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Growth of Radish (*Raphanus sativus*) Seedlings In Magnetic Fields

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Abstract: Radish seedlings were grown in asymmetric magnetic fields. The number of seeds germinated and the dry weight of the plants were the two criteria by which possible effects were examined. Two experiments were done; in the first the plants were grown for an average of 7·7 days and in the second for 14·1 days. A statistical analysis of the results failed to reveal any significant difference between control plants grown in dummy magnets and those subjected to the magnetic influence.

Biological effects have been ascribed to magnetism since this force has been known. For many years reports have been made purporting to show that magnetic fields effected a wide variety of living processes. The large literature on this subject has been cataloged by ALEXANDER (1962), DAVIS, PAPKAJOHN, PLAVNIEKS (1962), BARNOTHY (1960), BARNOTHY MADELEIN (1964). The most complete and recent review of this field is to be found in the book edited by BARNOTHY (1960). R. P. MERICLE et al. (1964) have summarized the work of others on the alleged effects of static magnetic fields on plant growth and given the results of their own work. These authors point out the controversial nature of the results recorded.

Some workers have claimed an acceleration effect on seed germination while others have reported complete inhibition. Increased rate of growth of shoots and roots has been recorded as well as retardation of growth. WHISH (1963) has presented evidence that magnetic fields cause curvatures of cress roots and oat coleoptiles down magnetic gradients and he refers to the effect as "magnetotropism". PITTMAN (1963) reported that the rate of germination and growth of two varieties of wheat was greater when the seeds were exposed dry before germination for 48 hours to magnetic fields. The seeds were then germinated on moist blotting paper. It was stated that the orientation of the previously magnetically exposed seeds with respect to the earth's magnetic field influenced growth. Studies on lower plants, bacteria, yeasts and molds, have given conflicting results.

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The experiments herein reported were designed to show the presence or absence of magnetic effects on germination and growth of radish seedlings. In an attempt to obviate any seasonal effect the experiments extended continually over a period of nearly 18 months.

Although the results of these studies are inconclusive, it is felt that their publication may be worthwhile for the following three reasons. In the first place, if there are any magnetic effects at the field strength used, upon the growth of the radish seedlings, they must be more subtle than can be detected by the number of seeds germinating and the net weight of the dry plants. Other workers in this field have sought to discover magnetic effects by measurement not more delicate than that used in these experiments and their reported findings vary. Secondly these experiments extended over a period of approximately 18 months, far beyond the period of observation reported by others working in this field, so seasonal variations to magnetic influences, if present, should have been seen. Finally the wide variation in results from group to group indicates that all variables, especially light, temperature, humidity, etc., should be as uniform as possible.

Material and Methods

Radish seeds (*Raphanus sativus*), purchased in a seed store, were used. The magnetic field was furnished by permanent magnets weighing approximately 8·3 kg. each and having a field strength of 4500 ($\pm$50) Gauss between the special pole pieces. Control seedlings were grown between the pole pieces of simulated magnets made of wood. The experimental set-up is shown in Fig. 1. The two wedge shaped steel poles were separated by a gap of 4 mm. Fig. 2 shows a magnet, a wooden "dummy", and the growing seedlings. The magnets and simulated magnets were placed on window sills, in one room which faced south. There was a building 2·44 meters (8 feet) away from the windows, gray in color, extending well beyond the windows from east to west. This arrangement gave evenly distributed diffuse light to each group of plants. To further insure uniform light, each pair (magnet and corresponding dummy control) was shifted to a different window location once a day. Each magnet and dummy was also changed from side to side once a day, and rotated 180 degrees.

Waterproof plastic was pressed between the poles to make a channel approximately 5 mm deep. Into this trough four layers of wer paper toweling were pressed. The ends of the toweling, extending from each end of the magnet poles, were submerged in equal size bottles filled with tap water which was replenished daily. The seed trough between the magnet poles was thus kept moist by the water drawn from these bottles.

Ten to twelve seeds were placed in each trough and spaced as evenly as possible by observation. The seeds were covered with a thin sheet of transparent plastic to insure high humidity until germination took place. At the end of each experiment the entire plants (stems, leaves, and roots) were carefully removed from the apparatus, and with the paper towel "seed bed"

Table 1

Summary of experiment I

Experiment number	Dates of experiment	Days of growth	Number of plants		Number of germinated		Number not germinated		Mean weight of plants in each group	
			Exp.	Cont.	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.
1	8/18/61—8/25/61	7	12	12	7	10	5	2	·0105	·0090
2	8/25/61—9/1/61	7	12	12	12	12	0	0	·0090	·0100
3	9/1/61—9/8/61	8	12	12	11	10	1	2	·0090	·0089
4	9/8/61—9/15/61	7	12	12	10	9	2	3	·0129	·0110
5	9/15/61—9/22/61	7	12	12	9	9	3	3	·0176	·0172
6	11/3/61—11/10/61	7	12	12	12	12	0	0	·0160	·0115
7	11/10/61—11/17/61	7	12	12	12	12	0	0	·0150	·0100
8	12/18/61—12/26/61	8	11	11	10	10	1	1	·0086	·0083
9	12/26/61—1/2/62	7	11	11	9	10	2	1	·0088	·0064
10	1/2/62—1/11/62	9	11	11	10	9	1	2	·0098	·0100
11	1/11/62—1/19/62	8	11	11	10	11	1	0	·0083	·0080
12	1/19/62—1/27/62	8	11	11	9	8	2	3	·0091	·0100
13	1/27/62—2/4/62	8	11	11	10	11	1	0	·0086	·0094
14	2/4/62—2/12/62	8	11	11	11	11	0	0	·0094	·0095
15	4/6/62—4/14/62	8	11	11	10	11	1	0	·0040	·0023
16	4/14/62—4/22/62	8	11	11	11	11	0	0	·0228	·0264
17	4/22/62—4/30/62	8	11	11	11	10	0	1	·0295	·0295
18	4/30/62—5/8/62	8	11	11	11	11	0	0	·0243	·0248
19	5/8/62—5/16/62	8	11	11	11	11	0	0	·0260	·0300
20	5/16/62—5/24/62	8	11	11	11	11	0	0	·0190	·0210
Totals or means	20 experiments	7.7	227	227	207	209	20	19	·2782	·2732
									·0139	·0136
									Mean wt.	Per plant

Table 2
Summary of experiment II

Experiment number	Dates of experiment	Days of growth	Number of plants		Number of germinated		Number not germinated		Mean weight of plants in each group	
			Exp.	Cont.	Exp.	Cont.	Exp.	Cont.	Exp.	Cont.
1	6/28/62 – 7/12/62	14	44	44	44	44	0	0	·0240	·0214
2	8/3/62 – 8/16/62	13	33	44	25	42	8	2	·0364	·0269
3	8/16/62 – 8/30/62	14	44	44	40	42	4	2	·0372	·0366
4	8/30/62 – 9/13/62	14	22	33	22	25	0	8	·0390	·0445
5	9/13/62 – 9/28/62	15	33	44	29	36	4	8	·0349	·0358
6	9/28/62 – 10/12/62	14	22	44	20	36	2	8	·0350	·0325
7	10/12/62 – 10/26/62	14	44	44	36	36	8	8	·0475	·0362
8	11/26/62 – 12/10/62	15	44	44	40	40	4	4	·0497	·0490
9	1/2/63 – 1/16/63	14	44	44	43	42	1	2	·0456	·0433
10	1/16/63 – 1/30/63	14	44	44	42	41	2	3	·0260	·0265
11	1/30/63 – 2/13/63	15	44	44	34	42	10	2	·0385	·0372
Totals or means	11 experiments	14.1	428	473	375	426	43	47	·4138	·3899
									·0376	·0354
									Mean wt. per plant	Mean wt. per plant

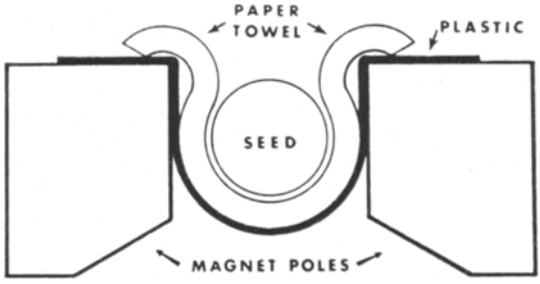

Fig. 1. Diagram showing the relation of the seed, paper towel, plastic, and the magnetic poles.

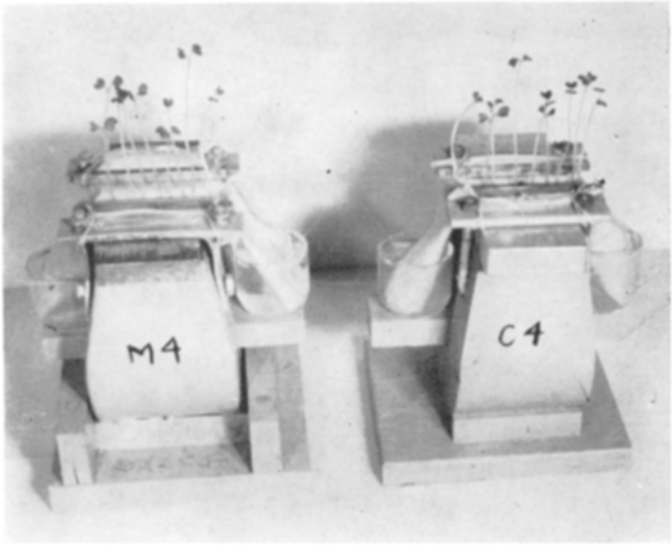

Fig. 2. Photograph of magnet (M-4) and the simulated magnet (C-4) with growing radish seedlings.

were dried in an oven for 24 hours at a temperature of 40° C. The plants were then removed from the toweling, put into tarred weighing bottles, placed in a desiccator 24 hours and weighed.

Two series of experiments were done. The first consisted of 20 trials. Only one magnet and one simulated magnet was available lin this group extending over ten months from August 1961 to May 1962. Eleven to 12 seeds were planted in the magnet and dummy. The plants were harvested after seven to nine days growth (average 7·7) and the number of non-germinated seeds noted, these were not weighed. In the second group of experiments four magnets and four dummies were used. In each separate experiment from 22 to 44 seeds were planted in the magnets and from 33 to 44 in the dummies. The lower number sometimes planted in the magnets is accounted for by one or two of the magnets being occasionally used for other experiments. This series of experiments began June 28, 1962 and terminated February 13, 1963. Each determination in this series extended from 13 to 15 days (average 14·1 days). Except for the number of magnets and dummies, numbers of seeds planted and duration of each growth period the two experiments were identical.

Results and Conclusions

In Tables 1 and 2 is tabulated the data for the two experiments. Values of χ^2 for the germination data was calculated; for experiment 1, χ^2 was ·033 and for experiment II, ·030. These small values (P = 0·85) provide no evidence that treatment by the magnets effected germination.

The mean weights were evaluated by the method of the paired comparison t-statistic. The relevant summary statistics are seen in Table 3.

The fascinating possibility of biomagnetic effects has not been demonstrated in the system and by the parameters measured in these experiments. This does not preclude the possibility of there being effects too subtle to be

Table 3
Results of statistical analysis

	Mean		Standard deviation	Std. error of mean	t*	P
Experiment I	Expt'l.	·0139	·007	·002		
	Control	·0137	·008	·002		
	Difference	·0002	·002	·0004	·50	·62
Experiment II	Expt'l.	·0376	·008	·002		
	Control	·0354	·008	·003		
	Difference	·0022	·005	·001	1·54	·16

* Degrees of freedom = 19 for Experiment 1 and 10 for Experiment II. The mean difference is not statistically significantly different from zero in either experiment.

detected by the technique used. JONNARD (1963) and BARNARD (1962) give theoretical reasons for suspecting that biomagnetic effects with moderate field strengths might be small and, therefore, difficult to detect.

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M. H. SIMMERS, Lékařská fakulta Kalifornské university: **Růst semenáčků ředkvičky (*Raphanus sativus*) v magnetickém poli.** — Biol. Plant. **9** : 377—382, 1967.

Semenáčky ředkvičky byly pěstovány v asymetrickém magnetickém poli. Kritériem možného účinku byl počet vyklíčených zrn a suchá váha rostlin. Byly provedeny dva pokusy s různou délkou trvání: první pokus 7 . 7 dní, druhý 14 . 1 dní. Statistická analysa ukázala, že neexistuje významný rozdíl mezi kontrolními rostlinami (rostoucími mezi póly simulovaného „magnetu" ze dřeva) a rostlinami pokusnými.

М. СИММЕРС, Медицинский факультет университета в Калифорнии: **Рост сеянцев редиса *Raphanus sativus* в магнитном поле.** — Biol. Plant. 9 : 377—382, 1967.

Сеянцы редиса выращивались в асимметрическом магнитном поле. Критерием, по которому оценивалось действие поля, являлось число проросших семян и сухой вес растений. Проводились опыты различающиеся длительностью: первый опыт 7,7 дня, второй 14,1 дня. Статистический анализ показал, что не существует достоверной разницы между контрольными растениями, растущими между полюсами «магнита» сделанного из дерева, и между опытными растениями.