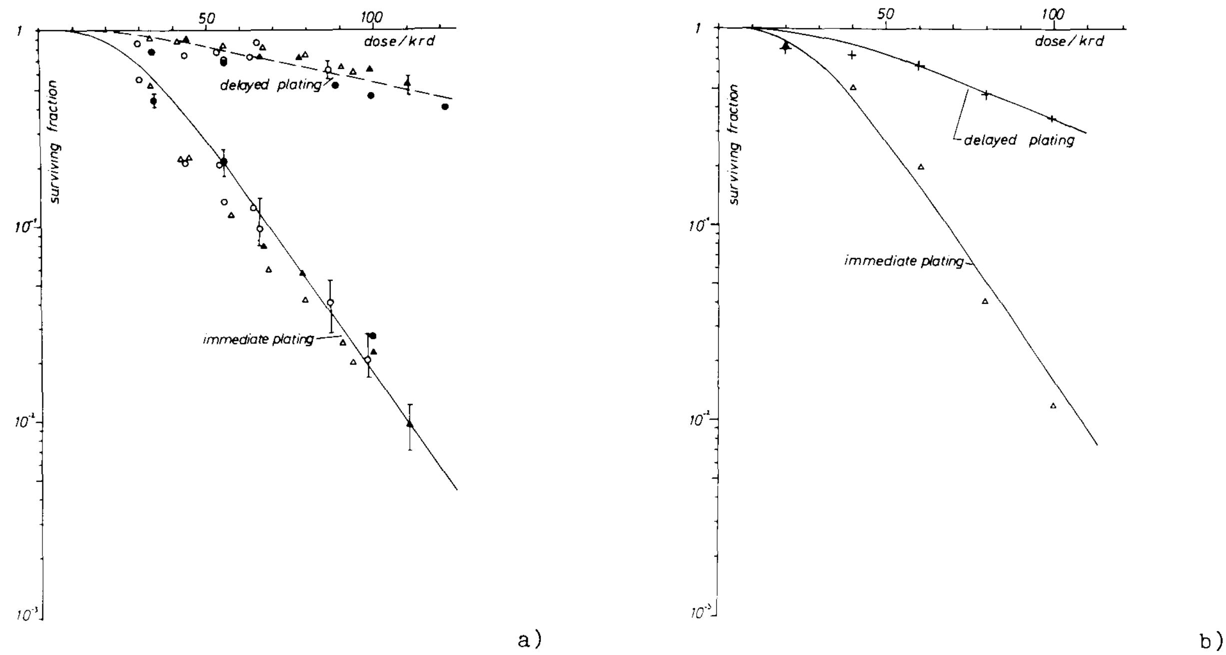

Fig.3 Dose-effect curves for diploid yeast after irradiation with a) (20.2±0.4) MeV protons. Dose-rate about 75 krd/min. LET_∞ =26 MeV $cm^2 g^{-1}$ b) deuterons of about 8 MeV. LET_∞=94 MeV $cm^2 g^{-1}$

III. Results and Discussion

Dose-survival measurements for diploid yeast, aerobically-irradiated with X-rays, fast protons, deuterons and α-particles are shown in figs.2 and 3. The plotted points result from different runs taken in a period of 3 month. For α-particle irradiation we used a Am-241-source of 1.05 mCi covered with a 3.9 µm gold foil giving a particle energy of 3,5 MeV. The dose-rate was 7 krd per minute [8]).The α-dosimetry has been based on studies in our laboratory published elsewhere [7]).The particle energies and the corresponding LET values are given in table I.
Within experimental error, as expected, immediate plating curves for 20 MeV protons and 8 MeV deuterons do not differ from the X-ray curve, since the LET-values are nearly equal.Nevertheless for delayed plating we got slightly different curves for X-rays, protons and deuterons. The repair, measured as a dose-modifying factor is for all particles essentially the same (DMF ≈4.5) as observed for X-rays.But the dose-modifying factor as well as the survival curves differ from the experimental findings of [5]).The measured results can be described by a model, developed by KATZ et al.,which has recently been applied successfully to predict survival curves for different radiation .Following the algorithm of the theory [1])[6]) survival parameters have been determined for particles with different LET.As demonstrated in figs.2 and 3 the experimental data can be well fitted to this model.
The solid lines in these figures are based on the following cellular radiosensitivity parameters: σ_0= 3,4 x 10^{-9} cm, K= 1100,m=6, E_0 =1.7 x 10^6 erg x cm^{-3}. To check the predictions gained with these parameters further experiments with protons of different energies, and deuterons are being performed and experiments with He^3 , He^4 -ions and neutrons will be possible in the near future.

ENERY AND STOPPING POWER FOR IRRADIATIONS OF THE DIPLOID YEAST STRAIN 211

Radiation	Energy	Mass stopping power for yeast $1/\rho$ (dE/dx) / MeV $cm^2 g^{-1}$
X - rays	70 kV	29
protons	20.2 MeV	26
deuterons	8.0 MeV	94
α- particles	3.5 MeV	1170

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