EFFECTS Of FAST NEUTRONS UPON FOREST TREE SEEDS, II. : RELATIONS BETWEEN THE INTESNITIES OF IRRADIATIONS AND THE GERMINATIONS OF SEEDS, THE GROWTH OF SEEDLINGS OF PINUS DENSIFLORA

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EFFECTS Of FAST NEUTRONS UPON FOREST TREE SEEDS, II. RELATIONS BETWEEN THE INTESNITIES OF IRRADIATIONS AND THE GERMINATIONS OF SEEDS, THE GROWTH OF SEEDLINGS OF *PINUS DENSIFLORA*

Keiji Satō and Yoshio Nishina

A number of experiments with neutron rays have been carried out on both animals and plants and certain biological effects have already been reported. But the effect of neutron rays on the forest tree seeds has not so far been analysed in detail. We ourselves have observed in the cases of some forest plantspecies, *Cryptomeria japonica, Larix Kaempferi, Chamaecyparis obtusa, Pinus densiflora, Pinus Thunbergii, Cinnamomum Camphora, Acacia decurrens, Gleditsia japonica, Rhus succedania* and *Rhus verniciflua* that the neutron irradiations produce abnormalities not only in germination rates, growth of seedlings but also in external morphological features (Nishina and Satō 1943). But in the first paper of this series a preliminary description has been given. In the present paper the detailed results of the repeated investigations made on the relations between the doses of irradiations and the germinations of seeds, the growth of seedlings of *Pinus densiflora* will be described. The work has been carried out in 1943.

Materials and methods

Be+D radiations produced by bombarding a berilium target with 2.8-3 MeV. deutrons from the cyclotron installed in the Institute of Physical and Chemical Research, were irradiated upon the three sets of the seed, viz., the dry seeds, the soaked seeds which have been immersed in tap water for 1 day and the soaked ones for 3 days. The seeds were placed in a wooden box which was inserted in the irradiation chamber of the cyclotron mentioned above, and were exposed for 5, 10, 15, 30, 60, and 120 min. to neutron rays respectively. The seeds were also classified into three groups, weak (A), medium (B), and strong (C) treatment, according to their distance from the target, namely 10, 7 and 3 cm. respectively. The intensity of the neutron rays was estimated by reference to the radioactivity induced in a thin sheet of red phosphorus placed in front of the samples and was expressed in an arbitrary units (cf. Nishina, Sinoto and Sato 1940 a, b; Nakaidumi, Kogure and Murati 1941; Nishina and Satō 1943).

After being irradiated by neutron rays, 200 grains were taken from each

of these treated seeds and were sown in soil in pots next morning, May 22, 1943. But in the case of dry seeds, the treated samples of each classes were divided into two parts equally 100, the one part was placed in Petri dishes, and the other was sown in pots as usual manner June 12, 1943. For control, non-irradiated seeds of equal number were used.

Experimental results

Days required to start germination, germinative energy (percentage germination in 7 days followed the start of germination), and percentage germination in 60 days were compared with each other between the plots, the data of which were summarized in Table 1.

Table 1. Comparison by Germination of Seeds among the Doses of Irradiations.

Dose of irradiation	Days required to start germination				Germinative energy* %				Percentage germinaton in 60 days %			
	Dry seeds sown in		Soaked seeds immersed in water for		Dry seeds sown in		Soaked seeds immersed in water for		Dry seeds sown in		Soaked seeds immersed in water for	
	Petri dish	pot	1 day	3 days	Petri dish	Pot	1 day	3 days	Petri dish	Pot	1 day	3 days
Control	5	7	6	6	51	57	90	81	99	91	98	99
A- 5 min.	5	7	7	6	61	46	83	44**	94	98	99	61**
A- 10 〃	5	9	8	8	54	48	79	87	94	95	99	95
A- 15 〃	4	9	8	8	59	42	83	84	97	93	96	94
A- 30 〃	5	8	9	7	46	40	79	71	97	95	95	96
A- 60 〃	5	11	10	8	45	62	78	75	98	99	95	90
A-120 〃	6	9	10	11	41	31	43	53	87	90	91	78
B- 5 〃	5	7	8	6	50	31	77	65	92	87	96	97
B- 10 〃	5	10	8	9	40	47	75	84	98	92	92	93
B- 15 〃	5	8	9	9	53	31	77	79	91	95	94	92
B- 30 〃	5	8	11	9	37	47	73	62	88	97	92	91
B- 60 〃	5	10	12	10	40	42	26	21	90	93	60	72
B-120 〃	7	12	14	12	42	30	7	3	95	88	13	9
C- 5 〃	6	8	8	8	46	53	83	85	94	100	90	93
C- 10 〃	5	8	8	9	41	45	71	85	96	92	95	90
C- 15 〃	4	9	10	10	27	50	76	82	94	95	86	95
C- 30 〃	6	9	11	9	34	32	30	54	98	89	68	81
C- 60 〃	7	12	12	12	24	20	4	6	86	77	7	18
C-120 〃	9	16	20		4	5	1	0	48	28	1	0

Weak, medium and strong treatments of each exposure to neutrons are indicated as A, B and C respectively.

* Percentage germination in 7 days followed the start of germination.

** Damage done by insects was observed.

Data in Table 1 indicate that all the treated seeds germinate, in every cases of weak, medium and strong treatments, as a rule, more slowly as the duration of exposure longer, and that the germination energy becomes lower, as the intensity of irradiation stronger, as the duration of exposure longer. It is to be noticed that, in general, the germination percentage decreases in proportion with the irradiation intensity or the duration of exposure increases (Figs. 1-3), however, the germinative capacity of seeds can be increased by exposure to certain doses of neutron irradiations, such as A-5, A-10, A-15, A-30, A-60, B-10, B-15, B-30, B-60, C-5, C-10, C-15 in the dry seeds sown in pots; A-10, A-15 in the soaked seeds immersed in water for 1 day.

Results obtained by comparing the survival rates and the mean height growth of the seedlings with each plots are shown in Table 2.

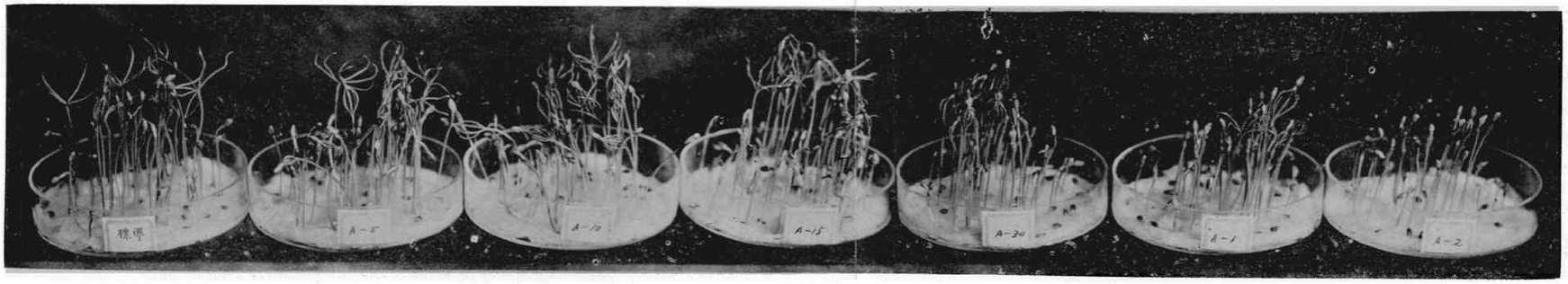
Table 2. Comparison by Growth of Seedlings among the Doses of Irradiaions.

Dose of irradiation	Survival rate* (Nov. 10, 1943)			Mean height growth (Nov. 10, 1943)		
	Dry seeds sown in Pot %	Soaked seeds immersed in water for		Dry seeds sown in Pot cm.	Soaked seeds immersed in water for	
		1 day %	3 days %		1 day cm:	3 days cm.
Control	83.5	100.0	93.4	3.1	5.2	4.5
A- 5 min.	78.6	99.0	89.3	3.5	5.1	4.5
A- 10 〃	84.2	96.4	99.5	3.4	4.9	4.7
A- 15 〃	79.6	97.9	94.1	3.5	4.9	4.5
A- 30 〃	55.8	102.6	88.5	3.6	4.5	4.3
A- 60 〃	76.8	78.9	86.1	3.4	3.9	3.8
A-120 〃	74.4	41.2	39.4	3.1	3.2	3.2
B- 5 〃	77.0	101.0	87.1	3.7	4.4	4.5
B- 10 〃	93.5	103.2	73.1	3.3	4.2	4.5
B- 15 〃	85.3	96.8	94.6	3.5	3.9	4.2
B- 30 〃	90.7	56.5	82.4	3.6	3.1	3.7
B- 60 〃	84.9	3.3	15.3	3.1	1.8	2.8
B-120 〃	12.5	0.0	0.0	2.4	—	—
C- 5 〃	96.0	105.6	98.4	3.6	4.3	4.2
C- 10 〃	79.3	93.1	57.5	3.9	3.7	4.1
C- 15 〃	91.6	84.2	82.5	3.5	3.5	3.7
C- 30 〃	68.5	14.0	27.3	3.3	2.3	3.3
C- 60 〃	19.5	0.0	0.0	2.3	—	—
C-120 〃	0.0	0.0	0.0	—	—	—

Weak, medium and strong treatments of exposure to neutrons are indicated as A, B and C respectively.

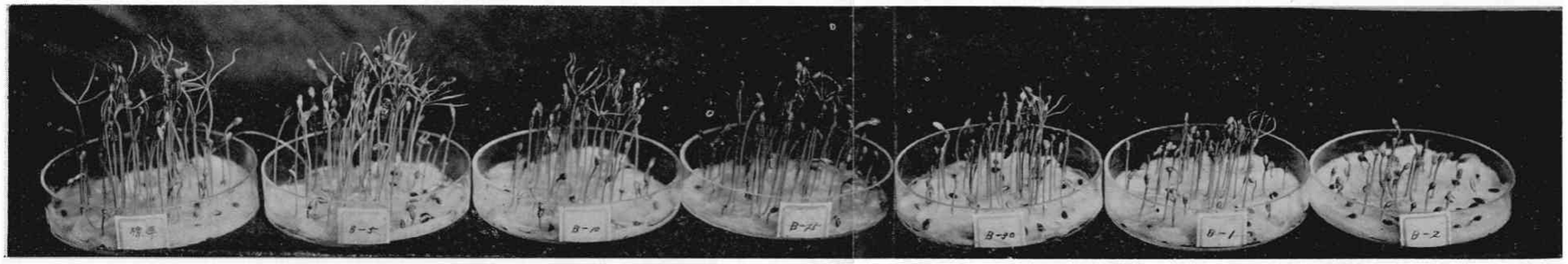
* survival rate = $\frac{\text{The present number of seedlings Nov. 10th}}{\text{Total number of germinated seeds in 60 days}}$

Table 2 clearly shows that, concerning to the dry seeds plots, no difference



a b c d e f g

Fig. 1. Comparison by germination of dry seeds, which have been exposed for 5, 10, 15, 30, 60 and 120 minutes to weak (A) neutron rays respectively, planted in Petri dish.
a, control (non-exposed), b, A-5 min., c, A-10 min., d, A-15 min., e, A-30 min., f, A-60 min., g, A-120 minutes.



a b c d e f g

Fig. 2. Comparison by germination of dry seeds, which have been exposed for 5, 10, 15, 30, 60 and 120 minutes to medium (B) neutron rays respectively planted in Petri dish.
a, control (non-exposed), b, B-5 min., c. B-10 min., d. B-15 min., e, B-30 min., f, B-60 min., g, B-120 minutes.

a b c d e f g

Fig. 3. Comparison bry germination of dy seeds, which have been exposed for 5, 10, 15, 30, 60 and 120 minutes to strong (C) neutron rays respectively, planted in Petri dish.
a, control (non-exposed), b, C-5 min., C-10 min., d, C-15 min., e, C-30 min., f, C-60 min., g, C-120 minutes.

in survival rates is found between the various doses ofirradiations except that the doses of B-120, C-60 and C-120, but remarkable differences are seen in them among the soaked seeds plots.

It is of particular interest to note that the survival rates of seedlings from the soaked seeds irradiated to neutron rays at certain doses (for example: A-30, B-5, B-10 and C-5 treatments in the soaked seeds for 1 day; A-10, A-15, B-15 and C-5 treatments in the soaked seeds for 3 days) are higher than the control. It is also to be pointed out that with the dose of irradiations becomes higher, exceedingly the limited point mentioned above, the survival rate will be decrease rapidly, results in zero (at the doses of B-120, C-60 and C-120).

Comparing the growth of seedlings among the various doses of irradiations, the seeds treated at certain intensities such as A-5, A-10, A-15, A-30, A-60, B-5, B-10, B-15, B-30, B-60, C-5, C-10, C-15, C-30 in the dry seeds; A-10 in the soaked ones for 3 days, they are larger in height than the control. The doses of irradiations become larger exceeding the limits, as a rule, the growth of seedlings will be decrease rapidiy.

Summary

1. Effects of fast neutrons upon the seeds of *Pinus densiflora* appeared not only in the germinative capacity, but also in the survival rate and the growth of the seedling.

2. By exposing seeds to irradiation of neutron rays, an appreciable retardation has been noticed in the germination of them.

3. The percentages of germinations, the survival rates were higher, and the growth of seedlings were found to be better in the classes exposed to the neutron rays at certain doses than in the control.

4. Exceeding the limits, the percentages of germinations, the survival rates and the growth of seedlings were inverse proportional to the doses of radiations. The survival rates results in zero when the intensities of irradiations being medium for 120 min. (B-120), strong treatment for 60 min. (C-60) and over (intensity, 600 arbitrary units and over).

5. The susceptibility of the pine seed to neutron radiations is higher in the soaked one immersed in tap water for 1 or 3 days, than in the dry.

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