producing odd shapes (Figs. 17 and 18). In necked crystals, the "necks" seem to be weaker than the other surfaces of synneusis relation, as the initial attachment of the grains on (001) is less stable than those of the parallel synneusis on (100) or twin orientations. The surfaces of parallel synneusis with attachment on (111) face are likewise weak mechanically. Paucity of the necked crystals and relatively common occurrence of odd-shaped zircon grains in the placers suggest that they have suffered mechanical breakage in the high energy beach environment.

In view of the undoubted igneous origin of synneusis, recognition of the various types of zircon in synneusis relation is of much value in problems of provenance, parentage, and petrogenesis.

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EFFECTS OF SEED TREATMENT WITH ^{60}CO GAMMA RAYS AND MICRONUTRIENTS ON GERMINATION AND GROWTH OF CORN SEEDLINGS

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ABSTRACT

Gamma irradiation and soaking in solutions of some micronutrient elements, as presowing treatments of corn seeds, towards improving the germination of seeds, and increasing the growth of seedlings were investigated. The seeds were exposed to 12 irradiation doses of gamma rays ranging from 250–8000 R. It was found that stimulatory effects on the germination percentage and capacity of seeds as well as the height and the dry weight of seedlings were exerted only by the low irradiation doses from 500–1000 R. Soaking cornseeds, before sowing, in any of the 4 concentrations ranging from 250–1000 ppm of molybdenum, manganese and zinc indicated that molybdenum treatment increased plant height and the dry weight of seedlings; 500 ppm molybdenum gave the best effect. Irradiation of 500 ppm molybdenum soaked seeds with low doses of gamma rays stimulated the germination process and early growth of seedlings, with the 500 R dose being most effective.

INTRODUCTION

PRESOWING treatments of seeds with gamma rays was reported to enhance germination of seeds and to increase the growth of the seedlings (Woodstock and Justic, 1967 and Singh, 1970). However, such stimulatory effects were found to be induced by certain exposure doses which depends upon plant species (Kuzin, 1963).

Soaking of seeds prior to sowing in solutions containing certain micronutrients was also reported to enhance the germination of seeds and the growth of seedlings (Shkolnik, 1963 and Pavel and Zakova, 1967). Only a few reports were found dealing with the plant responses to the combined seed treatment with gamma rays and micronutrients (Sidarskii, 1963 and Guseva, 1967).

The aim of this work was to investigate the effects of presowing seed treatment, with some trace elements and gamma rays on grmination of corn seeds and growth of seedlings.

Material and Methods

Seed Treatments.—Uniform corn seeds (*Zea mays* cv. Giza hybrid 67) were soaked without aeration, for a 24-hour period in either distilled water or in a solution of ammonium molybdate, zinc sulphate or manganese sulphate. Following the soaking, they were washed thoroughly with distilled water, air-dried and then irradiated, in air, in a ^{60}Co-gamma cell 220 unit (Atomic Energy Commission, Ottawa, Canada) at a constant exposure rate of 100R/sec. The temperature during irradiation ranged between 28° and 34° C. Thus, there were two experiments, the first one was concerned with the effect of separate seed treatment with either gamma rays or micronutrients. Whereas, the second experiment was concerned with the combination treatments which were limited to 500, 1000 and 2000 R with 500 ppm Mo only.

Cultivation of Plants.—Treated seeds were immediately planted in sand, at a rate of 10 per each betumin-coated eartheaware pots No. 25. A half strength complete nutrient solution of Hoagland and Arnon (1941) was utilized for duration of the experimental Pots were maintained under the prevailing climatic conditions at the Experimental Station of the National Research Centre at Dokki, Giza. Each treatment was replicated six times, and each replicate as represented by one pot.

Germination Studies.—Germination measurements were carried out on seeds, 200 per treatment, allowed to germinate on moistened cotton wool in 25 cm. glass evaporating dishes. Each treatment had 4 replicates. Germinated seeds (with emergent plumules) were counted daily and the results are reported (Table I) as the following values; the germination percentage after 5 and 14 days, and the germination rate index which was calculated from the following formula.

$$\frac{a + (a + b) + (a + b + c) + \cdots}{n(a + b + c + \cdots)}$$

where a, b and c are counts of seeds germinated after the first, second and third day respectively, and n is the number of counts.

Growth Measurements.—Stem height and dry weight of shoots and roots were determined for 14-days old seedlings. Samples were dried at 105° C to a constant weight and cooled down in a vacuum desiccator.

Results

Determination of the Effective Range of Radiation

Results of exposing seeds, soaked in distilled water, to any of the 12 doses ranging from 250 to 8000 R are shown in Table I. In general, germination was stimulated by 500 and 750 R only; other doses were ineffective or inhibitory. There was no significant difference in the germination rate index due to different exposure doses.

Table I

Effects of irradiation with various exposure doses on germination of corn seeds

Sl. No.	Irradiation dose, R	Germination percentage After 5 days	After 14 days	Germination rate index
1.	0	90·0	93·3	0·48
2.	250	93·3	93·3	0·49
3.	500	96·6	100·0	0·49
4.	750	93·3	100·0	0·49
5.	1000	93·6	96·6	0·49
6.	1500	93·3	93·3	0·49
7.	2000	93·3	96·6	0·46
8.	3000	80·0	93·6	0·46
9.	4000	80·0	90·0	0·45
10.	5000	60·0	67·0	0·45
11.	6000	50·0	66·0	0·48
12.	7000	50·0	50·0	0·45
13.	8000	36·6	36·6	0·45
L.S.D., at 5%		3·58	3·76	N.S.

Similar but not identical results were obtained for the stem height and dry weight of 14 days old seedlings grown from the irradiated seeds (Table II). Again here the low irradiation doses, particularly the 500, 750 and 1000 R doses, were effective in stimulating

TABLE II

Average values of height, and dry weight of corn seedlings developed from seeds irradiated with various exposure doses

Sl. No.	Irradiation dose, R	Seedling height, cm	Dry weight, g/100 seedlings			Shoot/root ratio (On dry wt. basis)
			Shoot	Root	Whole seedling	
1.	0	26·30	1·81	3·16	5·97	0·57
2.	250	25·80	1·92	3·04	4·96	0 63
3.	500	33·90	2·75	4·89	7·64	0 56
4.	750	33·56	2·58	4·67	7·25	0 55
5.	1000	39·16	2·82	4·56	7·38	0 61
6.	1500	29·40	2·21	4·61	6·82	0·48
7.	2000	24·56	2·11	3·85	5·96	0 55
8.	3000	30·46	2·06	3·58	5·64	0·58
9.	4000	27·16	2·10	3·26	5·36	0 64
10.	5000	26·56	2·32	2·89	5·21	0·80
11.	6000	26·86	1·09	2·78	4·67	0·68
12.	7000	26·40	1·55	2·52	4·07	0·62
13.	8000	23·05	1·58	1·92	3·50	0·82
L.S.D. at 5%		3·22	0·62	1·28	2·06	..

growth. As revealed by calculating the shoot/root ratio, the irradiation effect was equally well on both parts of the developing seedlings.

Determination of the Effective Type and Concentration of Micronutrients:

Results of soaking seeds in any of 4 concentrations, *viz*., 250, 500, 750 and 1000 ppm of solutions of each of the microelements are presented in Table III. All treatments generally resulted in a decreased growth measured as length of seedlings except the 500 ppm molybdenum treatment in which case an increase in height as well as in the dry weight of whole seedlings was evident. It is of interest that the dry weight increase resided totally in the root organ. The increase in dry weight or at least absence of inhibition of the roots was, however, a constant feature of all treatments with the three miroelements. (Table III).

Combined Effect of Irradiation and Molybdenum-Soaking

Results of irradiating molybdenum soaked seeds with any of three doses, namely, 500, 1000, and 2000 R on germination and growth of 14 days old seedlings are shown in Tables IV and V respectively. These results substantiated the above-mentioned ones in as much as irradiation increased the germination percentage of treated seeds with the 500 R dose being more effective. Molybdenum soaking was rather slightly inhibiting in this regard.

As shown in Table V irradiation with 500 or 1000 R but not with 2000 R tended generally to increase the seedling height. This stimulatory effect was more

TABLE III

Average values of height, and dry weight of corn seedlings developed foom the seeds treated with various concentrations of micronutrient elements

Type and concentration of element, ppm		Seedling height, cm.	Dry weight, g/100 seedlings			Shoot/Root ratio (On dry wt. basis)
			Shoot	Root	Whole seedling	
Water		26·30	1·81	3·16	4·97	0 57
Mo	250	25·27	1·81	4·62	6·43	0·39
	500	29·73	1·99	5 05	7 04	0·39
	750	23·75	1·46	4·62	6 08	0·32
	1000	23·91	1·09	4·89	5·98	0·22
Mn	250	25·52	1·08	3·10	4·18	0 34
	500	20·22	1·30	3·85	5·15	0·34
	750	20 85	1·36	3·45	4·81	0·39
	1000	20·67	1·28	3·60	4·88	0·36
Zn	250	21·18	1·26	3·47	4·73	0·36
	500	23·60	1·28	3·41	4·69	0·37
	750	22·23	1·18	3·28	4·46	0 36
	1000	23·19	1·03	3·77	4·80	0 27
L.S.D. at 5%		2·45	N.S.	1·26	1·42	..

marked in the seedlings developed from irradiated, molybdenum soaked seeds. Molybdenum soaking in itself, increased the seedling height more markedly than did any of the irradiation treatments of water soaked seeds. The effect of irradiating water or molybdenum soaked seeds on the dry weight of the seedlings shoots paralled more or less its effects on their height. Although the dry weight of root of seedlings grown from water soaked seeds was affected in much the same way as did their shoots, that of seedlings developed from molybdenum soaked seeds responded rather differently. In the latter case an inverse relationship existed between the exposure dose and the dry weight of the roots. The molybdenum treatment, on its own, induced an increase of a slightly more than 65% in the dry weight of roots, but had no effect whatsoever on the shoot's dry weight.

Of all experimental treatments, irradiating molybdenum soaked seeds with 500 R was most effective in improving the growth of the seedlings.

DISCUSSION

The enhancement of seed germination process by gamma irradiation may be atrributed to its known effect on activation of respiratory enzymes particularly those associated with mitochondria (Woodstock and Combs, 1965 and Singh, 1970). This would lead to a correspondingly increased rate of conversion of respiratory substrates to smaller molecules or building blocks required for synthesis of new cell constituents (Toole *et al.*, 1956). Moreover, the irradiation-increased enzyme activity may lead to an increased formation of indole auxins or of their precursors, thus, stimulating subsequent plant growth (Kutacek *et al.*, 1966). Gamma irradiation-induced stimu-

TABLE IV

Effects of irradiation and/or molybdenum soaking on gemination of corn seeds

Irradiation dose, R	Germination percentage After 5 days		Germination percentage After 14 days		Germination rate index	
	Water	Mo	Water	Mo	Water	Mo
0	90·0	89 0	93·3	99·0	0·48	0·51
500	96·6	91·0	100 0	100·0	0 49	0·52
1000	93·6	99·0	96·6	100·0	0·49	0·52
2000	93·3	90·0	96·6	88 3	0·46	0·52

L.S.D. at 5%	G. percentage	G. capacity	G.R. index
For irradiation	1·03	0 51	N.S.
For soaking	N.S.	0·99	N.S.
For interaction	N.S.	1·014	N.S.

lation of plant growth has been reported for various plant species including corn, wheat, radish, sugar beet, etc. (Vlasuk *et al.*, 1963; Kuzin, 1963; Sparrow, 1966 and Woodstock and Justic, 1967).

In a more or less like manner, the increased molybdenum content of seeds, subsequent to their soaking, is supposed to act through enhancement of the nitrate reductase (Peive and Zhiznevskaya, 1961) and amylase (Pavel and Zakova, 1967) enzyme systems. This would lead to enhancement of both nitrogen and carbohydrate metabolism and, as a consequence, to accumulation of dry matter particularly in the roots where nitrate is absorbed.

Irradiation of Mo-soaked seeds with 500 R gamma rays gave the most favourable effect on seed germination and the growth of the developed seedlings, which may indicate that these two factors had an additive effect.

The increased rate of dry matter accumulation in seedings may be taken as a good indication for acceleration of subsequent plant growth and may provide a basis for predicting the anticipated yield.

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TABLE V

Effects of irradiation and/or soaking in ammonium molybdate on growth of the developing seedlings as represented by the height and dry weight

Irradiation dose, R	Seedling height cm		Dry weight, g/100 seedlings Shoot		Root		Whole seedling		Shoot/Root ratio (on dry wt. basis)	
	Water	Mo	Water	Mo	Water	Mo	Water	Mo	Water	Mo
0	26·3	38·0	1·81	1·82	3·16	5·14	4·97	6·96	0 57	0 35
500	33·9	43·5	2·75	3·90	4·89	4·69	7·67	8·59	0 56	0·78
1000	32·2	44·1	2·82	3·71	4·56	3·83	7·38	7·54	0·61	0 97
2000	27·2	39·0	2·11	2·25	3·85	3·92	5·96	6·17	0 55	0 58

L.S.D. at 5% :	Plant heeght	Shoot	Root	Whole plant
For irradiation	1·30	0 120	0 035	0 54
For soaking	2·59	0 228	0 165	0·38
For interaction	N.S.	N.S.	0·168	N.S.

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