PLANT GROWTH IN EXPERIMENTAL SPACE FLIGHT MAGNETIC FIELD CONDITIONS

SILVIA NEAMȚU, V.V. MORARIU

National R & D Institute of Isotopic & Molecular Technologies, P.O.Box 700, Cluj-Napoca 5, 400293, Romania

Abstract: Seeds germination rate and the early stage of seedling growth of eight species of plants were investigated in the absence of the main static component of geomagnetic field (ZMF) and in geomagnetic field as control (GMF), in quiet and increased geomagnetic field activity (GMA). We found a similar rate of seeds germination both in ZMF and GMF, in quiet GMA periods. In the presence of major storm, the germination rate of *Medicago sativa* L. and *Secale cereale* L. seeds was stimulated in ZMF conditions. After four days of incubation, the growth of the tested plants was prevalently inhibited in ZMF in the early stage of stem elongation. However some plant species were stimulated. The results show that ZMF conditions could increase the rate of seeds germination in the presence of natural magnetic disturbance and affect the early stage of seedling growth in the dynamic growth phase. The response of plants to ZMF depends on plant species.

Keywords: zero magnetic fields, geomagnetic field, geomagnetic activity, seeds germination, seedling growth.

INTRODUCTION

The behavior of living organisms in space flight condition is a subject of current interest. At large distances from Earth, and on some celestial bodies there is no magnetic field comparable to Earth geomagnetic field (GMF). In upper magnetosphere and interplanetary environment magnetic field intensities attain near zero values (nT). Also during spacecraft revolution in near earth orbit, living organisms can be exposed to an average value of magnetic field intensity close to zero [3]. Such near zero magnetic field conditions can be obtained in laboratory by compensating the geomagnetic field (ZMF) or by shielding method (WMF). Literature offer scarce information concerning plants growth in ZMF. We started a systematic study of plants growth in ZMF i.e the germination of seeds, the early stage of seedling growth and growth of crop plants respectively. In this paper we present the growth characteristics of some species of plants to ZMF during periods of quiet and increased geomagnetic activity.

Received July 2005;
in final form September 2005.

MATERIALS AND METODS

Seeds germination and the early stage of seedling growth were investigated on eight species of plants in ZMF and in GMF as control. The basic static component of GMF was compensated in a pair of Helmholtz coils oriented along and against geomagnetic field. In this volume the geomagnetic field was reduced by a factor of ~ 100. We conventionally call this partially compensated field as a ZMF. A directional magnetometer with 1nT precision was used to determine the magnetic field map on the exposure surface chosen for work. At different position the field varied within the range of 0–500 nT. The values included the diurnal variation of geomagnetic field. The natural magnetic fluctuation still remains operative in this volume. To determine the influence of the magnetic fluctuations induced during magnetic storm, all the experimental data were analyzed in relation to the GMA variation in the time interval of seeds incubation. The magnitude of GMA represented by *Ap* index was downloaded from National Geophysical Data Center, USA for each period of the experiment [1]. As a measure of the GMA variation we used the standard deviation of the daily *Ap* index (Sd Ap_{index}).

Seeds of alfalfa (*Medicago Sativa*, var. *Luzerne Euver*), *Triticum aestivum* L. and *Secale cereale* L. were provided by Salonic University, Greece and seeds of *Tagetes patula* L., *Calendula oficinalis* L., *Fagopyrum esculentum* L., *Lepidium sativum* L., *Lens culinaris* L. by Agricultural Sciences and Veterinary Medicine University, Cluj-Napoca. Prior to germination, seeds were sterilized using a washing protocol with HgCl2, EDTA and KCl sterile solutions or were soaked in double-distilled water. Experimental and control groups consisted on two or four Petri dishes of 40–50 seeds disposed on a layer of filter paper and cotton pad, soaked with the same quantity of water. These dishes were packed in paper and than exposed in zero magnetic fields and geomagnetic field respectively, in the same temperature and humidity conditions.

The trend of seeds germination follows a sigmoid curve with a slope that characterizes the rate of germination. This curve was determined by the percent of seeds germinated at every three hours. ZMF effect was estimated from the normalized difference of the rate of germination given by x_0 parameter of the Boltzman fitted curve of the experimental data.

The early stage of plants growth was characterized after four-five days of seeds incubation by the length and branching of seeds root in the case of wheat and rye. ZMF effect was estimated from the normalized difference of the root, stem and total plant length. The influence of ZMF on root branching was characterized by the average values and distribution of root number/seeds. To evaluate the significance of the experimental data we used Student's t-test.

RESULTS AND DISCUSSION

SEEDS GERMINATION

In Table 1 were summarized the values of seeds germination rate in ZMF and GMF, the effect of ZMF and *Ap* index of geomagnetic activity during the period of seeds incubation. *Ap* index shows quiet magnetic field periods in the interval of the experiment.

Table 1

Seeds germination in GMF (M) and ZMF (P), ZMF influence and GMA variation in the days of the experiments

Plant species	x_0 (%/hour)	ZMF effect (%)	GMA (*Ap* index)
Medicago sativa	M – 30.49 ± 0.87; P – 29.67 ± 0.98	– 2.6	2–10
Tagetes patula	M – 26.5 ± 1.50; P – 26.92 ± 1.09	1.5	2–8
Calendula oficinalis	M – 26.06 ± 0.13; P – 26.03 ± 0.64	0.11	2–8
Fagopyrum esculentum	M – 33.76 ± 0.23; P – 33.28 ± 0.10	– 1.42	2–8
Triticum aestivum	M – 9.09 ± 0.16; P – 8.79 ± 0.12	– 3.3	2–11
Secale cereale	M – 8.93 ± 0.31; P – 9.11 ± 0.11	2	2–11
Lepidium sativum	M – 8.05 ± 0.05; P – 8.49 ± 0.02	5.1	2–7

The rate of seeds germination was not significantly different in ZMF compared with GMF for all plants investigated. According to these results, the lack of static component of geomagnetic field does not represent a stress for the plants in the phase of seeds germination.

Similar results were obtained in our previous investigations on alfalfa seeds carried in 1998–2001 period. The effect of ZMF on seeds germination rate and the variations of GMA during these experiments are illustrated in Fig. 1. Most of the experiments were performed in quiet GMA periods. In these conditions the rate of alfalfa seeds germination was similar both in ZMF and in GMF as in the cases discussed above. The effect determined in ZMF was less than 5%.

Significant GMA variations were recorded in the other experiments presented also in Fig. 1. The analysis of the relation ZMF effect – GMA variation shows the following:

- The presence of a moderate storm (*Ap* = 53) at the beginning of the experiment (Exp 2.) is associated with a statistically significant stimulation of seeds germination rate (10%).
- If a more intense magnetic storm (*Ap* = 80) appear at the end of seeds incubation period, no biological effect is recorded (Exp. 6);
- The appearance of a minor storm (*Ap* = 41) during the experiment corresponds to increases of seeds germination rate with 6% (Exp 9).

These results show that the rate of alfalfa seeds germination is significantly stimulated in the presence of magnetic storm if it occurred at the beginning of this process.

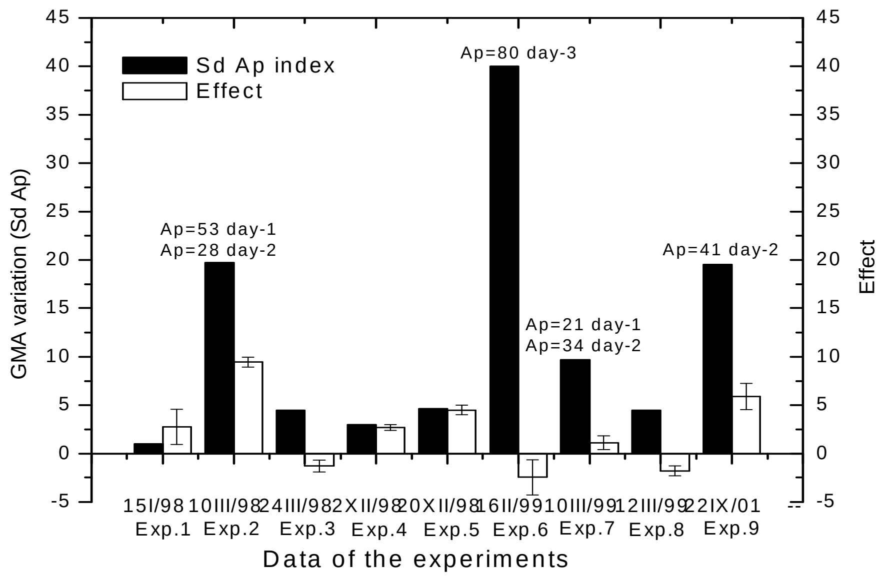

Fig. 1. The variation of GMA during the period of alfalfa seeds incubation and the effect of ZMF on seeds germination. *Ap* index and the day of magnetic storms occurrence are specified on the plot.

Recently we found similar behavior in the case of *Secale* L. germination. In the presence of a major magnetic storm (Ap = 61.55) the rate of seeds germination was stimulated with 10.2 ± 0.23% in ZMF. After 13 hours of incubation, the percent of seeds germinated in ZMF was 133% higher than in GMF. These findings support the idea that the rate of seeds germination can be stimulated in disturbed period of geomagnetic activity in ZMF conditions.

The same positive influence of increased GMA on plants growth was determined indirectly by Kamenir *at al*. [2]. He found that the inhibitory effect induced by corona-discharge field on the growth parameter of wheat (germination, mean length and mass of sprouts) was significantly diminished in the periods with high number of solar spots. The authors assigned the augmentation of seeds germination power to the presence of geomagnetic disturbances.

THE EARLY STAGE OF SEEDLING GROWTH

The early stage of seedling growth in ZMF was quantified after five days of seeds incubation by root, stem and entire seedling length. In most cases, the growth of the plants tends to be inhibited in ZMF as we can see in Fig. 2.

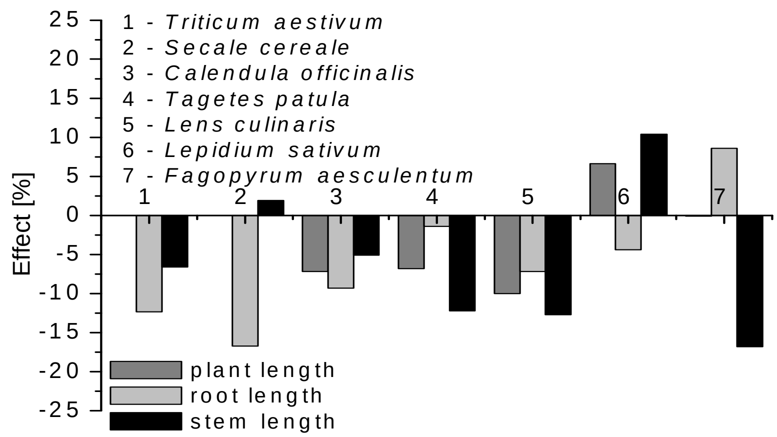

Fig. 2. The effect of ZMF on the early stage of plants growth

Calendula L was not significantly influenced in ZMF. The growth of wheat and rye root was inhibited both as total length and as the process of branching. In the cases of tap-roots plants we found a statistically significant inhibition in the phase of stem elongation ($p < 0.05$). The root length and total length of these plants were not significantly inhibited. We assumed that after five days of incubation the stem elongation was the dynamic growth phase of the tap-root plants that are sensitive to ZMF conditions. The growth of *Lepidium sativum* L. and *Medicago sativa* L was stimulated in ZMF. This variability of the plant response suggests that the influence of ZMF on the early stage of plants growth depend on plant species and can be either positive or negative.

Some experiments were performed in increased GMA periods. Minor storms were recorded in the third or on the fifth day of alfalfa seeds incubation (*Ap* = 44, *Ap* = 35) (Fig. 3.) and on the fourth and fifth days of the wheat and rye seeds incubation (*Ap* = 47, *Ap* = 40) (Fig. 4.). In most experiments alfalfa growth was stimulated in ZMF conditions. The effect determined in these cases was not influenced in disturbed GMA periods (Fig. 3). Significant stimulation of alfalfa seedling growth was noted both in quiet and in disturbed periods.

The growth of the rye and wheat roots was significantly inhibited in ZMF in quiet GMA periods (Fig. 4, Exp 1 and Exp. 2). In the presence of magnetic storms (Exp. 3) the inhibition of the root length was diminished in the case of rye and was not affected for wheat.

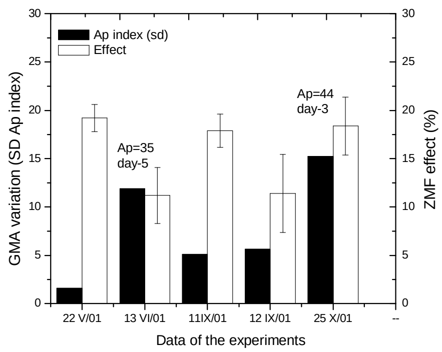

Fig. 3. The effect of ZMF on alfalfa seedling growth and the variation of GMA during the period of seeds incubation.

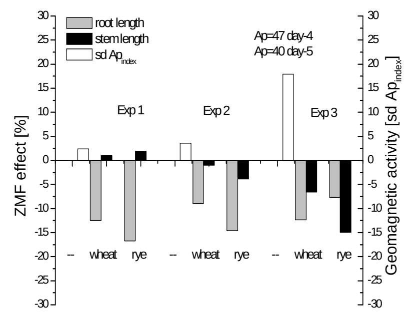

Fig. 4. The effect of ZMF on wheat and rye seedling growth in 3 experiments performed in quiet and in increased GMA periods.

At the same time, the sensitivity of the stem growth seems to be enhanced in increased GMA periods (Exp. 3). In these conditions the stem elongation was inhibited. We should mention that magnetic storms occurred in the second part of the experiment. It can be expected more pronounced effects if the growth of seedlings would be initiated under increased GMA variations.

CONCLUSIONS

In ZMF conditions (as defined in this work) the rate of seeds germination is increased during magnetic storms for some plant species. ZMF affect the early stage of plant growth in the dynamic phases of growth. The response of plants to ZMF varies with the type and species of plants.

Acknowledgements. This work was supported by a grant of the Romanian Aerospatial Agency

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