N O T I C E

NASA TECHNICAL MEMORANDUM

NASA TM-76281

GENETIC CHANGES INDUCED BY SPACE FLIGHT FACTORS IN BARLEY SEEDS ON "SOYUZ-5" AND "SOYUZ-9" CRAFT

N. I. Nuzhdin, R. L. Dozortseva

Translation of "Geneticheskiye izmeneniya, indutsirovannyye faktorami kosmicheskogo poleta v semenakh yachmenya, nakhodivshikh na korablyakh "Soyuz-5" i "Soyuz-9", Zhurnal Obshchey Biologii, Vol. 33, No. 3, 1972, pp 336-346

(NASA-TM-76281) GENETIC CHANGES INDUCED BY SPACE FLIGHT FACTORS IN BARLEY SEEDS ON SOYUZ-5 AND SOYUZ-9 CRAFT (National Aeronautics and Space Administration) 17 p HC A02/MF A01 CSCL 06C G5/51

N80-29013

Unclas 28205

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON D.C. 20546 JULY 1980

STANDARD TITLE PAGE

1. Report No. NASA TM-76281	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle GENETIC CHANGES INDUCED BY SPACE FLIGHT FACTORS IN BARLEY SEEDS ON "SOYUZ-5" AND "SOYUZ-9" CRAFT		5. Report Date JULY 1980
		6. Performing Organization Code
7. Author(s) N. I. Nuzhdin, R. L. Dozortseva		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASW-3198
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes "Translation of :Geneticheskiye izmeneniya, indutsirovannyye faktorami kosmicheskogo poleta v semenakh yachmenya, nakhodivshikh na korablyakh "Soyuz-5" i "Soyuz-9", Zhurnal Obshchey Biologii, Vol. 33, No. 3, 1972, pp 336-346.

N80 23662

16. Abstract

Air-dry seeds of the barley "Zimujuschij moscowskyi" of the 1969 harvest were taken into space on board the spaceships "Sojuz-5" and "Soyuz-9".

A cytological study of the mitoses in meristemic cells in rootlet terminals revealed that SFF in non-irradiated seeds induced about 3% of aberrant cells. After irradiation the effect of SFF increased over two-fold. Although the radio-protectors ensured the seeds against the γ induced damage, they failed to protect the seeds from the SFF-induced damage either in irradiated or non-irradiated seed cells which is inconsistent with the previously obtained data.

17. Key Words (Selected by Author(s))		18. Distribution Statement THIS COPYRIGHTED SOVIET WORK IS REPRODUCED AND SOLD BY NTIS UNDER LICENSE FROM VAAP, THE SOVIET COPYRIGHT AGENCY NO FURTHER COPYING IS PERMITTED WITHOUT PERMISSION FROM VAAP	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 17	22.

Introduction /336*

Previously published works (Nuzhdin et al., 1965, 1967a,b, 1970) have presented results of a study on seed material located on spacecraft during their flight. It was established, that the space flight factors (SFF) induce physiological and genetic changes in the seeds. The first type of changes include accelerated emergence of the seeds from the state of organic rest. Ionizing radiation does not produce such an effect, although a number of researchers have shown many times that in certain doses it can stimiulate germination of the seeds that are in forced rest.

The genetic changes induced by SFF were studied in the example of damage to the nuclear structures (chromosomal aberrations) in the cells of embryonal cells. It was established, that in each flight experiment the SFF induced in embryonal air-dried seeds from 1.5 to 3.0% aberrant cells in addition to the control.

During the combined effect on the seeds of SFF and radiation with a low /337
LEL (linear energy loss), regardless of the sequence of the two indicated factors, two forms of influence were established: 1) summation of the chromosomal damages (additive effect), regardless of those induced by each of the factors; 2) interaction of the two factors, resulting in an increase in the SFF effect on the background of irradiation (effect of interaction). Each of the two indicated forms is realized and is determined by the physiological condition of the biological system exposed to the factor, and the size of the radiation dose.

After using a radioprotector (cysteine), that protects the plant cells well from chromosomal aberrations, the possibility was shown of reducing the damaging effect of SFF on the nuclear cell structures.

Whereas the data on the physiological and genetic effects induced by SFF have been stably repeated in a study of the material that was on different spacecraft, the data on the type of reaction to the combined effect of SFF and irradiation, like the results on radioprotector-modification of the genetic effect of SFF, need further observations. This is important not only to establish the repetition of the findings, but also to clarify a number of questions studying the nature of these phenomena. The latter is especially necessary due to the

---

*Numbers in margin indicate pagination in original foreign text.

results from investigating the combined effect of radiation, G-forces, and radioprotectors on the animal organism that were obtained by a number of researchers in laboratory experiments. The data given below on the effect of the interaction of SFF with irradiation, and the effect of radioprotectors were obtained in an investigation of seeds that were on the craft "Soyuz-5" and "Soyuz-9" during their space flight.

2. Results of Investigation of Material on the Spacecraft "Soyuz-5"

The spacecraft "Soyuz-5" with the crew of B. V. Volynov, A. S. Yeliseyev, and Ye. V. Khrunov was put into orbit on 15 January 1969 (landed 18 January 1969). Seeds of the Zimuyushchiy Moskovskiy (Hibernating Moscow) barley in a state of organic rest were located on the craft during the flight. There were two experimental series: one series (series I) contained nonirradiated seeds, and the other (series II) had seeds that were irradiated (γ=Cs^{137}, 15 Ci, 620 R/min) before being sent to the cosmodrome. The control was the same seeds as in the experiment, some of them flew to the cosmodrome and back (control 1) and others were stored in the laboratory (control 2).

On 19 February 1970, the experimental and control seeds were germinated, which lasted for 7 days at 20-22°C. All the seeds that emerged from organic rest in the indicated period germinated (variant 1). In the remaining ungerminated seeds the seed shells were removed, and half of them were left for further germination (variant 2), while the second half was stored for 10 days in air at room temperature, then were germinated (variant 3). The calculation made of the seeds that emerged from organic rest indicated that by the beginning of the experiments, after return of the seeds from space, only 5% of them were in forced rest.

In the germinated seeds, the primary rootlets 4-8 mm in size were fixed in a mixture of 96° alcohol and glacial acetic acid (3:1). The rootlets were stained by Feulgen's method, their ends were placed in a drop of acetic acid carmine, and pressed preparations were made, that after dehydration in dry ice were mounted in Canadian balsam. The examination took into account the number of late anaphases and early telophases, and the percentage of mitoses with dicentric bridges and acentric fragments served as the index for the SFF effect. /338

TABLE 1. OUTPUT OF ABERRANT CELLS IN ROOTLETS OF EXPERIMENTAL ("SOYUZ-5") AND CONTROL SEEDS

Series	Variants	Experiment			Control		
		total cells	aber-rant	%	total cells	aber-rant	%
I (nonirradiated seeds)	1	1058	50	4,7±0,65	1615	21	1,3±0,28
	2	1381	47	3,4±0,49	2807	37	1,3±0,20
	3	1228	57	4,6±0,60	3012	40	1,3±0,20
II (irradiated seeds)	1	1138	448	39,4±1,45	1179	411	34,9±1,39
	2	1293	270	20,9±1,13	3693	705	19,2±0,65
	3	1455	520	35,7±1,07	2615	820	31,3±0,92

Table 1 presents the results of a cytological study. By comparing the data of the experiment with the corresponding controls (since the differences between control 1 and control 2 are uncertain, table 1 presents the summed control) we find a completely reliable effect of SFF in the series with nonirradiated material. By using Abbot's formula, the pure effect of SFF was determined, which for variants 1-3 of the discussed series respectively equals: 3.4±0.47, 2.1±0.26 and 3.3± 0.37%.

Irradiation of the seeds before they were sent into space changed the reaction to the effect of SFF (table 1, series II). First of all, one should note the absence of real differences between the results of the experiment and the control in variant 2 ($P>10$). This is not an accidental result, since the same data were obtained previously in this variant (Nuzhdin et al., 1970). We note that the sequence of the two effects does not alter the result.

Another distinguishing feature consists of a change on the background of irradiation in the SFF effect. This is clearly displayed after conversion of the table 1 results according to Abbot's formula, which makes it possible to isolate the pure effect of the SFF both without irradiation, and on its background (table 2).

The results of table 2 demonstrate that on the background of irradiation, the effectiveness of the SFF rose approximately two-fold in variants 1 and 3. In variant 2, the irradiation did not alter the effectiveness of the SFF, that remained on the same level , although under the influence of irradiation the output of aberrant cells sharply rose in the experiment and in the control. Simple

TABLE 2. PURE EFFECT OF SFF, CONVERSION OF TABLE 1 RESULTS BY ABBOT'S FORMULA

Variants	Series I	Series II
	% of aberrant cells with regard for control	
1	3,4±0,47	6,9±0,91
2	2,1±0,26	2,4±0,21
3	3,3±0,37	6,4±0,50

calculation demonstrates that in variant 2 and the control, due to the effect of radiation the same percentage of aberrant cells was induced (18.1%). Consequently, in the series with irradiation, in variant 2 there is no effect of interaction solely due to the realization of SFF-induced damages. This was also the cause of the absence of differences in the percentage of aberrant cells between the experiment and the control.

How can one explain the different manifestation of the SFF effect, which was found on the background of irradiation in the three discussed variants?

The causes of this are hidden in the features of the biological system that was exposed to the effect of SFF and irradiation. The response of the biological system that is characterized by its dissimilar state, also determined these dif- /339
ferences.

The batch of seeds used in the experiment was a population that consisted of seeds that had emerged from the state of organic rest (embryonal cells had passed into phase G_1), and seeds that were in organic rest (embryonal cells in phase G_0). Germination showed that the first comprised only 5% and in the experiment formed the first variant.

Seeds in variants 2 and 3 during the flight and at the moment of irradiation were in organic rest. The first were germinated immediately after transition of the cells from phase G_0 to phase G_1. Damages of the first class (true damages) only are realized in them in the first mitosis. The second, after transition of the cells from phase G_0 to phase G_1, were preserved in air for 10 days. During this period additional oxygen damage of potential chromosomal disjunctions occurred, and in the first mitosis damages of the first, as well as the second and third classes are realized (Nuzhdin, 1970).

The indicated distinguishing feature of variants 1,2,3 also determines the observed differences in the realization of damages induced by SFF and radiation with a low LEL. It is quite obvious that variant 2 lacks the "effect of interaction," as a result of which the effect of the SFF does not rise on the background of irradiation. This indicates that the "effect of interaction" is linked to the realization of potential, and not true damages.

It is not excluded that the SFF induce only true damages, i.e., damages of the first class, and do not induce potential damages. The results of series I (table 1) support this. In the limits of the indicated series there are no differences in the percentage of aberrant cells between variant 2 and variants 1 and 3, that should occur in the presence of potential damages. However, this assumption needs further confirmation, since there are data that contradict such a hypothesis. Thus, in the work to study material on the spacecraft "Zond-5" reliable differences were found in the percentage of aberrations among variants 1,2 and 3 in the series without irradiation (Nuzhdin et al., 1970). In another work (Nuzhdin, Dozortseva, 1967) the "defense effect" of cysteine was found in variant 1 of the nonirradiated material that flew on the spacecraft "Voskhod-5." This contradicts the advanced hypothesis, and only further research will make it possible to solve this question that is of basic importance.

3. Results of Study of Material on Spacecraft "Soyuz-9"

The spacecraft "Soyuz-9" with cosmonauts A. G. Nikolayev and V. I. Sevast'yanov was put into the orbit of an artificial earth satellite on 1 June 1970 and was in flight for 424 h up to 19 June 1970. During the indicated space flight, there were air-dried seeds of Zimuyushchiy moskovskiy barley from the 1969 harvest in the state of induced rest on the craft among the biological objects.

The experiment consisted of two series that were distinguished by preliminary (before being sent into flight) and subsequent (after return from the flight) treatment of the seeds. In series I before the seeds were sent into space they were not exposed to additional treatment. After return to the laboratory the experimental and control seeds were moistened: in water, neutral solution of cysteine hydrochloride (0.15%), in a solution of aminoethylisothiouronium (0.15%) for a day. After drying, half of the seeds were irradiated with γ-rays of Cs^{137} (15 Ci, 610 R/min). Fifteen days after irradiation, all the seeds were set up

TABLE 3. OUTPUT OF ABERRANT CELLS IN ROOTLETS OF EXPERIMENT ("SOYUZ-9") AND CONTROL SEEDS

Series	Experimental				Control			
	Variants	cells examined: total cells	aberrant	%	Variants	cells examined: total cells	aberrant	%
			Nonirradiated seeds					
I	water	1162	56	4,8±0,55	C1 water	1181	25	2,1±0,41
	cysteine	1132	52	4,7±0,61	cysteine	1257	28	2,2±0,40
	AET	1117	49	4,4±0,62	AET	1246	27	2,0±0,40
II	water	1170	64	5,3±0,63	C1 water	1193	24	2,0±0,40
	cysteine	1328	73	5,4±0,38	cysteine	1285	29	2,0±0,33
	AET	1267	73	5,7±0,65	AET	1195	26	2,2±0,41
					C2 water	1321	40	3,0±0,47
					cysteine	1136	33	2,9±0,51
					AET	1120	34	3,0±0,51
	Σ	7176	367	5,1±0,26	Σ	10934	266	2,4±0,14
			Irradiated seeds					
I	water	1403	390	27,6±1,19	C1 water	1252	295	23,5±1,21
	cysteine	1306	273	20,9±1,30	cysteine	1222	215	17,5±1,07
	AET	1490	284	19,0±1,00	AET	1185	212	17,8±1,11
II	water	1227	346	28,0±1,28	C1 water	2179	453	20,7±0,87
	cysteine	813	171	21,0±1,43	cysteine	1892	283	14,9±0,82
	AET	1268	303	23,8±1,19	AET	1646	255	15,5±0,89
					C2 water	1526	333	21,8±1,05
					cysteine	1100	194	17,6±1,15
					AET	1125	174	15,4±1,07

Note. Space without irradiation--2.75%. Space on background of irradiation--7.8%. Effect of irradiation--19%. Effect of protection from radiation--6.5±0.29. Effect of protection from radiation and SFF--5.8±0.14.

for germination.

In series II, before being sent to the cosmodrome, the seeds were moistened: in water and solutions of cysteine and AET of the concentrations indicated above. After drying, they were sent at the same time with the seeds of the series I to the cosmodrome. After return to the laboratory, half of the seeds were irradiated with γ-rays of Cs^{137} (15 Ci, 610 R/min), and the second half of the seeds were not exposed to radiation. Fifteen days after irradiation, all the seeds were set up for germination.

The control was seeds of the same type of barley, that except for being in space were exposed to treatment similar to the experimental seeds. Series I had one control that was stored in the laboratory (control 2). Series II had two controls. In one (control 1) the seeds flew to the cosmodrome and were returned to the laboratory together with the experimental seeds, and in the other (control 2) the seeds were stored in the laboratory. The production of the preparations and their examination did not differ from the technique described above for processing the material on the craft "Soyuz-5."

Table 3 presents the results that were obtained in a review of the experimental and control material in the two series described above. As is apparent from the table, among the nonirradiated material in the limits of the experiment /341 and the control the differences between the variants were statistically uncertain. This made it possible to sum the results, which facilitates their examination.

First of all, we note that there is an undoubted effect of the SFF which increases the output of aberrant cells on the average by 2.75%. The differences between the experiment and the control are statistically reliable ($P < 0.001$). These results are similar to those examined above in an analysis of the material that flew on the "Soyuz-5", as well as on other spacecraft.

As already noted above, in the limits of the experiment, the differences between the variants are uncertain. This shows that the two employed defense preparations (cysteine and AET) that reduce the output of chromosomal aberrations induced by radiation with a low LEL, proved to be ineffective when used to protect the chromosomes from SFF-induced damages.

Passing to the results of the combined effect on the seeds of γ-irradiation and the SFF, in the first place we will examine the manifestation of the SFF effect. By comparing the experimental results with the corresponding control variants, we are convinced of the distinct manifestation of the indicated effect. With the exception of one variant (series I, variant using AET), the differences in the frequency of aberrant cells in the experiments and the corresponding controls are statistically reliable.

Within the experimental group, in the same way as in the control, the defense effect of the employed protectors is clearly revealed. However, this does not mean that the defense effect is spread to the chromosomal damages induced by SFF, and especially on those that rise during the interaction of the SFF with γ-irradiation. By using Abbot's formula for the material in table 3, the following were defined: effect of SFF without irradiation and on the background of irradiation, effect of irradiation, effect of protection from irradiation, effect of protection from irradiation and the SFF. The corresponding results are presented in table 3.

In examining these results we find that on the background of irradiation, as a consequence of interaction, the effect of SFF triples. As in the case of the nonirradiated material, the effect of the protectors examined above is spread only to the SFF-induced damages. Thus, protection from damages induced by γ-irradiation equals $6.5 \pm 0.29\%$, and protection from the damages induced both by radiation and SFF reaches $5.8 \pm 0.14\%$. The differences between these amounts are uncertain. Consequently, the protection remains on the same level that occurred during the effect of γ-irradiation alone. This demonstrates, that with the combined effect the protectors affect only the damages induced by radiation, and are not spread to that part of the chnomosomal damages induced by SFF.

Among the data given in this study the following deserve special attention: 1) the presence of two types of responses under the combined influence on the seeds of SFF and irradiation (additive effect and effect of interaction); 2) the absence of chemical protection of the chromosomes both from the direct effect of SFF, and from the effect of interaction.

The presence of the additive effect during the combined effect of SFF and irradiation with low LEL was established for the first time in the example of aberrant cell output in the primary rootlets of Euonymus seeds (Euonymus europaeus L.) that flew with irradiation and without on the spacecraft "Vostok-5" (Nuzhdin et al, 1965). Later, on extensive material obtained in a cytological study of seed rootlets on the spacecraft "Voskhod-1," "Zond-5" and "Zond-6" it was shown that in addition to simple summation of the two independent effects, their interaction is observed which results in an intensification of the SFF effect (Nuzhdin, et al., 1970). Both indicated types of effects can be encountered simultaneously on the same space vehicle. As shown by an analysis of the material, the physiological /342 state of the biological system is decisive, although this does not exhaust the reason for the two types of responses to the combined effect. In the seeds that were exposed to the effect of SFF and irradiation in a state of organic rest (embryonal cells in the G_0 phase) an adaptive effect of the indicated factors was established. In the seeds exposed to the effect of the same two factors on seeds in a state of induced rest (embryonal cells in the G_1 phase) the effect was established of interaction of irradiation and SFF, as a result of which the output of aberrant cells noticeably rises. The phenomenon of the increased effect during the combined effect of SFF and ethylenimine was shown by L. G. Dubinina and O. P. Chernikova (1970) also on chromosomal aberrations induced in the cells of the seed rootlets of Crepis capillaris.

Thus, a similar-type effect was established during the combined effect on the seeds that were in a state of induced rest of SFF and physical (γ-irradiation) or chemical (ethylenimine) mutagen. It is not excluded, that with a combination of SFF and other physical or chemical effects, their influence will increase many times as compared to the influence of each of the factors, or their summary effect.

Currently, the very important relationship of the effect of SFF in combination with other effects has been shown in the example of chromosomal mutations. It still remains unclear whether this relationship is restricted only to damages to the nuclear apparatus, or is spread to other systems of the organism, as well as what the other combinations of effects are in which the interaction effect can arise. The solution to these questions has great importance that goes beyond the framework of the interests of strictly space biology.

The dependence of the combined effect on the physiological state of the biological system at the moment of the influence that was noted above is important. This was demonstrated, not only on seeds exposed to the combined effect in the state of organic and induced rest. The two discussed forms of effect were revealed with the use of barley seeds of the type Moskovskiy 121 that were on the spacecraft "Zond-5" during its flight by the moon.

The seeds of the named type do not go into the state of organic rest. The physiological differences were induced by dissimilar conditions in which they were grown. The plants grown from seeds of the Moskovskiy reproduction (Gorki Leninskiye) and that produced experimental seeds were developed in one case under high mountain conditions (West Pamir, Khorog Mountain, 2320 m above sea level), and in another in Estonia (Kharku near Tallin). One season of growing under the indicated conditions drastically altered the radio sensitivity of the seeds. The Pamir reproduction was characterized, as compared to the original Moskovskiy, by increased radio-resistance, while the Estonian, on the contrary, by increased sensitivity (Nuzhdin, Pastushenko-Strelets, 1967, 1968).

This is seen well from the percentages given below of the aberrant cells in the seed rootlets collected from plants grown in the regions listed above and irradiated with γ-Cs^{137} in a dose of 10 Ci:

Gorki Leninskiye	Estonia	West Pamir	
19.4±1.2	41.3±1.20	11. 8±0.80	Experiment
2.6±0.30	2.3±0.40	4.1±0.60	Control

It is necessary to note that the changes that occurred in the radio-sensitivity of the cells do not affect the SFF influence. This is indicated by the results obtained in a cytological analysis of seed rootlets of Pamir and Estonian reproduction that were on the spacecraft "Zond-5." Despite the varying radio-sensitivity, in the nonirradiated seeds the SFF induced the same percentage of aberrant cells in the seed rootlets of the Pamir and Estonian reproduction. Different results were obtained after the combined effect of SFF and irradiation with γ-quanta in a dose of 10 Ci. In the Pamir reproduction the SFF effectiveness remained on the same level as in the nonirradiated variant. In the seeds of Estonian reproduction , it rose 4-5-fold. The numbers given below for the percentage of aberrant cells induced only by SFF (result of processing by Abbot's formula) confirm what has been said:

Seeds	Pamir reproduction, %	Estonian reproduction, %
Nonirradiated	2.2	2.0
Irradiated before flight	2.5	8.5
Irradiated after flight	2.5	10.4

Thus, with the combined effect of irradiation and SFF on the seeds with low radiosensitivity an adaptive effect of these influences occurred, while in the seeds that are characterized by high radiosensitivity, the effect of interaction appeared.

The response of the biological system to the combined effect of SFF+Z (by Z we mean irradiation, chemical mutagens and other, currently not detected factors) is not exhausted by the examples given above for the importance of the physiological state of this system. Probably, there is a complicated complex of interrelationships that determine the shape of the organism's response to the effect of SFF. The following additional example can serve what has been said.

Barley seeds were on the craft "Zond-6" in a state of induced rest, that before being sent into space were irradiated with γ-quanta of Cs^{137} in doses of 5 and 10 Ci. Except for the irradiation dose, the other conditions were the same. The findings differed significantly. In the cells of the primary seed rootlets that received a dose of 5 Ci, the additive effect of irradiation and SFF was established, while in the same seeds that were irradiated with the dose of 10 Ci, the effect of interaction was recorded; as a result, the percentage of aberrant cells induced by SFF doubled (Nuzhdin et al., 1970).

All that has been said makes it obvious that to explain the nature of these complex interrelationships of SFF with other effects and the state of the biological system that they affect, further studies are needed both under laboratory conditions, and in experiments associated with flights into space. The latter are especially important, since in experiments carried out under ground conditions, one of the important components is excluded that enters into the SFF complex, weightlessness.

In the series of studies that covers an investigation of the combined effect of irradiation and dynamic factors (vibration, G-forces) carried out under laboratory conditions on animals, a number of important data were obtained. It was shown that the dynamic factors can significantly alter the organism's reaction to irradiation. We stress, that in some experiments an increased resistance of the organism was observed, and in others, its great susceptibility. The directivity and degree of the modification depend on the nature and strength of the influencing factor, time and sequence of the effect of irradiation and the dynamic factors, the object and its condition, etc. (Demin, 1964; Luk'yanova, 1964; /344

Ananasenko, 1964; Davydov et al., 1965a, b; Arsen'yeva et al., 1965; Parfenov, 1965; Davydov, 1966; Zhukov-Verezhnikov et al., 1966; Zharov, et al., 1966; Dobrov et al., 1971a, b; Kononova, 1971). All of this indicates both the complex interaction of the dynamic and radiation factors, as well as the complex response reaction of the organism to their influence.

No less complicated interrelationships were revealed in the experiments in which, on the background of the complex effect on animals of dynamic factors and irradiation a study was made of the effect of radioprotectors. It was shown that under the influence of G-forces the sensitivity of the organism to pharmaceuticals is signficiantly altered. This is expressed in the increased sensitivity and distortion of the organism's reaction to the effect of the preparation (Belay et al., 1963, 1966, 1967).

By studying on animals exposed to G-forces, the effect of radioprotectors (cystamine, AET, 5-MOT, serotonin) administered in optimal radiodefense doses, it was shown that the indicated preparations reduce the animals' resistance to acceleration. The cause of the depressing effect of the protectors is perceived in their creation of oxygen deficiency in the tissues and the rapid consumption of the energy supplies. Similar phenomena are induced by the G-forces themselves. With the combined effect of G-forces and the protector, this effect is summed, which also results in a reduction in resistance (Davydov, et al., 1966; Davydov, 1971; Gaydamakin, et al., 1971). The effect of the radioprotectors on the background of G-forces can have a phase nature of change in the organism's reactivity to them, which depends on the amount of acceleration and the chemical structure of the employed radioprotector (Antipov et al., 1969; 1971).

In a number of studies (Davydov, 1971; Gaydamakin et al., 1971; Dobrov et al, 1971a, b) on animals an investigation was made of the complex effect of G-forces, irradiation and radioprotectors. The radioprotectors increase the resistance to G-forces in the first 2-5 days after irradiation of mice. The G-forces given a day before the irradiation, reduced the radiation damage to the bone marrow and spleen, and accelerated the process of restoring their structure. The G-forces applied before irradiation do not reduce the defense effect of the radioprotector.

The results obtained in the controllable laboratory conditions indicate the complex response reaction to complex effects of G-forces, vibration, irradiation and with the use of radioprotectors in varying sequence and combination. There is no single type of appearance of the effects induced by these factors. The combination of irradiation with dynamic factors intensifies or attenuates the degree of damage to animals, radioprotectors in combination with G-forces reduce the animals' resistance to them, but cannot increase it. This contradiction not only indicates the complexity of the processes leading to the reaction of the living system, but also indicates the insufficiency of the data that we have and the need for their further accumulation.

In light of what has been said, it is not unexpected that we obtained a noncoincidence of results on the effect of radioreceptors on the output of aberrant cells induced by SFF in embryonal seeds on the craft "Voskhod" and "Soyuz-9." On the craft "Voskhod" there were irradiated and nonirradiated barley seeds in a state of organic and induced rest, that upon return from space were moistened in water and a neutral solution of cysteine hydrochloride. The defense effect was manifest both in the irradiated and in the nonirradiated material of both seed categories. We stress that in the seeds in organic rest the defense effect is manifest only in variants 1 and 3, and was missing in variant 2, in which, as indicated above, only damages of the first class are realized (Nuzhdin, Dozortsova, 1967a, b).

This work has cited extensive material that was obtained during an investigation of seeds on the craft "Soyuz-9." Two radioprotectors were used, cysteine and AET, that provided clear protection, reducing the output of aberrant cells induced by γ-quanta. In no variant (see table 3) was the effect of protection from chromosomal damages induced by SFF revealed. What determined the differences in the effect of the radioprotectors in the two discussed experiments? The answer to this question, as to the question of whether the radioprotectors provide protection from the genetic damages induced by SFF will be given by further studies, and in particular, investigation of the material that was on the orbital station "Salyut." /345

The authors are grateful to L. Ye. Petrova for technical assistance in conducting this work.

Bibliography

Antipov, V. V.; Vasin, M. V.; Davydov, B. I. ; and Shashkov, V. S. Izv. AN SSSR, Ser. biol., 3 (1969), 434.

Antipov, V. V.; Vasin, M. V.; et al., Problemy kosmicheskoy biologii [Problems of Space Biology], XIV, Moscow, Nauka, 1971, 53.

Apanasenko, Z. I. in Vliyaniye ioniziruyuzhchikh izlucheniy i dinamicheskikh faktorov na funktsii tsentral'noy nervnoy sistem ["Effect of Ionizing Radiation and Dynamic Factors on Function of Central Nervous System"], Moscow, Nauka, 1964, p. 92.

Arsen'yeva, M. A.; Belyayeva, L. A.; and Golovkina, A. V. in Problemy kosmicheskoy biologii, IV, 1965, Moscow, Nauka, 373.

Belay, V. Ye.; Vasil'yev, P. V.; and Kolchin, S. P. Farmakologiya i toksikologiya, 5 (1963), 559.

Belay, V. Ye.; Vasil'yev, P. V.; and Glod, G. D. Mater. XVII kongressa Mezhdunar. Astronavticheskoy federatsii ["Materials of 17th Congress of International Astronautical Federeation"], Madrid, 1966.

Belay, V. Ye.; Vasil'yev, P. V.; Glod, G. D. and Bryuzgina, M. I. Kosmich. biol. i med., 4 (1967), 47.

Gaydamakin, N. A.; Petrukhin, V. G.; and Davydov, B. N. 1971 in Problemy kosmicheskoy biologii, XIV, Moscow, Nauka, 38.

Gaydamakin, N. A., in Problemy kosmicheskoy biologii VI, Moscow, Nauka, 1967, 355.

Gaydamakin, N. A.; Kul'kin, S. G.; Davydov, B. I.; and Shashkov, V. S. in Problemy kosmicheskoy biologii, XIV, Moscow, Nauka, 1971, 336.

Davydov, B. I.; Antipov, V. V.; Kononova, N. I.; and Saksonov, P. P. Kosmich. issledovaniya, 3 (5), 1965a, 789.

Davydov, B. I.; Antipov, V. V.; and Saksonov, P. P. Kosmich. issledovaniya, 3 (1), 1965b, 159.

Davydov, B. I. Dokl. AN SSSR, 168 (3), 1971, 691. in Problemy kosmicheskoy biologii, XIV, Moscow, Nauka, 1971, 251.

Davydov, B. I.: Antipov, V. V.; et al., Kosmich. issledovaniya, 4 (1966), 489.

Davydov, B. I.; and Gaydamakin, N. A. in Problemy kosmicheskoy biologii, XIV, Moscow, Nauka, 1971, 7.

Demin, Yu. S. in Vliyaniye ioniziruyushchikh izlucheniy i dinamicheskikh faktorov na funktsii tsentral'noy nervnoy sistemy , Moscow, Nauka, 1964.

Dobrov, N. N.; Kozlov, V. A.; Parshin, V. S.; and Saksonov, P. P. in Problemy kosmicheskoy biologii, XIV, Moscow, Nauka, 1971a, 271; in Problemy kosmicheskoy biologii, XIV, Moscow, Nauka, 1971b, 285.

Dobrov, N. N.; Kozlov, V. A.; Parshin, V. S.; and Yezenchuk, N. I. in Problemy kosmicheskoy biologii, XIV, Moscow, Nauka, 1971b, 288.

Dubinina, L. G.; and Chernikova, O. P. Kosmich. issledovaniya, 8 (1970), 156.

Zharov, Ye. I.; Khrustalev, S. A.; et al., Izv. AN SSSR. Ser. biol., 2 (1967), 290.

Zhukov-Verezhnikov, N. N.; Mayskiy, I. N.; et al., in Problemy kosmicheskoy meditsiny ["Problems of Space Medicine"], Moscow, 1966, 172.

Konnova, N. I. in Problemy kosmicheskoy biologii, XIV, Moscow, Nauka, 1971, 292.

Luk'yanova, L. D. in Aviatsionnaya i kosmicheskaya meditsina ["Aviation and Space Medicine"], Moscow, 1964, 346.

Nuzhdin, N. I. Izv. AN SSSR, Ser. biol., No. 6 (1970), 863.

Nuzhdin, N. I.; and Pastuchenko-Strelets, N. A. in Eksperimental'nyye raboty po vliyaniye ioniziruyushchikh izlucheniy na organizm ["Experimental Works on the Effect of Ionizing Radiation on the Organism"], Moscow, Nauka, 1967, p. 37; Dokl. AN SSSR, 180 (1967), 993.

Nuzhdin, N. I.; Dozortseva, R. L.; Pastuchenko-Strelets, N. A.; and Samokhvalova, N. S. Izv. AN SSSR, Ser. Biol., No. 4 (1965), 576.

Nuzhdin, N. I.; and Dozortseva, R. L. in Eksperimental'nyye raboty po vliyaniye ioniziruyushchikh izlucheniy na organizm, Moscow, Nauka, 1967a, p. 3.; Zh. obshch. biol., 28 (1967b), 397.

Nuzhdin, N. I.; Dozortseva, R. L.; Pastuchenko-Strelets, N. A.; et al., Zh. obshch. biol., 31 (1970), p. 72.

Parfenov, G. P. Kosmich. issledovaniya, 3 (4), 1965, 643.