AD A023092

GERMINATION AND EARLY GROWTH OF SUNFLOWERS
IN WEAK ELF ELECTROMAGNETIC FIELDS

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Final Report, May 1975

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
IIT Research Institute
10 West 35 Street
Chicago, IL 60616

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
Germination and Early Growth of Sunflowers in Weak ELF Electromagnetic Fields.

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Report,

5. AUTHOR(S) (First name, middle initial, last name)
G. M. Rosenthal, Jr.

6. REPORT DATE
May 1975

7a. TOTAL NO. OF PAGES
33

7b. NO. OF REFS
2

8a. CONTRACT OR GRANT NO.
N00039-73-C-0030

b. PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
Distribution Unlimited

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

11. SUPPLEMENTARY NOTES
None

12. SPONSORING MILITARY ACTIVITY
Naval Electronic Systems Command

13. ABSTRACT

Sunflowers (Helianthus annuus) were raised in a weak ELF electromagnetic field under controlled laboratory conditions and in a greenhouse. The field levels were 10 or 1 volt/meter rms electric field and 1 ss rms magnetic field at 75 Hz. The observations and statistical analysis of these experiments is documented in the report. It has been concluded that under field conditions the small, but probably real, effects of a weak electromagnetic field would ' indistinct from, and interact with, those brought about by an, other micro-environmental factors.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Extremely Low Frequency (ELF)						
Weak Electromagnetic Fields						
Electromagnetic Influence						
Biological Effects						
Sunflowers						
Plant Growth and Germination						

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1. SUMMARY

Sunflowers were raised in a weak ELF electromagnetic field under controlled laboratory conditions and in a greenhouse. The field levels were 10 or 1 volt/meter rms electric field and 1 gauss rms magnetic field at 75 Hz. Although seed germination in the laboratory was unaffected, small but statistically significant differences in seedling mortality, stem and root length were found between experimental and control populations. Sunflowers grown in the greenhouse showed a large amount of variation in many early developmental traits, and differences attributable to electromagnetic influence can not clearly be separated from those brought about by other environmental influences. It is probable that under field conditions the small, but probably real, effects of a weak electromagnetic field would be indistinct from, and interact with, those brought about by any other micro-environmental factors.

2. INTRODUCTION

Experiments seeking to determine the effects of weak electromagnetic fields on the frequency of germination of sunflower seeds (*Helianthus annuus*) and on early growth of seedlings and older plants were performed in 1971-2 as a part of a program to determine possible biologic effects of ELF electromagnetic environments similar to those envisaged in the vicinity of the Navy's proposed ELF Communication System (e.g., Projects Sanguine and Seafarer). The work reported here was originally conceived as a repetition of earlier reported studies[1,2] to be done under highly controlled laboratory conditions. The scope was later broadened to include studies carried out under the somewhat more natural conditions occurring in a greenhouse, the testing sequence developing in an open-ended fashion.

3. EXPERIMENTAL DESIGN AND METHODS

Although culture methods were similar in all tests, it is convenient to assign experiments to two series, depending on the place where they were conducted.* These will be designated I or II, experiments within a series being further indicated by an arabic numeral. Series I comprises two experiments carried on at the IIT Research Institute and was designed to verify, under the best controlled environmental conditions available, experimental results reported from preliminary work completed elsewhere.[1] Sunflowers were raised in identical, tiled, inside rooms illuminated by artificial light, the experimental and control populations being grown in adjacent rooms for reasons of space and environmental control. By reversing the experimental and control culture rooms between the first and second experiments of Series I, the second experiment was made to serve as a control for the first with regard to possible influences of uncontrolled or unknown environmental variables that might have differed between the two culture rooms.

The seven experiments of Series II were conducted at the University of Chicago in a large "air conditioned" greenhouse in which environmental conditions were more natural and less controlled and controllable. Each experiment in this series consisted of two experimental and two control populations, each culture

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*Series I experiments were carried out under the supervision of Prof. G. M. Rosenthal; those in Series II, of Prof. M.D.E. Ruddat.

flat being located at a corner of a square approximately 6 meters on a side. The possibility of uncontrolled environmental variations was tested by repositioning the experimental and control populations after Experiment (II,1), but a plan for the schematic repositioning of populations in later experiments was abandoned after the second experiment when a comparison of the results of these two experiments suggested that micro-environmental variability within the greenhouse might be random and fluctuating rather than along regular gradients.

The frequency of germination and the length of stems were obtained in all experiments. In an effort to discover a developmental character susceptible to electromagnetic influences, a number of measurements in addition to stem growth were made in selected experiments. These are:

1. root length; Experiment I,2;
   root weight, dry: Experiments II,5; II,6;
   root weight, fresh: Experiments II,6; II,7; II,8;
2. stem-leaf weight, dry: Experiments II,5; II,6;
   stem-leaf weight, fresh: Experiments II,6; II,7; II,8;
3. stem length in plants having a length greater than 5 cm: Experiment II,7;
4. chlorophyll A and B production and ratios: Experiment II,7;
5. differential leaf growth: Experiment II,9.

Since the position coordinates of each plant were recorded along with other data at the time of harvest, it was possible to divide each culture into subpopulations according to location for statistical or sampling purposes Most populations were analyzed as "quadrants", obtained by bisecting each culture flat along the right-left and front-rear axes.

Table 1 summarizes the conditions of growth for all experiments.

3.1 Culture Methods and Conditions

Plants were grown in polyvinyl containers or wooden flats approximately 48 cm long, 40 cm wide, and 10 cm deep. Stainless steel strips were fastened along the shorter sides and, when energized, served as terminals for establishing an electric field in the substrate parallel to the long axis of the container. Galvanized screen, attached to the stainless steel strips, was used to extend the uniform electric field above the substrate. Each container was placed midway between 2 coils, each about 100 cm in diameter, spaced 100 cm apart (i.e., Helmholtz coils). Within the cylinder formed by these coils, a constant, uniform 1 gauss magnetic field was generated (Fig. 1).

Seeds were planted in a rectangular grid pattern at a depth of 2.5 cm in milled sphagnum in Series I and in sterilized potting soil in Series II. In Series I experiments, a combination of incandescent and high intensity fluorescent bulbs provided a daily 10-hour light/14-hour dark regime. Temperature was kept constant at $72^{\circ} \pm 2^{\circ}$F. Series II experiments were conducted between April and October 1972 in a greenhouse. Illumination, both its intensity

Table 1. SUMMARY OF EXPERIMENTAL CONDITIONS

Experiment No.	I,1	I,2	II,1	II,2	II,4	II,5	II,6	II,7	II,8	II,9
Light	Artificial		Natural →							
Substrate	Sphagnum		Potting Soil →							
Duration (days)	13	13	9	19	10	8	12	13	13	50
ELF	75 Hz, 10V/m, 1g →							75 Hz, 1V/m, 1g →		
Seed Source*	V	V	V	V	V	V	C	C	C	C
No. Populations	2	2	4	4	4	4	4	4	4	4
Seeds Planted per Population	252	252	360	360	100	288	288	288	286	48

*V - Vaughn Seed Company
C - University of Chicago greenhouse

NOTE: Experiment II,3 was discontinued after four days because of power failure.

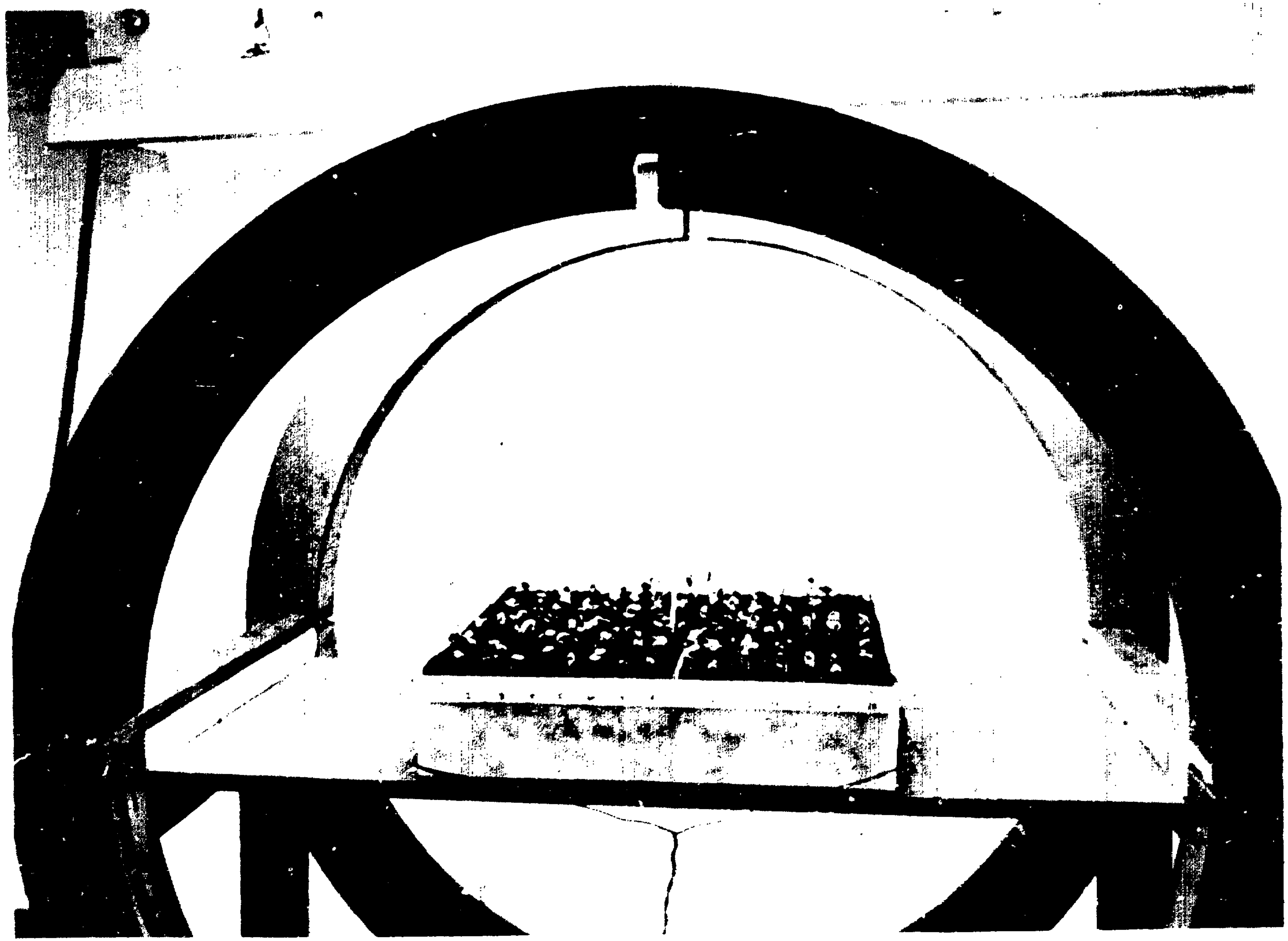

Fig. I ELECTROMAGNETIC FIELD SIMULATOR FOR SUNFLOWER EXPERIMENT and daily duration, varied with the season; but since the mean duration of a single experiment was twelve days (Range: 8-19 days, excepting the last 50-day test), this variation was not great for any one experiment. Temperatures varied similarly from about 65° to 95°F. Temperatures at a height of 2.5 cm and at the soil surface were monitored at 15-minute intervals with thermocouples and a Brown Recorder for each population in Experiments II,4,5, and 6.

All plants were watered on a regular schedule. Cultures were examined daily at the same time, and the plants were measured immediately at the termination of the experiment. Germination was measured in whole days from planting to the appearance of a shoot. Stem, root, and leaf growth were measured in terms of length, weight or number as seemed appropriate in various experiments.

3.2 Electromagnetic Field

The apparatus used to generate the ELF electromagnetic fields was designed to simulate the environment in the vicinity of an ELF Communications antenna system. A detailed explanation of the theory of this type of apparatus has been previously given.[2] For these experiments, the apparatus was installed and regularly monitored by engineers from the Electronics Division of the IIT Research Institute. In all experiments, the magnetic component of the experimental environment was 1 gauss rms at 75 Hz. The electric field used was 10 volts/meter rms at 75 Hz, except in Series II Experiments (7-9), where the level was reduced to 1 volt/meter rms at 75 Hz.

3.3 Seed Stock

Seed used in most of these experiments was from a commercial source (Vaughn Seed Company) and of high quality and genetic uniformity. This source was not available for Series II Experiments 6-9 and another stock, probably less uniform genetically and certainly less viable, was obtained from local greenhouse collections. This is indicated in Table 2A by a lower germination rate for these experiments.

3.4 Measurements

The various growth or developmental parameters measured were:

1. Germination: recorded daily as the above surface appearance of a shoot.
2. Stem length: distance in millimeters from root to stem apex.
3. Stem length of plants greater than 5 cm long: taller plants were removed from the total population for comparisons of "flourishing" plants (as opposed to those that were shorter for whatever reason).
4. Root length: distance in millimeters from top of root to end of growing tip; this measurement was obtainable only for plants grown in sphagnum.
5. Root weight, fresh: weight in milligrams of the whole root system of freshly harvested plants after washing and blotting; the basic datum is the total fresh weight of quadrant populations.

6. Root weight, dry: weight in milligrams after drying.

7. Stem-leaf weight, fresh: total weight in milligrams of freshly harvested plants exclusive of roots; the basic sample is the quadrant population.

8. Stem-leaf weight, dry: weight of the preceding samples after drying.

9. Chlorophyll A: Chlorophyll B ratio: a dimensionless number; chlorophyll determination methods are described in Section 3.5

10. Differential leaf growth: leaves produced during the early stages of sunflower growth are opposite (2,4 or occasionally 3 leaves at each node); later leaves are alternate on the stem. In Experiment (II,9) which ran for 50 days, the possibility of differential leaf growth as a result of electromagnetic influence was measured by counting the number of nodes having opposite leaves, the number of alternate leaves, and the number of "mature" leaves; i.e., those having a blade more than 1 cm long.

3.5 Chlorophyll Determination

Chlorophyll production, a complex synthesis possibly subject to electromagnetic influence, was measured in Experiment (II,7). Fresh leaves were ground in a mortar with small amounts of sand and $NaHCO_3$. Enough acetone was added to make a thick slurry and the grindate was transferred to a Buchner funnel and washed repeatedly with acetone until no green color remained in the plant tissue fraction. The chlorophyll containing solution was further diluted to a volume of 300 ml before spectrophotometric analysis. Optical density was determined for chlorophyll A at 663 nanometers and for chlorophyll B at 645 nm. Chlorophyll A and B concentrations were then calculated as milligrams of chlorophyll per gram of fresh leaf weight, and the ratios of A to B obtained. For this test, each sunflower population was divided into quadrants, and each optical analysis was of an extract obtained from all the leaves present in each quadrant subpopulation.

4. RESULTS

Germination of seeds typically was completed about four days after planting. Figure 2 is a plot of the time course of germination as percentage of germinated seeds in Experiment (II,4) and is illustrative of the general rate of germination. The basic data on the frequency of germination in all experiments are given in Table 2 and summarized according to seed source and experimental site in Table 2A. Inspection of the data shows that approximately 95% of the commercially obtained seeds germinated in the laboratory and the greenhouse under both experimental and control conditions. Forty seedlings in the experimental populations, 24 in Experiment (I,1) and 16 in Experiment (I,2) died within a week of germination; in contrast, twelve seedlings from the control populations, nine in Experiment (I,1) and three in Experiment (I,2) failed to live seven days. Early mortality of plants in these electromagnetic fields is significantly higher than for control plants ($\chi^2 = 17.87$ and $P < .0005$). Only 51% of the locally produced seeds germinated; of these, 888 developed in electromagnetic fields and 983 in control populations. This difference is significant at the 5% level.

4.1 Stem Length

Table 3 lists, for each experiment, the mean stem length for each experimental and control population, the means for all experimental, and the means for all control plants; and the mean stem length for all sunflowers grown. These data are presented graphically, in the order of mean stem length, in Figure 3.

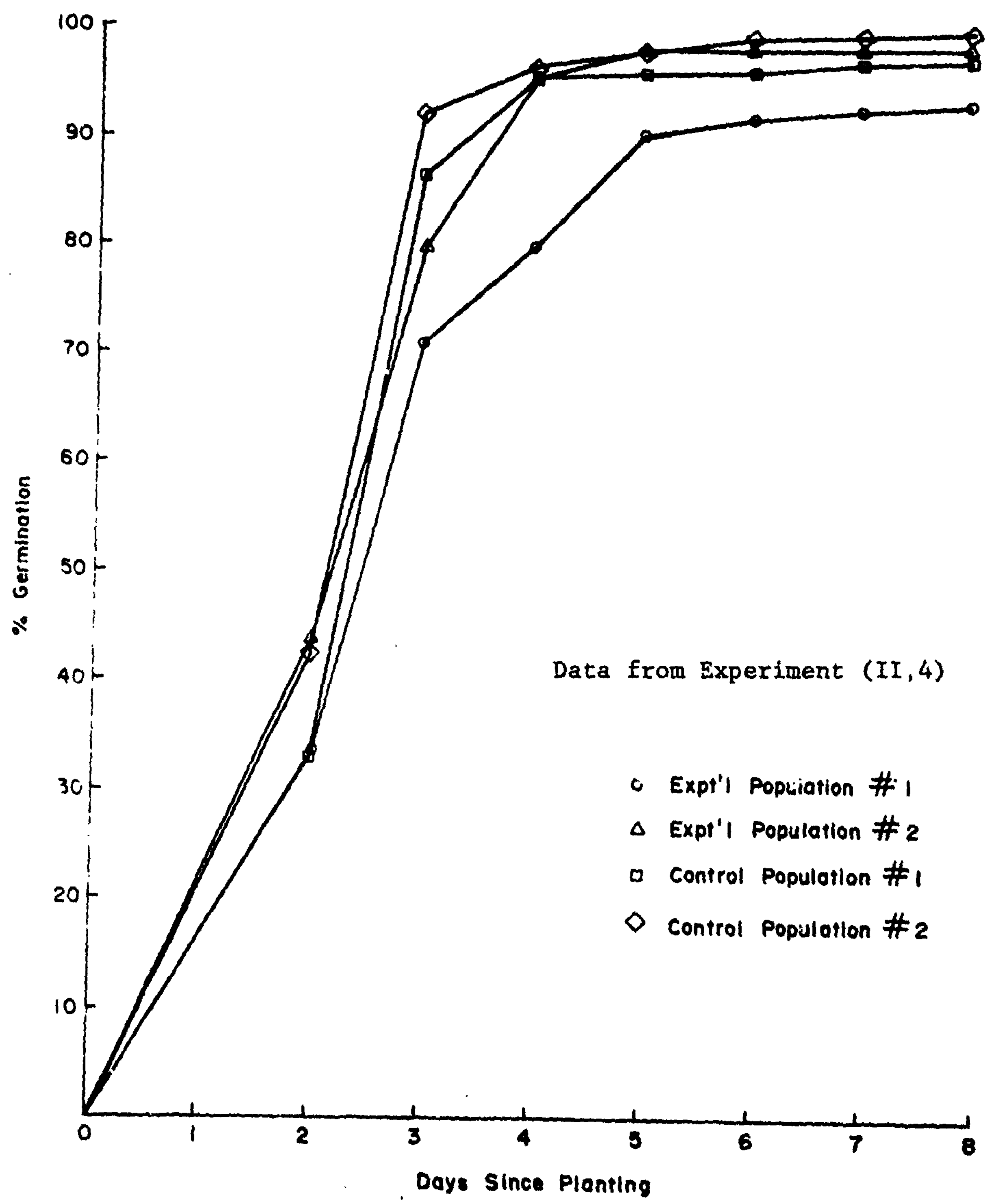

Fig. 2 TYPICAL GERMINATION RATES

Basic Data for Fig. 2 (Germination Rate)
(Data from Experiment (II,4)

Day	⊙	⊡	△	◇
0				
1				
2	33.3	32.8	43.6	42.2
3	70.8	86.1	79.7	91.9
4	79.7	95.6	94.7	95.5
5	90.0	95.6	97.8	97.2
6	91.7	95.8	97.8	98.6
7	92.2	96.7	97.8	99.0
8	92.8	96.9	97.8	99.4

⊙ Experimental Population #1

△ " " #2

⊡ Control " #1

◇ " " #2

Table 2. GERMINATION FREQUENCY

Experiment No.	I,1	I,2	II,1	II,2	II,4	II,5	II,6	II,7	II,8	II,9
Seeds Planted per Population	252	252	360	360	100	288	288	288	288	48
No. Germinated										
Expt. Pop. #1	243	252	334	334	99	263	170	168	119	10
Expt. Pop. #2			352	343	95	267	108	179	118	16
Control Pop. #1	244	248	349	331	89	274	195	163	163	15
Control Pop. #2			339	330	93	278	140	175	115	17

Table 2A. SUMMARY OF GERMINATION DATA

Experiment	Series I	Series II,1-5	Subtotal	Series II, 6-9	Average for All Seeds
Seed Source		COMMERCIAL		LOCAL	
% Germinated	97.22	94.09	94.67	48.52	75.53
No. Germinated					
Expt.	491	2087	2578	888	
Control	489	2083	2572	983	
Significance (from χ^2)	.95	.95	$.95 > P > .90$	$.05 > P > .02$	$.30 > P > .20$

Table 3. STEM GROWTH (mm)

Experiment No.	I,1	I,2	II,1	II,2	II,4	II,5	II,6	II,7	II,8	II,9*
Expt. Pop. #1	136.7	139.5	114.04	120.18	197.78	82.10	106.9	78.78	116.14	73.2
Expt. Pop. #2			127.50	129.34	190.87	88.61	71.2	103.37	122.06	62.3
Mean	136.7	139.5	120.77	124.76	194.93	85.36	89.05	91.08	119.10	67.75
Control Pop. #1	141.6	143.5	115.93	12[illegible].15	160.93	85.93	115.3	84.10	140.89	62.9
Control Pop. #2			122.90	127.00	202.22	84.46	80.0	93.30	136.93	67.1
Mean	141.6	143.5	119.42	125.08	181.58	85.20	97.65	88.70	138.96	65.0
All Populations Mean	139.2	141.5	120.09	124.92	187.95	85.28	93.35	89.89	129.03	66.38

*Growth in centimeters.

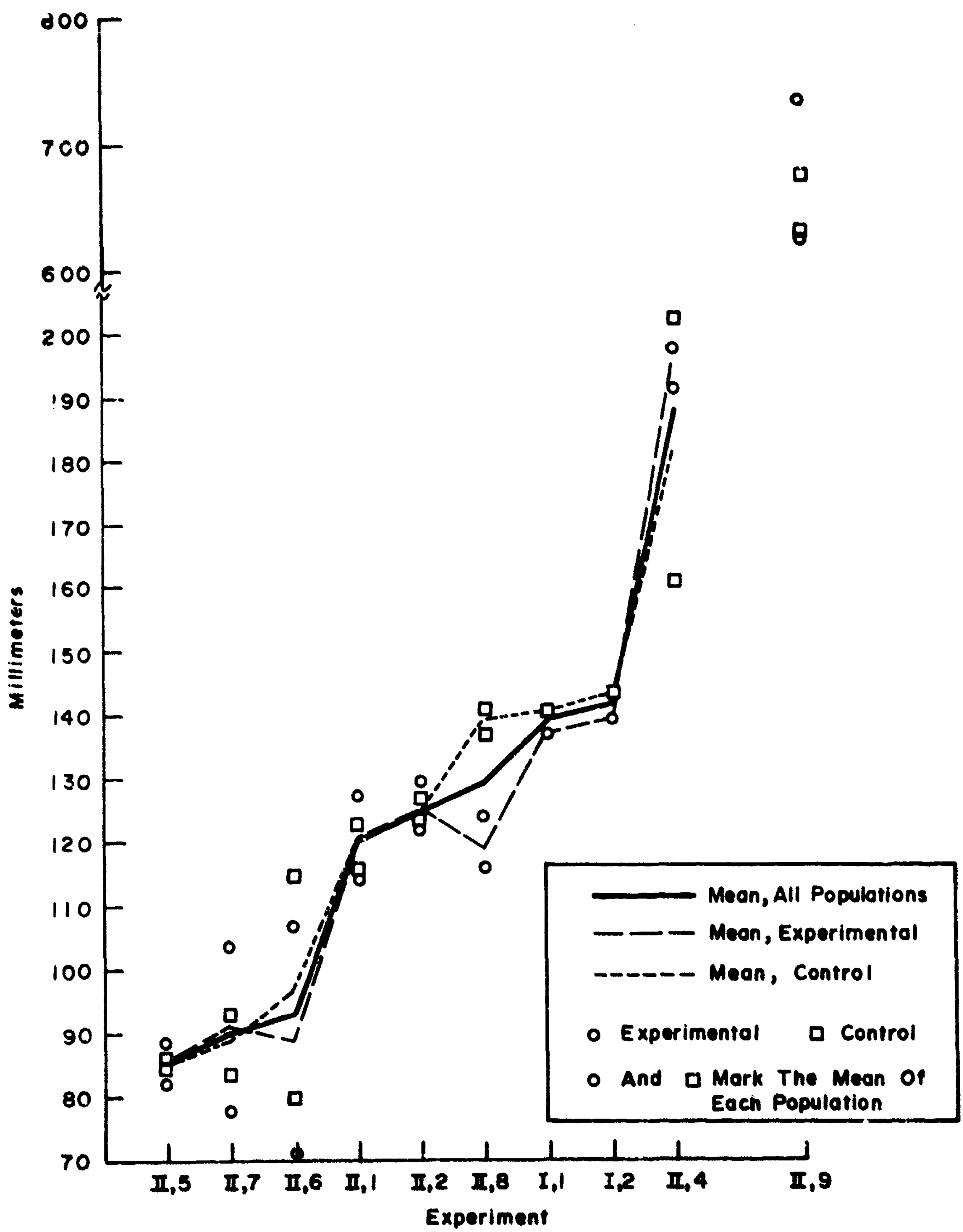

Fig. 3 STEM GROWTH OF SUNFLOWERS

Data for Fig. 3*

Experiment No.	II,5	II,7	II,6	II,1	II,2	II,8	I,1	I,2	II,4	II,9 (cm)
Mean, all Pop.	85.28	89.89	93.35	120.09	124.92	129.03	139.2	141.5	187.95	66.38
Mean, Expt.	85.36	91.08	89.05	120.77	124.76	119.10	136.7	139.5	194.93	67.75
Expt. Pop. #1	82.10	78.78	106.9	114.04	120.18	116.14			197.78	73.2
Expt. Pop. #2	88.61	103.37	71.2	127.50	129.34	122.06			190.87	62.3
Mean, Control	85.20	88.70	97.65	119.42	125.08	138.96	141.6	143.5	181.58	65.0
Cont. Pop. #1	85.93	84.10	115.3	115.93	123.15	140.99			160.93	62.9
Cont. Pop. #2	84.46	93.30	80.0	122.90	127.00	136.93			202.22	67.1

*All data in mm except Experiment (II,9)

The results of Experiments 1 and 2 in Series I are highly comparable and no significant differences can be demonstrated between the two. When populations are divided into quadrants and tested by analysis of variance techniques, the mean lengths of experimental and control plants in Series I, 138.2 and 142.6 mm respectively, are found to differ significantly at the 5% level. Statistical analysis of stem growth in Series II experiments is inconclusive.

4.2 Root Growth

The "tap root" was measured only for plants grown in the soft sphagnum substrate of Experiment I,2. Root length for the first fifty plants whose roots were judged to have been harvested unbroken averaged 107.1 mm and 124.1 mm in experimental and control populations, respectively. This difference, as determined by a rank comparison test, is highly significant ($P < .001$).

The fresh and dry weights of washed whole root systems in Experiments (II,5-8) are given in Table 4. Inspection of the data shows no correlation between treatment and effect, the greatest differences in weights of populations often occurring within the experimental or control groups rather than between them.

4.3 Stem-Leaf Weight

Table 5 lists the fresh biomass and dry weights of plants from which the root system has been removed. These data, like those for roots, show no relation between weight and treatment.

Table 4. ROOT WEIGHTS

Experiment No.	Fresh Weight (mg/plant) II,6	II,7	II,8	Dry Weight (mg/plant) II,5	II,6
Expt. Pop. #1	197.9	345.3	150.3	5.64	6.12
Expt. Pop. #2	179.7	318.9	168.2	5.69	5.53
Mean	190.9	330.7	159.2	5.67	5.89
Control Pop. #1	182.0	295.5	134.0	6.72	5.74
Control Pop. #2	190.2	333.1	169.5	7.64	5.43
Mean	185.4	315.1	148.7	7.12	5.61
All Populations Mean	187.9	323.0	153.7	6.45	5.74

Table 5. STEM-LEAF WEIGHTS

Experiment No.	Fresh Weight (mg/plant) II,6	II,7	II,8	Dry Weight (mg/plant) II,5	II,6
Expt. Pop. #1	2355.1	3237.7	1316.8	62.4	106.3
Expt. Pop. #2	1775.2	3418.2	1363.6	66.9	95.5
Mean	2129.8	3337.8	1340.1	64.7	102.1
Control Pop. #1	2197.0	3235.1	1445.9	55.7	117.1
Control Pop. #2	1836.0	3645.9	1705.2	64.7	82.3
Mean	2046.1	3449.4	1553.2	60.2	103.0
All Populations Mean	2084.1	3392.9	1455.1	62.4	102.6

4.4 Chlorophyll A and B Production

The concentrations of chlorophylls A and B, obtained spectrophotometrically and stated as micrograms per gram of fresh tissue, and the ratios of A to B are given in Table 6. No statistical differences can be demonstrated between the two experimental populations, the two control groups, or between the experimental and the control plants. The concentration for each population is the mean of the quadrant samples in Experiment (II,7).

4.5 Growth in Plants Longer Than 5 cm

The stem length of plants in Experiment (II,7) greater than 5 cm long is compared with the lengths of all plants in that experiment in Table 7. The percentage of "flourishing" plants is 68.6% for both experimental and control populations, and there is no significant difference between their mean lengths, 118.71 and 115.31 mm respectively.

4.6 Differential Leaf Growth

Several measures of development over a fifty-day period are reported in Table 8. The mean height of all experimental plants was slightly greater than that of the controls, 66.5 and 65.0 centimeters, respectively. This difference is consistently maintained with regard to the number of nodes having opposite leaves, a characteristic of early growth; the number of alternate leaves, typical of leaf position in later growth stages; and in the number of large leaves, a measure of total growth.

Table 6. CHLOROPHYLL PRODUCTION AND RATIOS*

	Chlorophyll A	Chlorophyll B	Ratio A:B
Expt. Pop. #1	9.346	6.092	1.547±.0086
Expt. Pop. #2	8.472	5.466	1.552±.023
Mean	8.909	5.754	1.549±.0129
Control Pop. #1	9.600	6.056	1.585±.0092
Control Pop. #2	7.464	4.863	1.535±.026
Mean	8.532	5.460	1.560±.0158
All Populations Mean	8.720	5.607	1.555±.0094

*Chlorophyll content in µg/gram of fresh leaf; data from quadrant samples in Experiment II,7.

$t_{exp\ 1,2} = 0.2303 \quad P > .80$

$t_{control\ 1,2} = 1.813 \quad P > .30$

$t_{exp,\ control} = 0.5664 \quad P > .60$

Table 7. MEAN STEM GROWTH OF SUNFLOWERS TALLER THAN 5 CENTIMETERS*

	Plants > 5 cm		All Plants		
	No.	Height	No.	Height	% > 5 cm
Expt. Pop. #1	106	107.73	168	78.78	63.1
Expt. Pop. #2	132	127.54	179	103.37	73.7
Mean	238	118.71	347	91.08	68.6
Control Pop. #1	111	110.31	163	84.10	68.1
Control Pop. #2	121	119.89	175	93.30	69.1
Mean	232	115.31	338	88.70	68.6

*Height of plants in millimeters; data from Experiment II,7.

Table 8. DIFFERENTIAL LEAF GROWTH
(Data from Experiment II,9)

	No. of Plants	Average Height (cm)*	Average No. of Nodes w/Opposite Leaves**	Average No of Alternate Leaves**	Average No. of Leaves Longer than 1 cm
Expt. Pop. #1	10	73.2	3.5	12.2	21.5
Expt. Pop. #2	16	62.3	3.3	10.6	19.8
Mean	26	66.5	3.38	11.23	20.42
Control Pop. #1	15	62.9	3.2	11.1	18.1
Control Pop. #2	17	67.1	3.5	10.0	18.5
Mean	32	65.0	3.34	10.47	18.39
All Populations Mean	58	65.7	3.36	10.81	19.28

*The height of all plants exceeds that of the magnetic field generating coil (54 cm).

**Early leaves are opposite; later leaves alternate.

5. DISCUSSION

These experiments were undertaken as preliminary tests to discover useful parameters of the effects, if any, of weak ELF electromagnetic fields on the early growth of sunflowers and to quantitize these effects if possible. Taken as a whole, the results of these experiments appear inconsistent and confusing. Nevertheless, several trends and conclusions, both theoretical and practical, emerge.

Plants raised in an electromagnetic environment under the highly controlled conditions of Series I differ significantly from their controls in three ways. These are:

1. increased early mortality rate; $P < .0005$;
2. decreased length of stem; $P < .05$;
3. decreased length of root; $P < .001$.

If failure of germination and early mortality are considered a continuum of early developmental failure, then the frequency of survival to harvesting of 504 experimental and 504 control plants (= seeds) in Series I is 89.5% and 94.6%, respectively. This is not a significant difference ($.50 > P > .30$) by χ^2 test. Germination and survival of 3856 plants from an inferior seed stock in Experiments (II,6, 7, 8, 9) were 41.6% (experimental) and 51.0% (control). This difference is statistically significant ($.05 > P > .02$). A total of 4432 seeds from superior stocks planted in the greenhouse in Experiments (II,1-5) germinated and survived equally well under experimental and control conditions (94.18% and 94.00%). When all information pertaining to failure of germination and early mortality is considered together, no statistical significance is noted (.30 > P > .20) although a trend is perhaps observable. It is likely that this trend, if real, may be attributable in part to genetic differences.

The significant depression of stem growth found in Series I is not confirmed in Series II where results are variable. Reference to Table 3 and Figure 3 suggests that, compared to their controls, the average stem growth of all plants in the experimental environments is depressed in Experiments (II, 6 and 8), enhanced in Experiments (II,1, 4, 7, and 9) and approximately the same in Experiments (II, 2 and 5). The mean stem growth of the two experimental and two control populations, considered as separate populations, is so divergent in all experiments, except (II,8), as to suggest that environmental factors in the greenhouse other than the electromagnetic components were responsible for these differences. Furthermore, it is apparent that these presumably micro-environmental differences in light, temperature, humidity or air movement fluctuate randomly. This divergent growth relationship is shown graphically in Figure 4 as percent deviation of the means for each culture from the means of all populations.

Analysis of all other aspects of sunflower growth shows similar variability within any single experiment. Comparison of Tables 3, 4, 5, 7, and 8 leads to the not surprising conclusion that groups of sunflowers having larger average stem length tend also to have longer and heavier roots, heavier stems, and

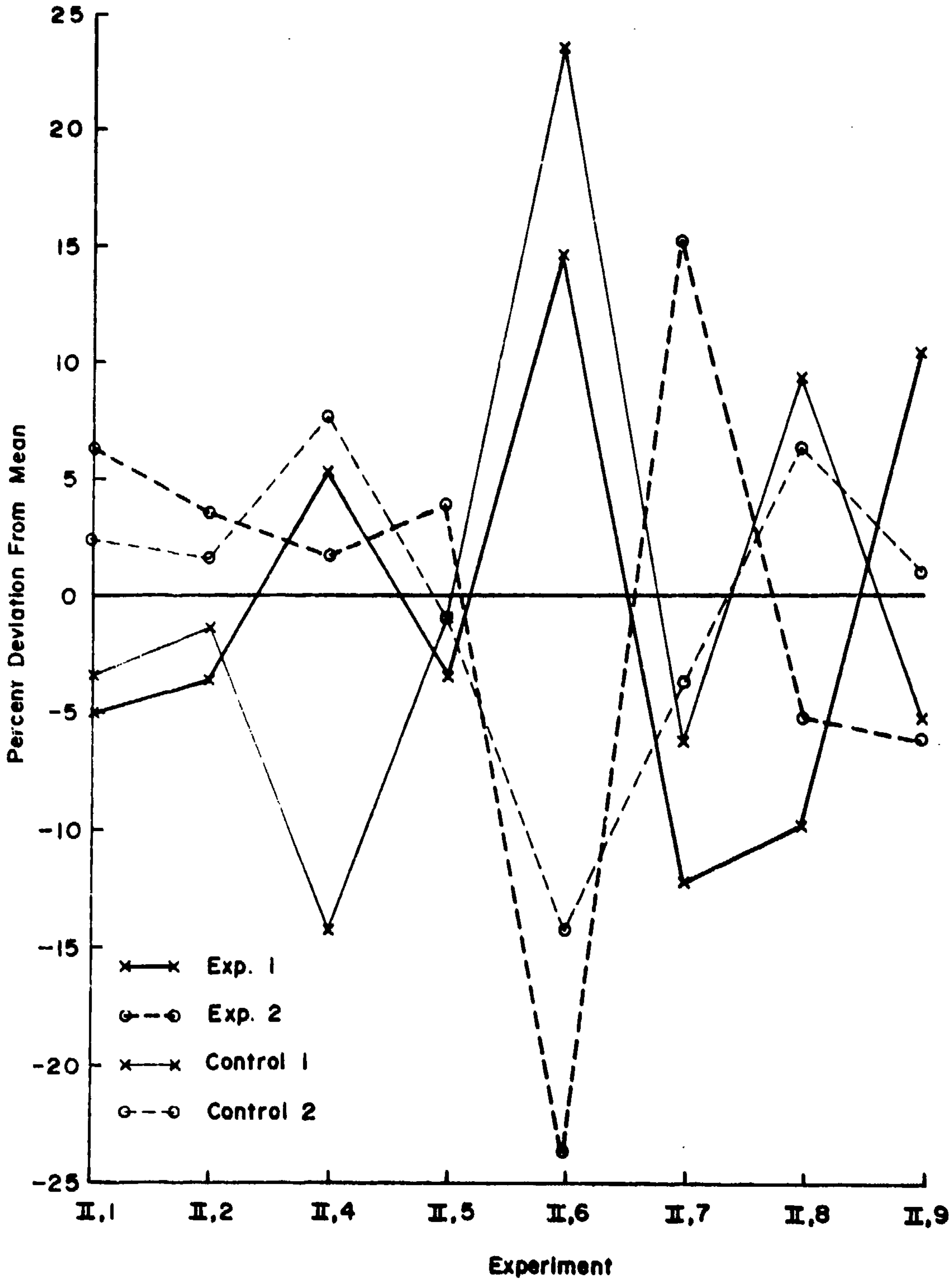

Fig. 4 PERCENT DEVIATION OF MEAN STEM GROWTH FOR SERIES II EXPERIMENTS

Data for Fig. 4 (% Deviation from Mean)

Expt. No.	II,1	II,2	II,4	II,5	II,6	II,7	II,8	II,9
Expt. Pop. #1	-5.04	-3.79	+5.23	-3.73	+14.52	-12.36	-9.99	+10.27
" " #2	+6.17	+3.59	+1.55	+3.90	-23.73	+15.00	-5.40	- 6.15
Control Pop. #1	-3.46	-1.42	-14.38	-0.76	+23.51	- 6.44	+9.27	- 5.24
" " #2	+2.36	+1.66	+7.59	-0.96	-14.30	- 3.79	+6.12	+ 1.08

more leaves. In short, flourishing plants tend to be better developed for all characters measured in these experiments, and we have not observed any sunflower trait which appears to be regularly and clearly affected by the electromagnetic environments imposed in these experiments.

Chlorophyll production is a complex and fundamental biosynthesis and its failure would lead to general inhibition of plant growth shortly after germination. No significant differences of chlorophyll content within or between experimental and control cultures were found. It is noteworthy that these syntheses are apparently normal, at least in rates. That no real differences in ratio of chlorophyll A to B production can be demonstrated is especially meaningful in that it implies that basic solar energy transformation reactions are unaffected by the electromagnetic environment imposed here.

6. CONCLUSION

When these experiments and observations are examined as a whole, it is difficult to arrive at a fixed conclusion as to the effects of low intensity ELF electromagnetic environments on the early growth of sunflowers. The statistically significant results of Series I must be contrasted with the variability of response and the absence of significant differences in Series II. Small environmental differences in light, temperature, humidity, air movement, etc., appear to be more important in influencing growth than the electromagnetic conditions present here. This conclusion is of great importance for future testing under natural field conditions where, to the small variables probably present in these experiments, must be added the many likely variations of soil character and quality, and of microclimate and the effects of competition by other species, and loss or destruction by predators and other agents.

7. REFERENCES

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