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Effect of x-rays on the somatic chromosomes of the exotic fish, *Tilapia mossambica*

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Abstract. Male and female *T. mossambica* were x-rayed with 100 r and the metaphase chromosome aberrations in their gill epithelia were studied at 13 different intervals against suitable control. The chromosomes of males appeared more radio-sensitive than those of females. Among the diploid complement of 44 chromosomes, the individual type aberrations were non-random in both sexes. The longest pair of chromosomes, taken as the marker pair, was found very highly radio-sensitive, while the remaining 21 pairs as non-markers were somewhat resistant to x-radiation when the observed and the expected numbers were subjected to statistical analysis. The break in the marker chromosome was also non-randomly distributed as the distal half had a significantly large number of breaks.

Keywords. Fish ; *Tilapia mossambica* ; x-irradiated chromosome aberrations ; differential radio-sensitivity.

1. Introduction

In comparison to some insect and mammalian models, very limited studies on the radiation induced chromosome aberrations in fish have so far been carried out. Such studies have, however, dual importance because fish in general serve as an important biological monitor in aquatic environment for the study of radiation pollution and secondly their stock could be improved through radiation induced mutation and selection. Schroder (1973) reviewed the works on radiation induced mutations in fish while Hickling (1962) reported the genetics and hybridization effect of some fish including *Tilapia*. At the chromosomal level Hama *et al* (1976) studied the chromosome aberrations in gill epithelia of the mosquito fish, *Oryzias latipes* from 2 to 10 days after radiation, while Pechkurenkov (1976) studied the chromosome aberrations in embryonic fish induced by chronic radiations. The dose-dependent effects of x-rays on the frequency of mitosis in regenerating tail fin of *O. latipes* was studied by Hama and Egami (1977). Mong and Bena (1979) also studied the effect of x-rays on chromosomes of mud minnow using different doses. The present paper deals with the x-ray induced chromosome aberration in the fish *T. mossambica* with special reference to the study of the differential radio-sensitivity of chromosomes between males and females and between and within the chromosomes in each sex which were not studied before. *T. mossambica* has been chosen not only for its easy rearing and handling, but

also its mitotic metaphase complements containing a pair of conspicuously large chromosomes which, as markers, served better to study the problem of the intraand interchromosomal radio-sensitivity.

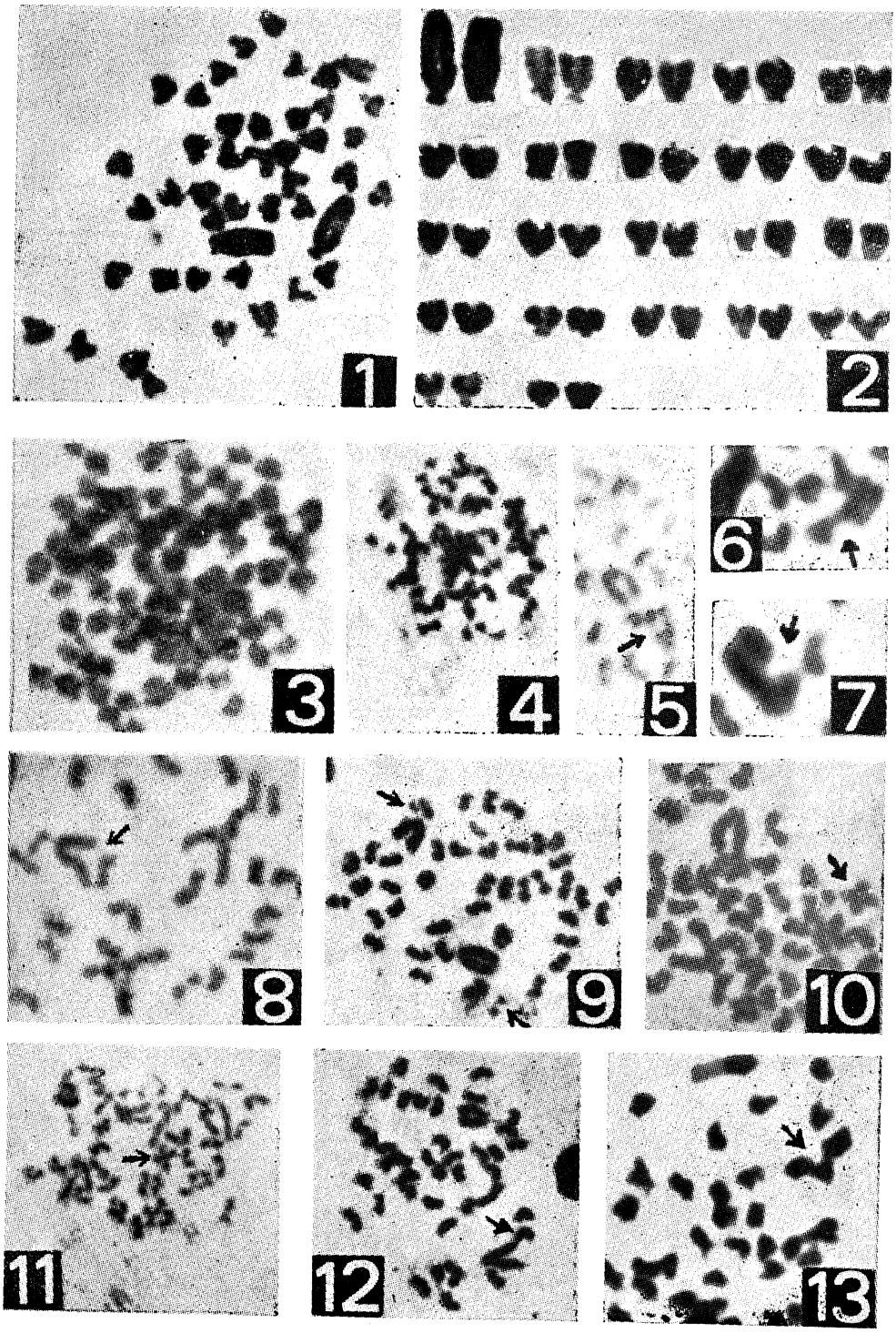
2. Material and methods

The herbivorous freshwater higher group of teleostean fish, *Tilapia mossambica* Peters (Family Cichlidae, Order Perciformes) domestic to the rivers of East coast of Africa was introduced to the Indian inland waters for its exotic habit of breeding. They breed throughout the year almost every 2 months except in winter (see Jhingram 1974). Specimens used in the present investigation were from the 4th inbred generation raised by us. Before irradiation living male and female specimens were acclimatized in the aquarium for a day or two. Immediately after taking them out of the aquarium, their body was gently rubbed once with a piece of dry cloth to remove surface water. They were then irradiated with the dose of 100 r from the x-ray machine operated at 110 kV, 4 mA with 1 mm aluminium filter emitting 2·5 r per second. After irradiation the specimens were stocked into the aquarium for fixing their gills at different intervals. As controls unirradiated specimens of the same brood were kept into another aquarium under similar laboratory conditions. An hour before the fixation time each specimen was intramuscularly injected with 0·1% colchicine solution at the rate of 2 ml per 100 gm body weight. No colchicine was injected if the fixation of the tissue was to be done within an hour after irradiation. The gills of each specimen immediately after removal were minced in 1% sodium citrate solution and the minced tissue was left into citrate solution for an hour at room temperature. The tissue was then fixed in acetic-alcohol (1 : 3) mixture for a brief period after removing the citrate solution by centrifugation. The fixed tissue suspension was taken on a slide and after air-drying the slide was stained with Giemsa stain at pH 7·2 . The observations were made from the stained air-dried slides.

3. Observations

3.1. *Control series*

The diploid number of chromosomes in both the sexes of *T. mossambica* was 44, the sex chromosomes being undifferentiable cytologically (figure 1). With regard to the morphology of the chromosomes different workers (Natarajan and Subramanium 1968 ; Hideo and Muramoto 1975 ; Prasad and Manna 1976 ; Manna and Som, unpublished) were not in complete agreement with one another excepting, of course on the first pair of the longest subtelocentric chromosomes, referred to here as the marker pair. The controversy was on the exact morphology of the remaining 21 pairs of non-marker chromosomes. Their relatively small size and variable length and disposition of the shorter arm caused confusion. Anyhow none of the chromosomes was of the true metacentric type which helped us to determine the cases of centric fusion leading to form metacentric chromosome in the treated material (*vide infra*). Thus, without entering into any controversy, for our present analysis we put the first longest pair into the marker group and

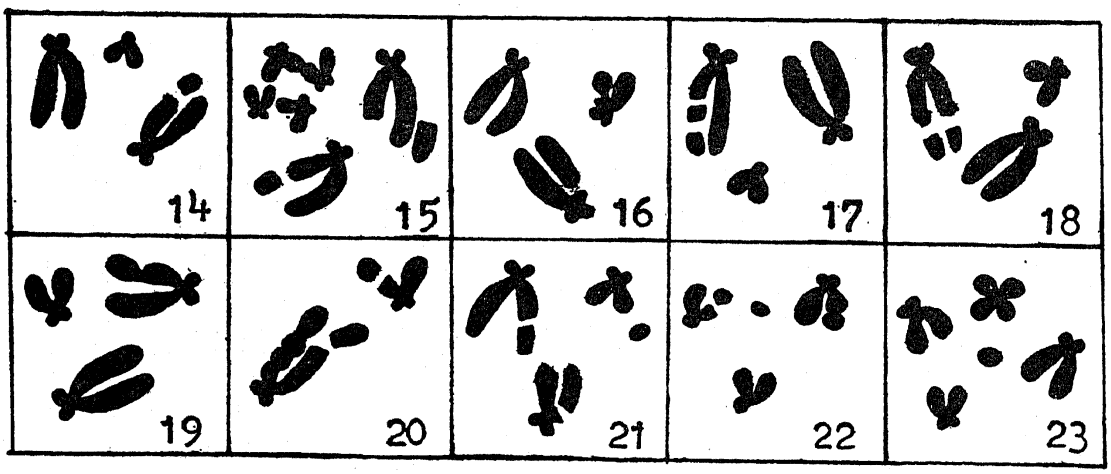


Figures 1–13. Photomicrographs, part and full metaphases. **1.** A normal complement in male ($2n = 44$), **2.** Male karyotype, **3.** Polyploidy, **4.** Stickiness, **5.** A marker chromosome with a subchromatid break, **6–8.** Each with a chromatid break in a marker chromosome, **9.** Two isochromatid and one chromatid fragment of unknown origin, **10, 11.** Each with a small metacentric chromosome formed by the centromeric fusion of two non-marker chromosomes, **12, 13.** Terminal association and/or chromatid exchange between two chromosomes.

the remaining 21 smaller pairs into the non-marker group (figure 2). Since the first marker pair was about double the size of the second pair (figure 2), there was not the least difficulty in identifying the first marker pair in any plate. This marker pair formed 1/22 part in the haploid number and approximately measured 1/10 (average 15·0 μ) of the total genome length (149·6 μ). The second pair also considered as marker chromosome (Hideo and Muramoto 1975) is, however, not considered as its size difference from the 3rd pair is not very conspicuous (figure 2). In the control series out of 150 metaphases examined in each sex at each of the 13 intervals corresponding to the treated series (table 1), only 2 constrictions were encountered at 96 hr in females. Thus these two were the individual type solely found in a total of 3,900 metaphases examined in two sexes while there were metaphases with gross effect found at all intervals. The frequency in the combined data of two sexes was 5·0% in 5 min, 8·7% in 1 hr, 4·3% in 6 hr, 6·0% in 12 hr, 8·0% in 24 hr, 8·7% in 48 hr, 3·3% in 72 hr, 7·0% in 97 hr, 5·0% in 120 hr, 6·0% in 144 hr, 5·0% on 7th day, 7·7% on 10th day, 3·7% on 15th day and 6·0% as average (table 1). The gross effect was mainly due to the stickiness of chromosomes and the frequency fluctuated erratically.

3.2. *X-rayed series*

In comparison to the control series, the gill epithelia of the x-irradiated specimens contained various types of aberrations (figures 3–23). For the sake of convenience



Figures 14–23. Camera lucida drawings × ca. 3,000 showing some rearranged metaphase chromosomes mostly with aberrations induced by x-rays. **14.** One marker chromosome with a terminal chromatid break **15.** Each marker chromosome with a chromatid break, and three non-markers with terminal association or chromatid exchange, **16.** A marker chromosome with a proximal chromatid break and a non-marker chromosome with a constriction, **17.** A marker chromosome with two breaks in the same chromatid, **18.** A marker chromosome with isochromatid breaks, **19.** A marker chromosome with a chromatid constriction, **20.** A marker chromosome with beaded constrictions in one chromatid and the other with a break while a non-marker chromosome with a chromatid break, **21.** A chromatid gap in a marker, a chromatid break in the first non-marker (2nd marker) chromosome and a fragment of unknown origin, **22, 23.** Each with a fragment of unknown origin while one (No. 22) also contained a chromatid break in a non-marker chromosome and the other (No. 23) a centric fusion.

Table 1. The frequency of chromosome aberrations in 300 metaphases (150 each of male and female) at each interval of 100r x-irradiated *Tilapia mossambica*. Data on female are in bracket ( ).

Fixa time	Individual type aberrations					No meta involved	No meta gross effect	Total affected metaphase	% in sex combined aff. met.		% Net increase
	Breaks	Fragm	Trans	Gaps and Cons	Total				Treated	Control	
5 mi	13 (14)	12 (8)	– (–)	12 (9)	37 (31)	26 (18)	18 (29)	44 (47)	30·3	5·0	25·3
1 hr	13 (7)	9 (7)	1 (1)	14 (11)	37 (26)	21 (12)	22 (18)	43 (30)	24·3	8·7	15·6
6 hr	6 (4)	4 (3)	1 (2)	10 (8)	21 (17)	17 (15)	8 (3)	25 (18)	14·3	4·3	10·0
12 hr	11 (10)	7 (6)	2 (1)	6 (9)	26 (26)	19 (16)	26 (30)	45 (46)	30·3	6·0	24·3
24 hr	5 (8)	4 (1)	3 (2)	7 (4)	19 (15)	12 (9)	27 (10)	39 (19)	19·3	8·0	11·3
48 hr	10 (12)	8 (9)	1 (2)	9 (7)	28 (30)	22 (19)	25 (27)	47 (46)	31·0	8·7	22·3
72 hr	6 (9)	4 (3)	2 (2)	7 (3)	19 (17)	15 (12)	18 (26)	33 (38)	23·7	3·3	20·4
96 hr	6 (9)	7 (6)	1 (2)	8 (10)	22 (27)	13 (12)	25 (25)	38 (37)	25·0	7·0	18·0
120 hr	5 (5)	2 (2)	– (1)	6 (5)	13 (13)	9 (9)	23 (20)	32 (29)	20·3	5·0	15·3
144 hr	9 (4)	4 (3)	3 (1)	– (2)	16 (10)	13 (10)	6 (10)	19 (20)	13·0	6·0	7·0
7 day	6 (2)	1 (1)	– (–)	5 (5)	12 (8)	7 (7)	1 (1)	8 (8)	5·3	5·0	0·3
10 day	– (–)	2 (2)	– (–)	3 (3)	5 (5)	3 (3)	22 (17)	25 (20)	15·0	7·7	7·3
15 day	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	10 (9)	10 (9)	6·3	3·7	2·6
Total	90 (84)	64 (51)	14 (14)	87 (76)	255 (225)	177 (142)	231 (225)	408 (367)	19·8	6·0	13·8

polyploidy (figure 3), stickiness (figure 4), *c*-mitosis etc. were put under gross effect in which the entire chromosome complement was affected while subchromated (figures 5, 14), chromatid (figures 6–8, 14–17, 20, 21) and isochromatid (figure 18) breaks, fragment of unknown origin (figures 9, 22, 23), translocation and fusion (figures 10–13, 15), constriction (figures 16, 19, 20), gap (figure 21) etc. were put under individual effect in which one (figures 5–8) or more (figures 14–21) chromosomes of the whole complement were involved. It appeared that the individual type aberrations were mostly of the chromatid type. If the marker chromosome was arbitrarily divided into 3 equal regions as proximal, middle and distal from the centromeric end, the chromatid breaks were somewhat localized in the distal region because out of 106 breaks in the marker pair, 15 were in the proximal, 33 in the middle and 58 in the distal region against the expected number of 35·3 breaks per region with random occurrence. The difference was statistically significant at 1% level ($X^2 = 26{\cdot}40$, d.f. 2). Thus, broadly speaking the distal half was more radio-sensitive than the proximal half of the marker chromosomes. However, in the present material such an analysis in the non-marker chromosomes was not possible for the inherent difficulties with the morphology and size of chromosomes. Definite translocation between the marker and non-marker chromosomes except for some terminal chromatid association or exchange (figure 12) was not encountered but centric fusion between two non-marker chromosomes (figures 10, 11) was common. While scoring the data some individual type of aberrations in the non-marker group might have escaped due to the inherent observational difficulty for the small size and morphology of the chromosomes. But the frequency of such an omission, if it occurred at all, would not exceed more than 2%.

In presenting the data the different individual type aberrations were put into one category *e.g.*, subchromatid, chromatid and isochromatid breaks as breaks etc. while for the gross types all of them were put together (table 1). An analysis of the data (table 1) indicated that chromosomes in irradiated males were affected more than those in females because in the same number of 150 metaphases, the number of aberrations was higher in males at all intervals and in their total except at 5 min, and from 24 hr to 96 hr for breaks, except at 48 hr for fragment of unknown origin and except at 12 hr, 96 hr and 144 hr for gaps and constrictions.

As the translocation data were limited, we made no comment. The statistical analysis of the total data showed that the difference was below the significant level because $X^2 = 0{\cdot}20$, d.f. 1 for breaks, $X^2 = 1{\cdot}47$, d.f. 1 for fragment of unknown origin and $X^2 = 0{\cdot}74$ for gaps and constrictions. In the combined data of all individual type aberrations, it was also higher in males at each interval except at 48 hr and 96 hr (table 1). In the total of all intervals, the males had 255 aberrations against 225 in females. The difference was also a little below the significant level because the X^2 value was 1·87 with 1 d.f. Therefore, on the whole the higher frequency of individual type aberrations in males was somewhat indicative that the sex factor might have some differential radio-sensitivity, but the data needed be extended for further confirmation. That the sex factor could have differential radio-sensitivity was supported by the fact that when the number of affected metaphases which contained individual type aberrations was compared between the two sexes, it was found higher in males in 9 intervals while

it was at par with females at 120 hr, 7th day and 10th day (table 1). In the total 1950 metaphases 177 were affected in males against 142 in females. The X^2 test gave a value of 3·84 with 1 d.f., indicating that the difference was significant at 5% level.

The number of affected metaphases with gross effects like polyploidy, stickiness etc. was not significantly different in the two sexes. It was a little higher in males at 6 out of 13 intervals and in the total (table 1). The X^2 value was 0·08 with 1 d.f. which indicated that the difference was highly insignificant. This was expected because gross effect was mostly physiological in origin. The number of affected metaphases with individual and gross type aberrations if combined, would be higher in males in 8 out of 13 intervals and in the total (table 1). The X^2 test showed that the value 2·17 with 1 d.f. was a little below the significant level. Thus, though the analysis of the data of aberrations and the affected metaphases did not conclusively prove, that the males and females responded differentially, there were reasonable indications beyond doubt for the same.

The individual type aberrations did not show a regular mode of incidence in both the sexes. The maximum number of the different types was mostly found in 5 min (breaks, fragments in male, total) and 1 hr (gaps and constriction) which reduced to nil on the 15th day or earlier (breaks) but the mode of decrease was very erratic as number fluctuated oddly at different intervals (table 1). The frequency of affected metaphases in male showed the same trend but in female the maximum number was found at 48 hr. The occurrence of the affected metaphases with gross effects was still more erratic as the maximum number of 27 was found at 48 hr in males and 29 in females at 5 min and the effect continued in a lower frequency in both sexes even on the 15th day (table 1). On the whole, the present data showed that the individual type of aberrations did not continue up to the 15th day while the gross type continued longer and in both cases the frequency fluctuated at different intervals (table 1). That the x-radiation induced a higher frequency of chromosome aberrations and affected more metaphases was beyond any doubt. The net increase in the individual type aberrations when the data of two sexes were combined was 22·7% at 5 min, 21·0% at 1 hr, 12·7% at 6 hr, 17·3% at 12 hr, 11·3% at 24 hr, 19·3% at 48 hr, 12·0% at 72 hr, 15·7% (2 constrictions in control) at 96 hr, 8·7% at 120 hr and 144 hr, 6·7% on 7th day, 3·3% on 10th day and nil on 15th day. The net increase in an average was 12·4%. On the other hand, the net increase in the frequency of total affected metaphases over the control was 25·3%, 15·6%, 10·0%, 24·3%, 11·3%, 22·3%, 20·4%, 18·0%, 15·3%, 7·0%, 0·3%, 7·3% and 2·6% respectively in 13 intervals and 13·8% in the average (table 1).

3.3. *Non-random distribution*

To find out if the aberrations were non-randomly distributed between the marker and non-marker chromosomes, some individual type aberrations like breaks, gaps and constrictions were quantitatively assessed at each interval from 150 metaphases examined in each sex (table 2). The other individual types like fragment of unknown origin and translocation were not considered as the chromosome involved was not known in the former type.

Table 2. Frequency distribution of some individual type aberrations between 1st 'Marker' pair and 21 pairs of non-marker chromosomes in X-irradiated male and female *Tilapia mossambica*. Data of females are in brackets ( ).

Fixa time	No of metaphase	Marker chromosome			Non-marker chromosome			Grand total
		Break	Gap and Cons	Total	Break	Gap and Con.	Total	
5 min	150 (150)	7 (7)	4 (2)	11 (9)	6 (7)	8 (7)	14 (14)	25 (23)
1 hr	150 (150)	5 (1)	8 (5)	13 (6)	8 (6)	6 (6)	14 (12)	27 (18)
6 hr	150 (150)	5 (3)	7 (8)	12 (11)	1 (1)	3 (–)	4 (1)	16 (12)
12 hr	150 (150)	7 (7)	6 (8)	13 (15)	4 (3)	– (1)	4 (4)	17 (19)
24 hr	150 (150)	4 (7)	4 (4)	8 (11)	1 (1)	3 (–)	4 (1)	12 (12)
48 hr	150 (150)	9 (11)	8 (2)	17 (13)	1 (1)	1 (5)	2 (6)	19 (19)
72 hr	150 (150)	5 (3)	6 (3)	11 (6)	1 (6)	1 (–)	2 (6)	13 (12)
96 hr	150 (150)	4 (5)	6 (6)	10 (11)	2 (4)	2 (4)	4 (8)	14 (19)
120 hr	150 (150)	4 (5)	4 (4)	8 (9)	1 (–)	2 (1)	3 (1)	11 (10)
144 hr	150 (150)	3 (2)	– (2)	3 (4)	6 (2)	– (–)	6 (2)	9 (6)
7 day	150 (150)	– (2)	2 (3)	2 (5)	6 (–)	3 (2)	9 (2)	11 (7)
10 day	150 (150)	– (–)	3 (1)	3 (1)	– (–)	– (2)	– (2)	3 (3)
15 day	150 (150)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Total obs.	1950 (1950)	53 (53)	58 (48)	111 (101)	37 (31)	29 (28)	66 (59)	177 (160)
Expected per number				8 (7)			169 (153)	177 (160)
Expected per length				18 (16)			159 (144)	177 (160)

It was interesting to note that there was some difference in the data of the two sexes. In the marker chromosome no difference was seen in the total number of breaks, while it was higher by 10 in males for gaps and constrictions (table 2). In the non-marker chromosomes it was higher in males by 6 for breaks and meagrely by 1 for gaps and constrictions. Therefore, no definite claim was made as to the differential response of the two sexes, it was just to draw attention to the trend.

That the marker chromosomes in each sex were highly sensitive to x-radiation was clear when the observed and the expected values calculated according to the number of chromosomes and according to the mean length were compared. Out of the total 177 individual type aberrations in males, 111 were observed in the marker pair-against the expected number of only 8 as calculated per proportionality of number indicating thereby that the marker pair was about 14 times more susceptible to x-ray damages. The expected number was 18 if the mean length was considered. Even then the observed number was more than 6 times indicating the higher susceptibility of the marker pair. On the other hand, in the non-maker chromosomes of males, 66 aberrations were found against 169 expected, calculated per number of chromosomes and 159 calculated per length of chromo-

somes, indicating thereby that the susceptibility of the non-marker chromosomes was 2·5 times and 2·4 times less. The chi-square tests of the expected data per number and per length against the observed number showed in each case that the difference was highly significant ($P < 0·001$). Therefore, in males some individual type aberrations mentioned early were non-randomly distributed between the marker and non-marker chromosomes, the former group was highly susceptible and the latter group was somewhat resistant to the x-ray damages.

In females like males the marker chromosomes were also found to be highly radio-sensitive, while the non-marker ones were somewhat less susceptible. Out of the total 160 individual type aberrations analysed, 101 were observed in the marker pair against the expected number of 7 as calculated per proportionality of number and 16 as calculated per length of chromosomes (table 2). Thus, like in males, in females also the marker chromosomes were 14 times more susceptible according to the number and over 6 times susceptible according to the length of chromosomes. On the other hand, in the non-marker chromosomes the observed number of individual type aberrations was 59 as against the expected number of 153 calculated per proportionality of number and 144 calculated per proportionality of length of the non-marker chromosomes, indicating that they too, like marker chromosomes, were 2·5 times less vulnerable according to the number and 2·4 times less vulnerable according to the length of chromosomes. The chi-square tests of the observed number and the expected number calculated per number and the expected number calculated per length of chromosomes showed that the difference in both the cases was very high ($P < 0·001$). Therefore, just like males, the two groups of chromosomes showed the same type of response to x-rays, the marker chromosomes were highly susceptible, while the non-markers were somewhat less responsive.

Since the data of each sex showed differential radio-sensitivity, it was expected naturally that in the combined data of the two sexes the same manifestation would be shown. Thus, out of the total 337 aberrations, 212 were observed in the marker pair against the expected numbers of 15 and 34 calculated per number and length of chromosomes respectively which also showed 14 times and 6 times more susceptibility of the marker chromosomes (table 2). In the non-marker chromosomes 125 aberrations were observed as against the expected number of 322 and 303 calculated per number and per length of chromosomes respectively which also showed that the non-marker chromosomes were 2·5 times and 2·4 times less vulnerable to x-ray damages. The chi-square test of the observed number and the expected numbers calculated in two different ways showed in each case that the difference was highly significant ($P < 0·001$).

4. Discussion

Most of the effects of ionizing radiations on chromosomes of fish reported by different investigators did not elaborate on the aberration types. The qualitative aspect of the present study revealed that the aberrations were of a similar nature as found in the somatic chromosomes of some classic material induced by radiations. But as the chromosomes of fish were not cytologically ideal, all types could not be studied in every detail. The individual type aberrations

could only be studied more elaborately in the marker chromosomes. The quantitative study of the chromosome aberrations in *T. mossambica* at different intervals showed that the effect lingered for a long time. There was not much indication of the cell lethality caused by the dose of 100r. The individual types continued mostly up to the 10th day, while the gross type did so till the end of the fixation intervals. Anyhow the persistence of mainly the chromatid type aberration as long as 10 days after irradiation deserved some consideration. Though the timing of the cell cycle in *T. mossambica* has not been worked out, yet within 10 days some cells must have completed the cycle unless their further division was inhibited. The prevalent occurrence of the chromatid type aberrations at late intervals indicated the possibility. Further, the chromatid type break has been supposed to be induced by the radiation acting on the post-synthetic period of DNA or else after the replication of chromosome, the reason for which could not be suggested. It has been a matter of common experience that the chromosome aberrations induced by odd chemical (Kihlman 1966 ; Manna 1971, 1975, 1978) and living mutagens (Manna 1980) were mainly of chromatid type. The same type of chromosome response of having mainly chromatid type aberrations to ionizing radiations like other chemically induced ones might lead us to think that the post-synthetic period, in general, was most sensitive for mutagenic damage to chromosomes. Since the aberrations were found within 5 min after radiation it was all the more suggestive that the chromosome nearing metaphase was more vulnerable to x-ray lesion. The occurrence of more or less the same chromatid type aberrations from the beginning to almost the end of fixation interval would further lead us to suspect if the chromosomes approaching metaphase were the vulnerable stage. This was suggested to explain the chromosome aberrations induced by odd mutagens in mice (Manna 1971, 1975). The present study indicated the differential radio-sensitivity of chromosomes and metaphase nuclei of males and females irradiated with x-ray. In the past various parameters were used to test the differential radio-sensitivity in different materials (Evans 1962; Sparrow 1962; Manna and Mazumder 1968) while the testing of the differential radio-sensitivity of chromosomes in the two sexes in fish has not been carried out. The present data need be extended to confirm because there were some lecunae in the data.

The analysis of the data of the region-wise distribution of chromatid breaks in the marker chromosomes of *T. mossambica* revealed that the distal region or more broadly the distal half was more vulnerable to x-ray damages. More or less the same trend was shown by the chromosomes of mice treated with physical, chemical and living mutagens (Manna 1971, 1975, 1978, 1980) for which it was suggested by Manna (1975, 1978) that there could be some inherent weaker region in chromosomes. The same might be the reason for the somewhat localized break found in the marker chromosome of *T. mossambica.* The other possibility of having localized breaks by radiation was the differential restitution as suggested to explain the localized breaks in the *X* chromosome of irradiated grasshopper (Manna and Mazumder 1962).

Interchromosomal radiation damages by x-ray have been studied in different animals. The differential radio-sensitivity between chromosomes of the same species was seen in the Syrian hamster (Manna and Dey 1981), grasshopper (Manna and Mazumder 1962, 1968) and Heteroptera (Manna and Dey 1978,

1980). In the above cases the differential radio-sensitivity was shown between the sex chromosome and autosome of the species concerned, while in the present study on *Tilapia*, it was found between two groups of autosome. It was claimed that the radiation injury was directly proportional to the chromosome volume (Marshak 1937), length etc. but it was not found in other material (Manna and Mazumder 1968). It was also not supported from the present data because the marker chromosomes had more breaks than the expected number calculated proportional to the length of the chromosomes. The present study, therefore, revealed some interesting results on the x-ray induced chromosome aberrations in *T. mossambica*. Further studies are in progress.

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References

Evans H J 1962 *Chromosome aberrations induced by ionizing radiations.* In : *Int. Rev. Cytol.* (eds.) G H Bourne and J F Danielli (New York : Academic Press) **13** 221–308

Hama A and Egami N 1977 The dose-rate effect of gamma radiation on the initiation of mitosis in the regenerating tail fin of the fish *Oryzias latipes*, *J. Fac. Sci. Univ. Tokyo*, Sec. IV, **14** 47–60

Hama A, Egami N, Arai R and Shiotsuki K 1976 Note on chromosome abnormalities found in irradiated *Oryzias latipes*, *J. Fac. Sci., Univ. Tokyo*, Sec. IV, **13** 405–408

Hickling C F 1962 In *Fish culture* (London : Faber and Faber) pp. 245–259

Hideo F and Muramoto J I 1975 Somatic and meiotic chromosomes of *Tilapia mossambica* Peters. Chromosome Information Service, Japan **18** 4–6

Jhingram V J 1974 *Fish and fisheries of India* (Delhi : Hindusthan Publishing Corporation)

Kihlman B A 1966 *Actions of chemicals on dividing cells* (New Jersey : Prentice Hall)

Manna G K 1971 Bone marrow chromosome aberrations in mice induced by physical, chemical and living mutagens, *Proc. 1st All India Cong. Cytol. Genet.* (Chandigarh), *J. Cytol. Genet.* (*Cong. Suppl.*) pp. 144–150

Manna G K 1975 Induced breakage in chromosomes—mechanical and/or chemical. *Proc. Symposium on structural and functional aspects of chromosomes* (Bombay, BARC) March 25–26, pp. 194–204

Manna G K 1978 Nonrandom aberrations and their implications on the possible existence of weaker regions in chromosomes. *Proc. 3rd All India Cong. Cytol. and Genet.* (Hissar) In : *Perspective of Cytology and Genetics* (eds.) G K Manna and U Sinha (Delhi : Hindasia Publisher) **3** 221–233

Manna G K 1980 The living mutagens. In : *Golden Jubilee Commemoration Volume of National Academy of Sciences, India* (Allahabad) (ed.) U S Srivastava (Calcutta : Naya Prakash) pp. 573–606

Manna G K and Dey S K 1978 X-ray induced chiasma-like configuration between sex chromosomes of the pyrrhocorid bug, *Physopelta schlanbuschi. Proc. 3rd All India Cong. Cytol. Genet.* (Hissar), In : *Perspective of Cytology and Genetics* (eds.) G K Manna and U Sinha (Delhi : Hindasia Publisher) **3** 367–672

Manna G K and Dey S K 1980 Preferential sex chromosomal aberrations induced by X-rays and their alterations by penicillin in male heteropteran bug, *Physopelta schlanbuschi. Symp. on Chromosome Methodological approaches in cytogenetics* (In *Cytogenetics in India* (eds.) R P Roy and U Sinha (Delhi : Hindasia Publisher) In press

Manna G K and Dey S K 1981 Differential X-ray sensitivity of Syrian hamster chromosome, *Nucleus* **24** 48–56

Manna G K and Mazumder S C 1962 The grasshopper X-chromsome as an indicator for X-ray induced chromosome breakage, *Proc. Zool. Soc.* (*Calcutta*) **15** 103–110

Manna G K and Mazumder S C 1968 Induced X-chromosomal aberrations in the study of intra- and interspecific radiosensitivity of grasshoppers. In : *Seminar on chromosomes, Nucleus* (ed.) A K Sharma (Calcutta) pp. 197–207

Manna G K and Som R C Unpublished

Marshak A 1937 The effect of X-rays on chromosomes in mitosis, *Proc. Natl. Acad. Sci. U.S.A.* **23** 362–369

Mong S J and Bena T M 1979 The effects of increasing dosages of X-radiation on the chromosomes of central mud minnow ; *J. Fish Biol.* **14** 523–527

Natarajan R and Subramanyam K 1968 A preliminary study on the chromosomes of *Tilapia mossambica* (Peters) ; *Curr. Sci.* **37** 362–363

Pechkurenkov V L 1976 Formation of chromosomal aberrations in fish embryos induced by chronic radiation ; *Radiobiologiya* **16** 842–846

Prasad R and Manna G K 1976 Chromosomes of fishes, *T. mossambica* and *N. notopterus* ; *Chromosome Information Service* Japan No. **21** 11–13

Schroder J H 1973 Teleosts as a tool in mutation research. In *Genetics and Mutagenesis in Fishes* (ed.) J H Schroder (New York : Springer-Verlag) pp. 91–98

Sharma A K and Chatterjee A 1962 Chromosome size as a factor on radio-sensitivity ; *Nucleus* **5** 67–74

Sparrow A H 1962 The role of nucleus in determining radio-sensitivity ; *Brookhaven Lecture Series* No. 17.