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# Effect of Magnetism on Some Morphological Characters in Sweet Basil *Ocimum basilicum* L. (Lamiaceae)

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## ABSTRACT

Thirty six morphological characters have been studied in sweet basil plants which were cultivated under the influence of magnetic forces. Two groups of sweet basil, *Ocimum basilicum*, seeds have been subjected to this study. The first group has been cultivated under three different magnetic regimes originated from permanent magnets: 1- above soil surface, 2- at soil surface and 3- under soil surface. The second group of sweet basil seeds was exposed to one to six static magnetic cycles, each last 1/2 an hour to 14.36mT with one hour interval between the two cycles. After three months of cultivations, the effects of magnetism at the different magnetic forces and different seed cycles were assessed using 36 morphological characters compared with the control group. The results obtained showed that magnetism, in the three regimes, affected the maturity of the flowers, pollen grains, and seeds and micropyles shapes. Both the magnet positions and magnetic forces affect the examined characters. The more affected characters were the root and shoot systems lengths; the number of lateral branches; the number of leaves and their sizes and color as well as the lengths of aerial branches carrying the inflorescences. The most positively affected plants were those with the magnet above soil surface, followed by the magnet under soil surface. The least affected plants are those exposed to the surface magnet. Plants resulted from few cycles of exposure to the seeds, have better morphological characters than the control ones. Whereas plants resulted from three cycle's seeds were the most exhausted plants. Those resulted from four cycles seeds started to be morphologically adapted, but the physiological processes of the plants seemed to be disturbed with the increase in the number of cycles. Number of lateral branches and total number of leaves increased significantly at four, five and six cycles of seed exposure but the seeds became fragile and the pollen grains shape has been slightly changed.

**Keywords:** Flower maturation, Lamiaceae, Leaf morphology, Magnetic forces, *Ocimum basilicum*, pollen morphology, seed morphology, taxonomic characters, vegetative morphology.

## INTRODUCTION

Magnetic forces have significant effects on plants, animals and humans. These effects can be due to the exposure to either high or low intensity magnetic fields. Plants and animals use electromagnetic pulses or signals in communication, mating, warning, and protection (Jake, 2000; Stern and Peredo, 2004). Magnetism is a part of electromagnetism which affects all the biological processes, and originates from the flow of electrons, and is one of the forces of nature which can be lost or decreased by heating and environmental disorders. We can realize that the Earth's magnetic field comes from either the molten metals at the interior of the Earth's core (geomagnetic field) or the air through the charging particles found around our planet (magnetosphere). Broad (2004) warned that earth's magnetic force has decreased through the last 150 years by 15% as a result of high temperature and environmental disorders. Natural magnetic field has a great effect on all living creatures as it controls plant growth and existence as well as animal migration and has an important role in our life. So, many studies have been done to investigate the optimum magnetic force which improves plant characters and yield without causing any disorders. Verma (2002) claimed that till now most of the studies about Earth's magnetic field concern navigation, communication and processing but least on living organisms. Studies concerning magnetism and its effect on plant growth and germination have been increased in the last twenty years. From the works on plants are Ellingsrud and Johnson (1993) who noticed that electromagnetic Radio-Frequency caused perturbations of plant leaflet rhythms and it affects the physiological processes inside the plant and its general appearance. Martinez *et al*. (2002) stimulated the growth of wheat by the application of low magnetic doses. Germana *et al*. (2003) found that the exposure to electromagnetic fields modify the biological behavior of seeds, roots, pollen grains and buds of several plants. They concluded that magnetic field exposure affects pollen germination, morphology and pollen tube length. While Fischer *et al*. (2004) found that sunflower seedlings exposed to experimental magnetic field showed significant changes in root and shoot fresh weights as well as germination rates, Florez *et al*. (2004) found that stationary magnetic field has increased the growth parameters of rice seeds. The same was previously mentioned by Edmiston (1972) who showed that the presence of permanent magnet has affected the germination and growth of mustard seeds. While Moller and Shykoff (1999) found minor bilateral or radial asymmetry of leaves and flowers in response to external artificial fields. Dattilo *et al*. (2005) reported that pollen tube growth of kiwi fruit is affected by magnetic fields and they referred that to the changes in the ionic charges within the pollen tube cytoplasm. Taia *et al*. (2005 and 2007) recorded that magnetic forces affected the rate of germination, seedling morphological characters, water contents and photosynthetic pigments of sweet basil plants.

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The present investigation deals with the effect of different regimes of magnetism as well as different pre-exposure magnetic seed cycles on some morphological characters of sweet basil plants (*Ocimum basilicum* L. Green Ruffle's cultivar). This investigation has been carried to realize how much the modern technology will affect the morphological characters of the plant and to know the more stable morphological characters to be considered in the first steps in constructing a taxonomical keys.

## MATERIALS AND METHODS

Mature seeds of sweet basil (*Ocimum basilicum*) were collected from wild plants grown in the beginning of Jeddah-El-Medina road after 20 km from Jeddah, in Saudi Arabia during November 2005 for this investigation. The collected seeds were tested for their viability by germinating 50, randomly mixed, seeds in 5 Petri-dishes before the experiments. Afterwards, the seeds subdivided into two divisions, the first division were subdivided into three groups each with three replicates. Each group contained 300 X 3 seeds was subjected to one of three magnetic regimes. The seeds in each regime was subdivided into three subgroups (Fig.1), each contain 100 X 3 seeds was exposed to one of three different magnetic forces in each regime. The seeds were arranged in circles at regular intervals at different radius to obtain different forces. Each 100 seeds were put in separate and isolated pots at the same radius in three isolated replicates. Magnetic field in each regime was obtained from a piece of permanent magnets, been put at different positions; 50 cm. above soil surface (group1) and magnetic force has been measured at seed positions to be 0.42, 0.38 and 0.22 milli Tesla; at the middle of the pots, soil surface (group 2) with three magnetic forces 1.42, 0.78 and 0.36mT; and buried 10 cm. deep under soil surface (group 3) with three magnetic forces 0.71, 0.44 and 0.35m T (Fig. 1). These magnetic forces are lower than the magnetic forces originated from electrical lamps, equipments and communication lines which cause an environmental stress on the plants in nature.

The second division was exposed to a permanent magnet with a magnetic force of 14.36 m T. which put it in the middle of a container and the seeds were arranged in a circle of 25 cm. radius. The seeds were exposed for six different times, each treatment contained 100 X 3 seeds, was exposed for 1/2 an hour with intervals of one hour (one cycle, two cycles, 3 cycles, 4 cycles, 5 cycles and 6 cycles) before germination, each cycle has three replicates ( Fig. 2). This magnetic force is considered very low compared with those originating from normal electrical lamps and equipments.

Another group of 100 seeds were cultivated as control in another pots and far enough from the treated ones. The percentages of germination had been calculated in each treatment beside the control.

Magnetic forces had been measured using Gausemeter at the points of seeds, as well as in the control pots which was 0.005mT.

All the seeds of the whole treatments were planted in mixed soil of sand and peat (1:1) and irrigated by 50 ml. tap water every 48 hours for three months. All the resulted plants were subjected to macro-morphological examinations after three months. Ten representatives from each treatment beside the control have been chosen for micro-morphological examinations. . Lower and upper surfaces of the leaves as well as pollen grains and seeds had been examined by stereomicroscope before their examination by the SEM. Selected mature seeds and pollen grains as well as part of the lower surfaces of the leaves had been put onto stubs and coated with gold and examined and photographed by JEOL SEM.

Statistical analyses of the data obtained had been carried out using SPSS Version 11 and SATISTICA Version 7 programs to determine the significances and standard deviations of the differences in characters measurements caused by the magnetic regimes and the different forces inside each regime. Meanwhile, to measure the correlation coefficient of the most

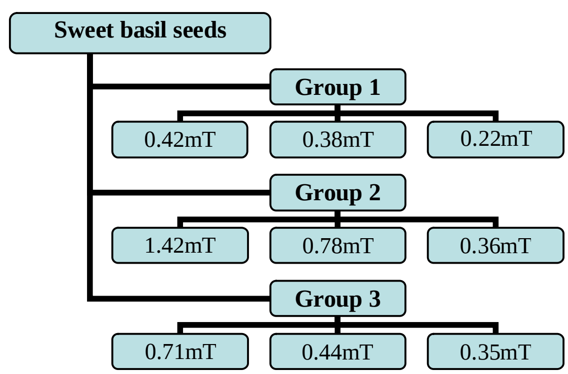


**Figure (1):** Experimental set up of sweet basil seeds

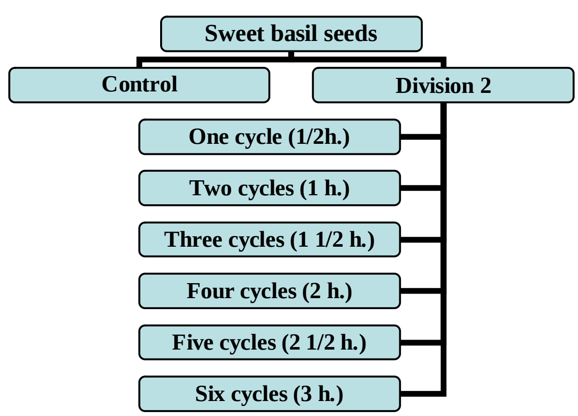


**Figure (2):** Experimental set up of sweet basil seeds division 2.

significant characters observed in the resulted plants of the different cycles of seed exposure to the static magnetic force.

## RESULTS

In all treated seeds and the control, the germination started from day 6 and lasted to day 20. From Tables 1 and 2, it can be noticed that in the first treated division, the germination was accelerated at the buried regime and retarded at the surface regime while at the aerial regime the germination process was not affected greatly. Meanwhile, in the second treated division, one and two cycles of exposure accelerates the germination while three cycles retarded it and reaccelerated at four, five and six cycles. Moreover, the lengths of both root and shoot systems have been affected according to the different regimes of magnetism as well as to the forces within the same regime and according to the number of seed exposure cycles. The length of the primary root in the first division decreased at 0.42mT in the above soil regime and then increased with the decrease in the magnetic force. At the soil surface regime, there was increase in the primary root lengths as compared to the control at the three magnetic forces used. In this regime the primary root elongated significantly compared to the control at 1.42mT (Table 1), while decreased slightly at 0.78mT and elongated at 0.36mT in the buried magnet regime, the primary root lengths increased compared to the control in all the forces, but in 0.35mT it began to decrease. In general the primary root under magnetic effect became longer than the control. The effect of magnetism was obvious on plants grown under the effect of surface magnets. While those resulted from the different cycles of exposure the primary root length did not affect at those resulted from one cycle seeds and start to decrease from the plant resulted from two cycles seeds with the most exhausted plants are those resulted from three cycles seeds. At four, five and six cycles the plants start to be adapted with the magnetic forces gradually to reach the same root length as the control plant after six cycles of seed exposure time (Table 2).

Primary roots in the first treated division were straight at all the forces of the first group as well as the second group, except at 0.78mT where it becomes slightly curved. At the third group, the buried magnet, the primary roots became curved or sinuate at the lowest force only. The secondary roots were longer than the primary root in all the treatments, except at the first group, magnetic force 0.42mT and the second group, magnetic force 1.42mT The secondary roots surrounded the primary root in all treatments, except at 0.38mT within the above surface regime and 0.36mT in the soil surface regime they were lateral. At both 0.38mT above surface regime and 0.71mT under soil regime they were adhered to the primary root (Plate 1). While in the second division, the primary root was curved in all plants with few and short secondary roots, except in the plants resulted from the seeds exposed to six cycles it is straight with dense secondary roots (Plate 2).

The shoot system was less affected by magnetic fields compared to the root system in the first division while in the second division, it increased significantly in all the plants resulted from treated seeds compared with the control plants, except in plants resulted from three cycle's exposed seeds where it was remarkably shortened. In spite of that the ratio between both root

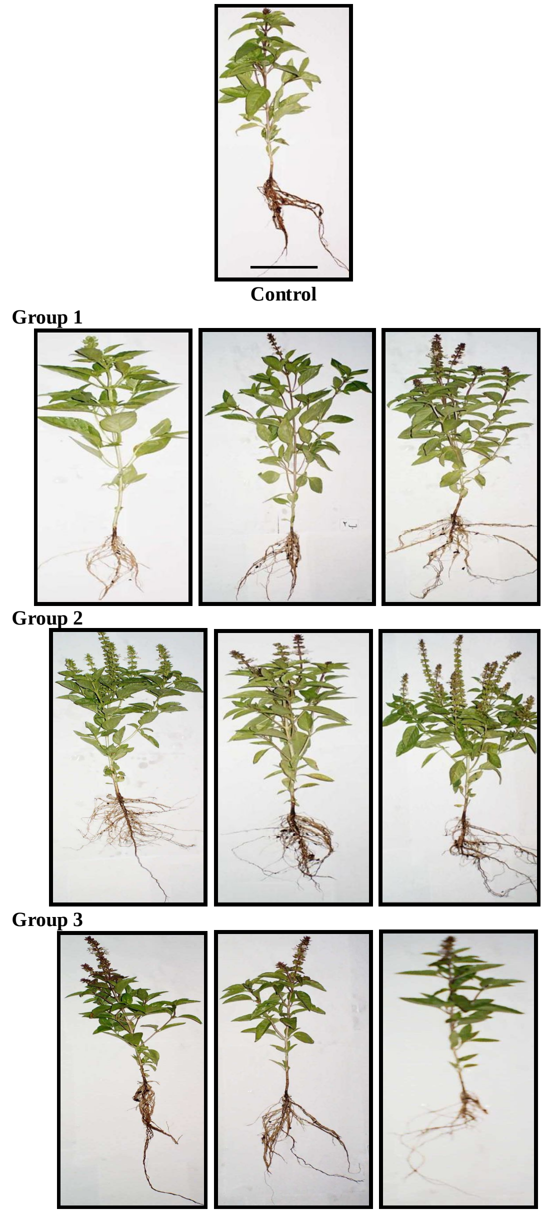


**Plate (1):** Photographs showing the most common morphological characters of the plants cultivated under the different regimes of magnetism, Group 1 = above soil surface magnet with the three forces (0.42, 0.38 & 0.22mT), Group 2 = at soil surface magnet with the three forces (1.42, 0.78 & 0.36mT), Group 3 = buried magnet with the three forces (0.71, 0.44 & 0.35mT), mT = millimeter Tesla, Bar= 5 Cm.

**Table (1):** Measurements and status of the morphological characters in the three magnetic regimes.

| Characters | Control 0.005mT | Above soil surface | | | At soil surface | | | Under soil surface | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.42mT | 0.38mT | 0.22mT | 1.42mT | 0.78mT | 0.36mT | 0.71mT | 0.44mT | 0.35mT |
| **%Germ.** | 72.23-75.47 ± 0.33 | 85.33-89.77 ± 0.66 | 75.22-79.23 ± 0.33 | 76.0-79.22 ± 0.46 | 34.22-36.75 ± 0.33 | 51.34 ± 0.66 | 51.66-54.15 ± 0.23 | 91.4-93.85 ± 0.33 | 81.8-83.66 ± 0.25 | 95.2-95.92 ± 0.25 |
| **primary root length** | 15.14-17.44 ± 0.21 | 13.08-14.22 ± 0.48 | 20.78-21.33 ± 0.51 | 25.65-26.5 ± 0.42 | 30.00-31.5 ± 0.52 | 21.0-22.5 ± 0.12 | 34.0-35.5 ± 0.53 | 24.00-26.00 ± 0.02 | 25.00-26.5 ±0.3 | 18.00-19.5 ±0.71 |
| **primary root morphology** | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 2 | 2 | 3 |
| **secondary root length** | 1 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| **secondary root direction** | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| **secondary root status** | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 |
| **Shoot System L.** | 43.00-45.00 ± 0.57 | 39.25-41.5 ± 0.46 | 43.00-44.5 ± 0.61 | 45.00-47.5 ± 0.56 | 37.00-38.5 ± 0.22 | 30.50-31.5 ± 0.29 | 44.00-45.8 ± 0.53 | 32.70-33.8 ± 0.41 | 29.50-31.5 0.51± | 25.50-27.0 ± 0.34 |
| **primary root L. / Shoot system L.** | 2.65 ± 0.07 | 2.86 ± 0.13 | 2.02 ± 0.04 | 1.73 ± 0.06 | 1.27 ± 0.03 | 1.43 ± 0.09 | 1.29 ± 0.03 | 1.35 ± 0.05 | 1.18 ± 0.02 | 1.44 ± 0.06 |
| **Stem color** | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 |
| **No.of lat. Bran.** | 2-3 | 3-5 | 5-7 | 5-7 | 6-9 | 6-9 | 9-12 | 4-6 | 2-4 | 2-4 |
| **Hair D.** | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 |
| **Hair T.** | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| **Hair P.** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| **T.No.of leaf** | 70-75 | 63-66 | 88-92 | 121 | 97-99 | 103 | 112 | 74-79 | 52-55 | 58-62 |
| **Leaf color** | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 3 | 3 | 3 |
| **Leaf L.** | 5.18 ± 0.09 | 5.94 ± 0.04 | 6.20 ± 0.2 | 7.1 ± 0.24 | 4.87 ± 0.12 | 5.94 ± 0.04 | 5.70 ± 0.30 | 5.30 ± 0.25 | 4.80 ± 0.12 | 4.40 ± 0.24 |
| **Leaf W.** | 2.10 ± 0.04 | 4.14 ± 0.01 | 4.16 ± 0.10 | 4.92 ± 0.09 | 4.06 ± 0.15 | 3.06 ± 0.04 | 4.04 ± 0.16 | 3.36 ±0.10 | 2.82 ±0.18 | 2.48 ±0.02 |
| **Leaf Shape** | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 |
| **Leaf apex** | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 |
| **Leaf sym.** | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 2 |
| **Leaf Hair** | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 |
| **L.T.of hair** | 2 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 | 2 |
| **Epid.Blad.** | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 3 | 3 |
| **No.lat.bran.** | 0 | 1-2 | 1-3 | 3-4 | 5-6 | 3-4 | 9-11 | 3-5 | 2-3 | 1-2 |
| **Lat.bran.L.** | 10.4 ± 0.80 | 6.00 ± 0.22 | 9.70 ± 0.58 | 16.54 ± 0.52 | 16.00 ±0.67 | 7.46 ± 0.62 | 15.72 ± 0.50 | 12.40 ± 1.19 | 9.98 ± 0.57 | 6.40 ± 0.46 |
| **Bract color** | 1 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| **Flower pres.** | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 |
| **Pollen maturity** | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 2 |
| **Pollen shape** | 3 | 1 | 1 | 1 | 2 | 1 | 1 | 3 | 1 | 3 |
| **Pollen L.** | 18.84 ± 0.034 | ---- | ---- | ---- | 18.82 ± 0.36 | ---- | ---- | 19.01 ± 0.62 | ---- | 16.83 ± 0.62 |
| **Pollen W.** | 21.84 ± 0.034 | ---- | ---- | ---- | 18.82 ± 0.36 | ---- | ---- | 21.41 ± 0.47 | ---- | 19.65 ± 0.38 |
| **Seed Pres.** | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 |
| **Seed L.** | 0.78 ± 0.35 | 0.52 ± 0.13 | 0.78 ± 0.13 | 0.82 ± 0.09 | 0.80 ± 0.32 | ---- | 0.69 ± 0.02 | 0.83 ± 0.32 | 0.67 ± 0.12 | 0.81 ± 0.21 |
| **Seed W.** | 0.45 ± 0.21 | 0.28 ± 0.02 | 0.46 ± 0.06 | 0.45 ± 0.18 | 0.49 ± 0.21 | ---- | 0.49 ± 0.13 | 0.42 ± 0.05 | 0.52 ± 0.08 | 0.42 ±0.12 |
| **Seed shape** | 1 | 1 | 1 | 1 | 1 | ---- | 2 | 1 | 3 | 2 |
| **Microp.shape** | 2 | 1 | 1 | 1 | 1 | ---- | 2 | 1 | 1 | 2 |

### Key to table 1

**1- Germination %**; **2-Length of primary root(cm); 3- Morphology of primary root**: 1- Straight 2-Curved 3-Sinuate; **4- Length of secondary root:** 1= shorter than primary root 2= longer than primary root**; 5- Direction of secondary roots:** - 1- Along the two sides 2- Lateral **6- Status of secondary roots:-** 1- twining with the primary root 2- not so **7- Length of shoot system (cm) 8- Ratio between 1ry root and shoot system lengths 9-Color of the stem:-** 1- Green 2-Pinkish green **10- Number of lateral branches 11- Degree of hairiness on the stem:**1- Sparsely hairy 2- Hairy **12- Type of hairs on the stem:-** 1-non –glandular 2- glandular **13- Position of hairs on the stem:-** 1- Allover the stem 2- On the deep areas only **14-Total number of leaves in plants 15- Leaf color:**1- Bright green 2- Green 3- Olive green **16- Leaf length (cm) 17-Leaf width (cm) 18- Leaf shape: -** 1- Ovate 2- Broadly-ovate **19-Leaf apex: -** 1- Acute 2- Acuminate **20- leaf symmetry: -** 1- Symmetric 2- Asymmetric **21- Leaf hairiness:-** 1- Glabrous 2- hairy **22- Type of hairs: -** 1- Glabrous 2-Glandular 3- Non glandular **23- Leaf epidermal bladder** 1= Absent 2= Present 3- Present in high density **24- Number of aerial branches carrying the inflorescence / plant 25- Length of aerial branches carrying the inflorescences(cm) 26- Bract color: -** 1- Green 2- Reddish **27- Presence of flowers inside the bract: -** 1- Absent 2- Present **28- Pollen maturity: -** 1- Immature 2- Mature **29- Pollen shape:-** 1- Immature 2-Spherical 3- Sub-oblate **30- Pollen length(Um) 31-Pollen width (Um) 32- Presence of seeds:-** 1-Immature 2- Mature **33- seed length (mm) 34-seed width (mm) 35- seed shape:-** 1- longitudinally elongated 2-Ovate 3- Rectangular **36- Micropyle shape:** 1-Rouded 2-Pointed.

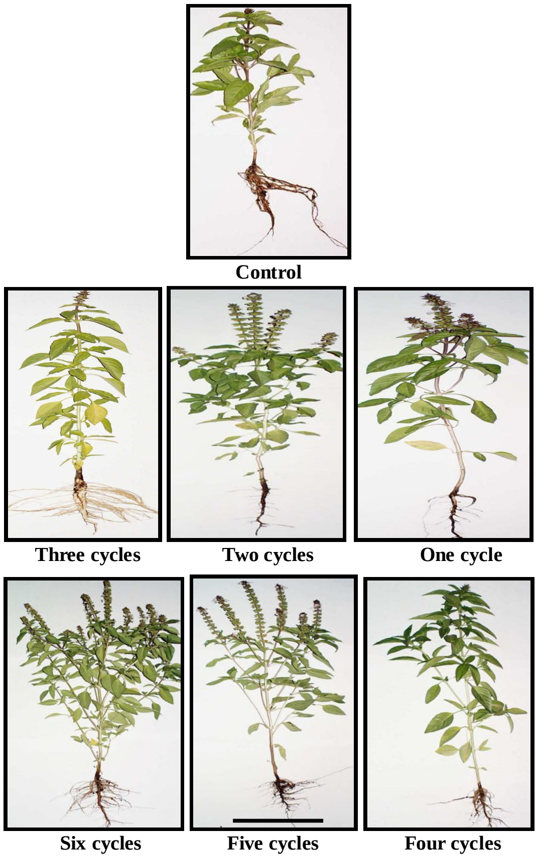


**Plate (2):** General appearance of the control plant and the most common resulted treated plants of the pre exposed seeds, Bar= 5 Cm.

system and shoot system lengths increased in all the treated plants, even in the three cycle's exposure seeds, with maximum increase in the plants resulted from two and five cycles exposed seeds (Table 2). In the above surface regime, the shoot system shorter than the control at 0.42mT, while it elongated to be taller than the control in the other two forces. At the soil surface regime the shoot system length decreased than the control at the first two forces (1.42 and 0.78mT) and increased slightly to be taller than the control at 0.36mT when the magnets were under soil surface, the shoot systems decreased gradually with the decrease in the magnetic forces used. In all the magnetic treatments the ratio between the primary root and shoot system lengths decreased significantly than the control, except in the above surface regime 0.42mT where it slightly increased (Table 1).

The stem which is green, light green or pinkish green is either sparsely hairy or hairy with glandular hairs distributed allover the stem. Under the three forces of the above surface magnets and in those resulted from three and four magnetic cycles, the hairs are pointed and non-glandular. The hairs are distributed allover the stem except in case of the lowest two magnetic forces of the buried magnets and plants resulted from two and three magnetic cycles they are allocated in the four depressions only.

The number of lateral branches and total number of leaves was affected in all the treated plants relative to the control in the two divisions, with the greatest number of lateral branches in the three forces of the soil surface magnets (Plate 1) and those resulted from six cycles seeds (Plate 2). The total number of leaves was affected in response to the different regimes and forces inside each regime where it was insignificantly affected in the soil surface regime while in the above surface regime and under soil surface regime it was significantly affected by the magnetic force used (Table 3). In case of above surface magnets, 0.42mT the number of leaves was decreased than the control, then as the forces decreased the number of leaves increased to be more than the control. In soil surface magnets, the number of leaves increased than the control under all the three forces used and increased as the forces decreased. In case of using under soil magnets, the 0.71mT gave total number of leaves near that of the control, then as the forces decreased the total number of leaves decreases as well to be less than the control in the other two forces. The total number of leaves was increased significantly in the plants resulted from six cycles seeds, whereas it was decreased in those resulted from three cycle's seeds (Table 2).

The leaves sparsely hairy, green or dark green, usually broadly ovate with acute apices, except in the under soil magnets and at 0.78mT soil surface magnet they were ovate with acuminate apices. At 0.78mT soil surface magnet and 0.44 and 0.35mT under soil magnet the leaves become asymmetric where the two halves become unequal (plate 3). The hairs are glandular or non-glandular and bladder-like cells are noticed in the lower leaf surfaces with different densities in all forces in the under soil surface magnets and in the first two forces in the above soil surface magnets which are absent in the rest of the first division treatments and the control while they are present in all plants resulted from the exposed seeds (Plate 4).

The leaves in three cycle's plants are yellowish green and become smaller in size than all the other plants. The leaves in the plants resulted from two and five cycles seed exposure became asymmetric with the two halves are not equal (plate 3).

Number of aerial branches carrying the inflorescences and their length varied according to the three regimes and the different forces inside each regime. The number of aerial branches carrying inflorescences increased in the soil surface and under soil surface regimes than the control. Their lengths decreased in the first two forces in the above soil surface regime than the control, then it elongates in the third force (0.22mT). At the soil surface regime 1.42mT, the length of them increased, then it drops suddenly at 0.78mT and re-elongates again at 0.36mT At the under soil surface regime, their lengths decreased with the decrease in the magnetic force (Table 1). The aerial branches carrying the inflorescences increased in both number and length slightly in the plants resulted from one and two cycles seed exposure, then in the plants resulted from three cycles seed exposure, one short inflorescence is recorded in the whole plants of this cycle. In plants resulted from four and five cycle's seed exposure, the number and length of the inflorescences in creased than the control and reached their maximum number and length in the plants resulted from six cycle's seed exposure. In all the plants resulted from three cycles exposure seeds the bracts were not enveloping any flowers i.e. the inflorescences are sterile, while those resulted from seeds exposed to two cycles the flower were small with rudiment anthers and those resulted from six cycle's seed exposure the seeds were fragile and very small.

Pollen grains maturity had greatly affected by magnetic forces in the two divisions, as most of the treated, as well as, the control had immature flowers after three months of cultivation. Mature flowers with pollen grains are found only at 1.42mT, at soil surface regime, and 0.71 and 0.35 T under soil surface regime only. In spite of that, pollen grains from mature, untreated plants have been studied in order to compare the effect of the magnetic treatments on both pollen shape and size. The pollen shape in the matured untreated plants is symmetric, sub oblate (17.8-18.8 X 20.4-22.6 micron), with hexa-colpate aperture. The colpi are 14.8 – 15.3 micron length and 2.0-2.2 micron width granulated membranes. The exine is tectate reticulate with hexagonal luminae and narrow muri. In the treated plants the type and number of apertures were not affected, but pollen shape has been slightly changed and became spherical (17.8-18.4 micron). In the soil surface regime 1.42 m T The luminae become either irregular in 0.71mT under soil surface magnet, remain hexagonal in 0.35mT of the same regime or become ongitudinally elongated in1.42mT soil surface regime (Plate 5).

Seeds of the treated plants are black or deeply brown, ovate or elongated with rectangular seed coat cells with elevated boundaries and flat surfaces. The micropyle was circular or pointed. At 0.44mT under soil surface magnet, the seed became rectangular in shape (Plate 6). The sizes of the seeds have slightly changed according to both magnetic regime and the forces inside each regime (Table 1). Seeds were absent in three cycles plants where they are fragile in six cycles ones. The rest plants resulted from treated seeds have flowers contain normal seeds. Treated plants have seeds bigger in sizes than the control ones (Table 2).

Statistical analysis of the results showed that there are no obvious relations between the studied characters and the position of the magnet with respect to the different forces except in few characters only such as both root and shoot lengths as well as total number of leaves and their shapes and number of lateral branches as shown in

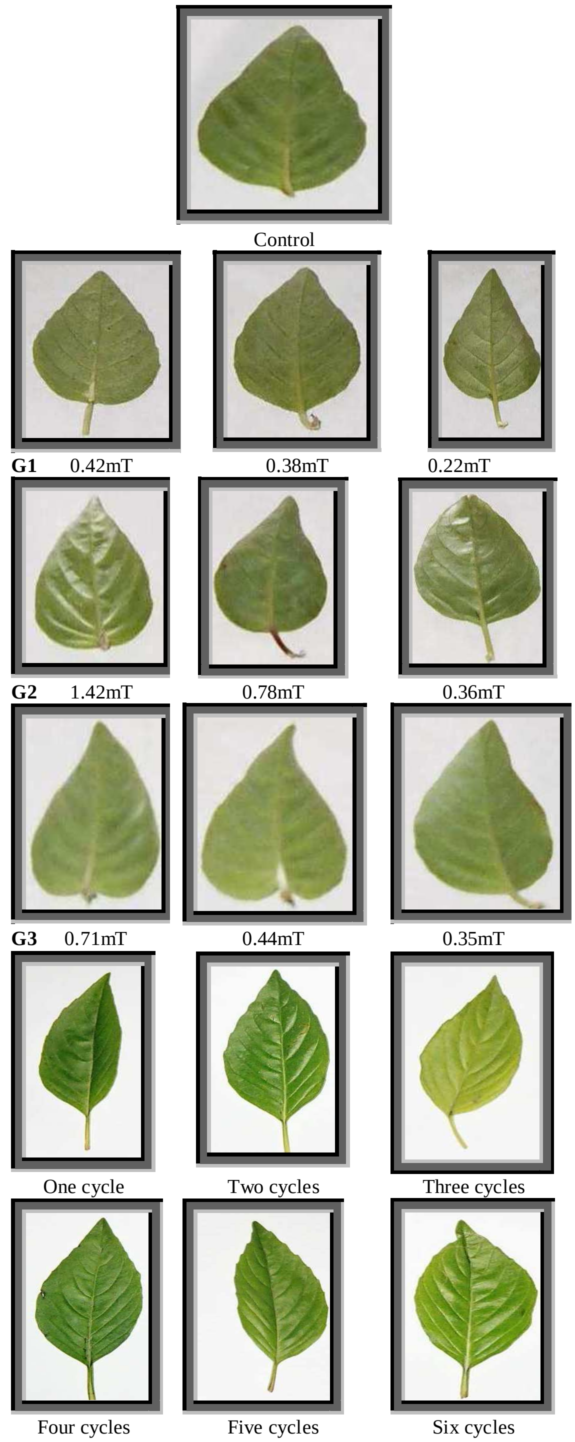


**Plate (3):** Lower leaf surfaces showing leaf shapes from plants grown under the three forces in each regime (G1= above soil surface regime; G2= at soil surface regime, and G3= under soil surface regime) and resulted plants of pre exposed seed cycles.

table (3). These characters are significantly altered according to the different forces inside the regime in both the above soil surface and under soil surface

**Table (2):** Measurements and status of the morphological characters in the pre-exposed seeds.

| | Control 0.002mT | Magnetic seed cycles | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| **%Germ.** | 85.00-87.9 ± 0.33 | 89.00-91.25 ± 0.26 | 89.37-91.5 ± 0.33 | 36.00-39.95 ± 0.26 | 85.00-91.0 ± 0.38 | 92.00-94.22 ± 0.12 | 72.23-75.47 ± 0.33 |
| **1ry.root length** | 16.00-17.5 ± 0.59 | 12.00-13.5 ± 0.58 | 11.5-12.5 ± 0.39 | 6.00-7.5 ± 0.49 | 12.00-13.5 ± 0.17 | 15.5-16.5 ± 0.34 | 15.00-17.5 ± 0.21 |
| **1ry.root mor.** | 2 | 3 | 3 | 2 | 2 | 2 | 1 |
| **2ry.root length** | 1 | 1 | 1 | 3 | 2 | 1 | 1 |
| **2ry.root direction** | 2 | 1 | 1 | 1 | 2 | 1 | 1 |
| **2ry.root status** | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| **Shoot System L.** | 43.00-45.00 ± 0.57 | 51.30-53.5 ± 0.89 | 54.50-55.7 ± 0.50 | 22.00-24.00 ±1.04 | 49.50-51.75 ± 1.16 | 55.50-57.00 ± 1.33 | 60.50-62.5 ± 1.63 |
| **1ry.root L./** | 2.65 ± 0.07 | 3.18 ± 0.02 | 4.39 ± 0.06 | 3.29 ± 0.19 | 4.07 ± 0.10 | 4.36 ± 0.13 | 3.69 ± 0.13 |
| **Stem color** | 2 | 1 | 3 | 3 | 1 | 2 | 2 |
| **No.of lat. Bran.** | 2-3 | 7 ± 0.75 | 8 ± 0.49 | 2±0.75 | 9±0.49 | 11±0.49 | 18±1.02 |
| **Hair D.** | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| **Hair T.** | 2 | 2 | 2 | 1 | 1 | 2 | 2 |
| **Hair P.** | 1 | 1 | 2 | 2 | 1 | 1 | 1 |
| **T.No.of leaf** | 70-75 | 66-69 ± 0.49 | 110-117 ± 2.06 | 13-18±1.17 | 125-140±4.64 | 110-128±3.8 | 135-158±3.83 |
| **Leaf color** | 1 | 1 | 1 | 3 | 1 | 2 | 2 |
| **Leaf L.** | 5.18 ± 0.09 | 5.64 ± 0.10 | 5.76 ± 0.11 | 3.28 ± 0.10 | 5.72 ± 0.17 | 5.28 ± 0.16 | 6.44 ± 0.10 |
| **Leaf W.** | 2.10 ± 0.04 | 3.14 ± 0.05 | 3.56 ± 0.16 | 2.02 ± 0.04 | 3.16 ± 0.04 | 2.28 ± 0.06 | 4.00 ± 0.06 |
| **Leaf Shape** | 2 | 2 | 1 | 1 | 1 | 2 | 2 |
| **Leaf apex** | 1 | 1 | 2 | 2 | 1 | 2 | 1 |
| **Leaf sym.** | 1 | 2 | 1 | 1 | 1 | 2 | 1 |
| **Leaf Hair** | 2 | 1 | 2 | 1 | 1 | 1 | 1 |
| **L.T.of hair** | 2 | 1 | 2 | 1 | 1 | 1 | 1 |
| **Epid.Blad.** | 1 | 2 | 2 | 2 | 2 | 2 | 3 |
| **No.lat.bran.** | 0 | 5.0 ± 0.24 | 7.0 ± 0.51 | 1.0 ± 0.24 | 2.0 ± 0.40 | 8.0 ± 0.58 | 16.0 ± 1.03 |
| **Lat.bran.L.** | 10.4 ± 0.80 | 12.3 ± 0.83 | 14.9 ± 0.78 | 0.80 ± 0.51 | 3.00 ± 0.27 | 17.32 ± 0.63 | 21.1 ± 1.13 |
| **Bract color** | 1 | 2 | 1 | 2 | 1 | 1 | 2 |
| **Flower pres.** | 1 | 2 | 2 | 1 | 2 | 2 | 2 |
| **Pollen maturity** | 2 | 1 | 1 | 1 | 2 | 2 | 2 |
| **Pollen shape** | 18.84 ± 0.034 | 3 | 1 | 1 | 3 | 3 | 2 |
| **Pollen L.** | 21.84 ± 0.034 | 17.93 ± 0.32 | ---- | ---- | 18.01 ± 0.39 | 18.58 ± 0.63 | 17.03 ± 0.63 |
| **Pollen W.** | 1 | 20.12 ± 0.64 | ---- | ---- | 21.38 ± 0.56 | 21.65 ± 0.66 | 17.03 ± 0.66 |
| **Seed Pres.** | 0.78 ± 0.35 | 2 | 2 | 1 | 2 | 2 | 1 |
| **Seed L.** | 0.45 ± 0.21 | 1.40 ± 0.22 | 1.26 ± 0.33 | ---- | 1.08 ± 0.33 | 1.08 ± 0.12 | ---- |
| **Seed W.** | 1 | 0.64 ± 0.36 | 0.62 ± 0.52 | ---- | 0.68 ± 0.41 | 0.74 ± 0.08 | ---- |
| **Seed shape** | 2 | 2 | 2 | --- | 3 | 3 | --- |
| **Microp.shape** | 2 | 3 | 3 | --- | 2 | 2 | --- |

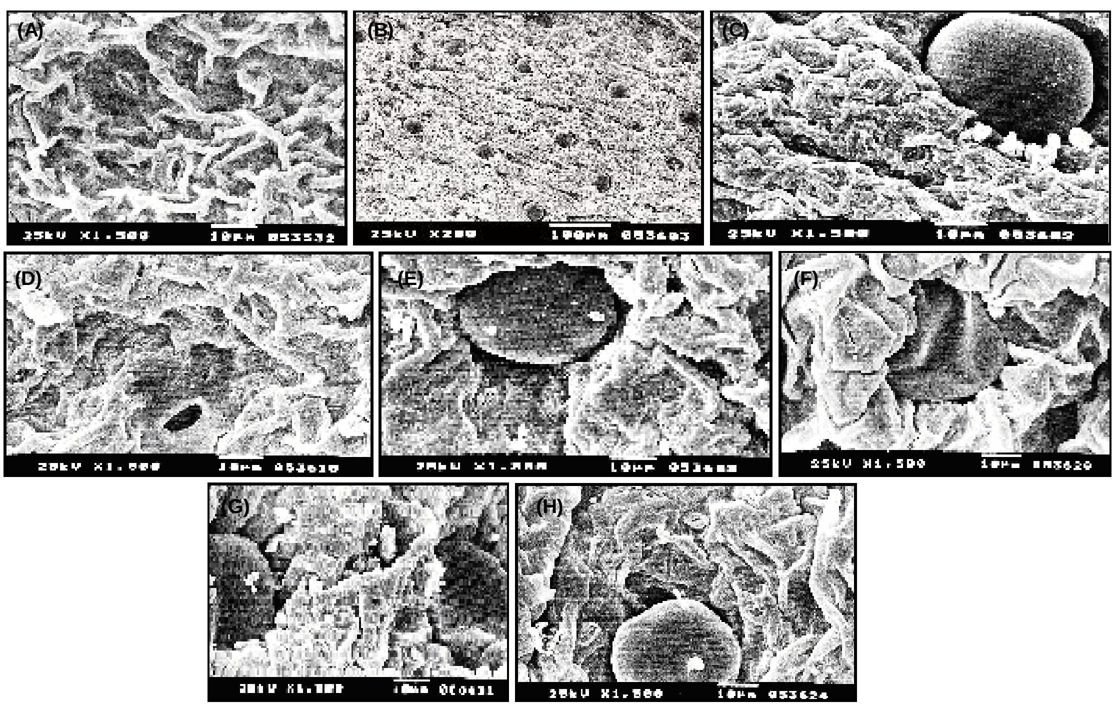


**Plate (4):** Lower leaf surfaces by SEM showing bladder-like structures in the buried magnets plants compared with the control and aerial magnet (0.22mT) without these structures and in plants resulted from two, four and six pre exposure seed cycles, **(A)** Lower leaf surface of the control plant, **(B, C)** lower leaf surface of the treated plant under the influence of 0.44 mT buried magnet shows bladder-like cells, **(D)** Lower leaf surface in plants under aerial magnet 0.22mT, **(E)** Lower leaf surface in plants under surface magnet 1.42mT, **(F)** two cycles, **(G)** four cycles, and **(H)** six cycles.

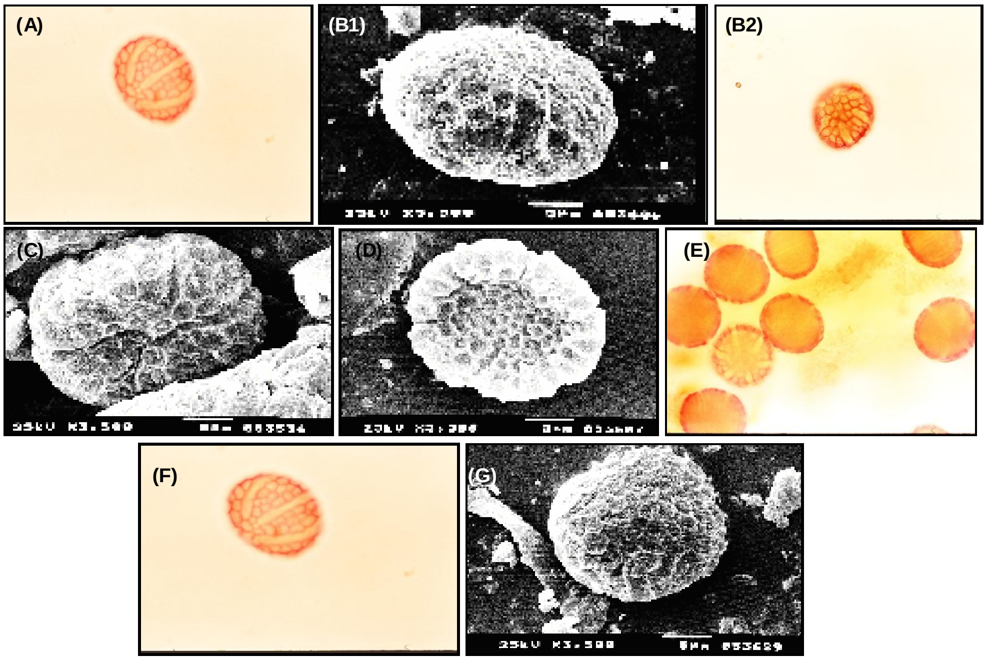


**Plate (5):** Pollen grains of both the control and treated plants by both light and scanning microscopes. **(A)** pollen grain of the control (L.M.) x=1000**, (B)** pollen grain of plants under buried magnet 0.35mT **(B1)** SEM (buried magnet), **(B2)** buried magnet L. M. x=1000, **(C)** Pollen grain of 0.71mT, buried magnet (SEM), **(D)** Pollen grain of 1.42 m T surface magnet (SEM), **(E)** P.G. five cycles x=1000(LM), **(F)** P.G. four cycles x=1000 (LM) **(G)** Pollen grains of five cycles (SEM).

regimes than in the soil surface regime. Correlation analysis between the most affected characters; root length, shoot length, ratio between them, number of lateral branches, total number of leaves beside their lengths and widths and number of inflorescences and their lengths; by the number of exposure cycles to magnetic force are shown in table (4). From table 4 we can find that the number of branches and inflorescence are very highly correlated with the number of exposure cycles. The shoot length decreased with the increase in the number of exposure cycles and the root system length decreased with the increase in the ratio between shoot and root systems. From table 2 we can find that shoot and root system lengths and number of lateral branches and leaves/plant were very highly correlated with most of the investigated characters. In the same time the number of inflorescences/plant is very highly correlated with their lengths.

## DISCUSSION

Throughout evolutionary process, the Earth's magnetic field was a natural component of the environment for all living organisms. Naturally, the Earth's magnetic field is 50 micro-Tesla (Belyavskya, 2004). The Earth's magnetic field started to lose 10 to 15 percent during the last 150 years and this will affect all the living organisms; plants and animals. Broad (2004) expected that the decrease in the Earth's magnetic field will lead to species disorders and extinctions as well as increase the ozone holes and global warming which in turn will decrease the natural magnetic force of the earth.

For that, our research considered both directions (above soil surface and under soil surface), beside the surface one to investigate their effects on the morphological characters of sweet basil plants as well as the pre exposure of the seeds to different doses of constant magnetic force. Our results showed that aerial regime does not affect greatly the germination percentage, while surface regime retarded the germination whereas; the buried one and the pre exposed seeds accelerated the germination in all the forces and cycles used. Also, it was found great variations in root, shoot, leaf, inflorescence and flower maturity of the plants under the three different regimes and the plants resulted from the pre exposed seeds with the different cycles compared with the control. Pollen grains shape and aperture was not greatly affected by the magnetic regimes, but pollen maturity and seed formation varied greatly within the studied treatments. Es`Kov and Darkov (2003) found that magnetic fields can affect the early growth processes of seeds and may be responsible for plant low reproducibility and they called this effect by the magneto biological processes. This opinion might explain the immaturity of the flowers in some treated sweet basil plants. Meanwhile, the change happened in both the root and shoot lengths in treated plants can be explained by the changes happened in the membrane transport processes in root tips as indicated by Stange *et al*. (2002). This opinion was given before by Kato (1988) who observed, as well, that magnetic stimulus may induce an increase in the rate of root growth. The same has been obtained by Namba *et al.* (2003)

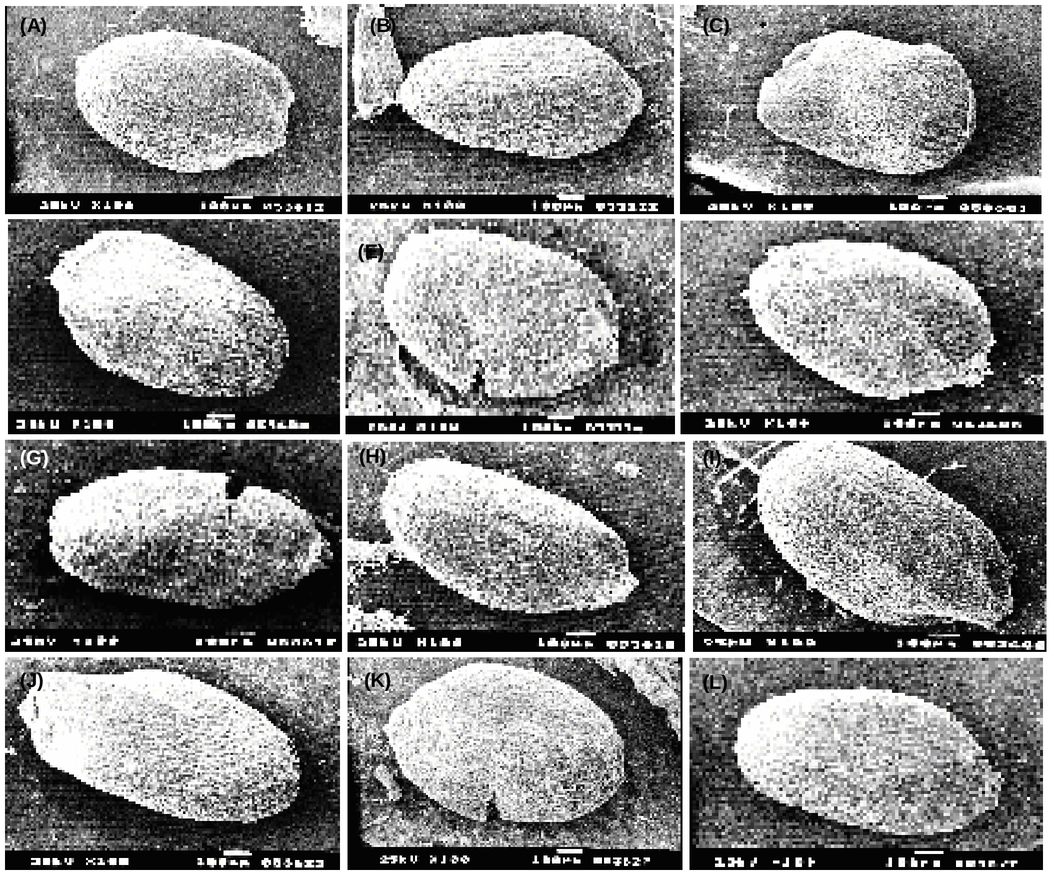

**Plate (6):** Seeds of both control and treated plants of Sweet Basil under SEM showing seed and micropyle shapes, testa ornamentations; **(A)** Seed of the control, **(B)** Seed of 0.36mT surface magnet, **(C)** Seed of 0.44mT buried magnet, **(D)** Seed of 1.42mT surface magnet, **(E)** Seed of 0.35mT buried magnet **(F)** Seed of 0.71mT buried magnet, **(G)** Seed of 0.22mT aerial magnet, **(H)** Seed of 0.31mT aerial magnet, **(I)** Seed one cycle, **(J)** Seed two cycles, **(K)** Seed four cycles, **(L)** Seed five cycles.

who found a significant increase in the plant growth when exposed to magnetic field.

The number of lateral branches and inflorescences, which is greatly increased by the increase in the number of cycles, except the three cycled plants, coordinates with the results of Tkalec *et al.* (2005). They found that a significant decrease in the growth of plants exposed for 2 hour to weak electric field, while the growth is completely inhibited in those exposed to high electric field with longer time. Thus, the increase of lateral branches and inflorescences in the six cycled plants may be due the change in hormonal levels in plants which leads to the production of lateral branches and complete their life cycles quickly as shown by Soja *et al.* (2003) and this can prove the concept of the similar effect of magnetic force on plants to that of drought**.**

Moller and Shykoff (1999) noticed a bilateral or radial asymmetry in the leaves and flowers grown under the effect of environmental stress. The same has been noticed in our experiments, where the leaves become asymmetric according to the effect of magnetic field. The presence of bladder like structures in the leaves may be due to the feeling of drought by the plants under the stress of magnetism; these structures were found by Lyshede (1977) in the epidermal surfaces of the desert plants leaves. Taia *et al.* (2007) concluded that magnetic field cause stress on plants in a way like that of drought.

The extremely low magnetic fields or the high forces may have some physiological disorders, as indicated by Hong (1995). These disorders may cause morphological variations, symmetry and may affect the reproductive cycle of the plant as indicated by Moller and Shykoff (1999). If these effects last for long times it will be inherited and may lead to species morphological variations or gene mutations. Thus magnetic forces cause a kind of stress on the plants which may alter their morphological characters and their life cycle and productivity as well.

From this study we can conclude that magnetism has its effect on the morphological characters of sweet basil (*Ocimum basilicum*) plants, especially the leaf characters beside seed sizes and maturation. Pollen

**Table (3):** Significance and standard deviations for the affected morphological characters by the different magnetic forces in the three regimes.

| Charact. | Above soil surface | | At soil surface | | Under soil surface | |
|---|---|---|---|---|---|---|
| | Sig. | St. D. | Sig. | St. D. | Sig. | St. D. |
| 1rv.root length | 2.245*** | 0.968 | 0.126** | 0.994 | 0.074* | 0.998 |
| shoot system length | 1.703*** | 0.921 | Insig. | ---- | 3.429**** | 0.961 |
| No. lateral branches | 0.3825** | 0.998 | Insig. | ---- | 1.001*** | 0.929 |
| No. total leaves | 1.351*** | 0.999 | Insig. | ----- | 1.714*** | 0.970 |
| Leaf length | 0.207** | 0.989 | 0.022* | 0.999 | 0.257** | 0.931 |
| Leaf width | 0.379** | 0.983 | Insig. | ----- | 0.114** | 0.985 |

Sig.= Significance, Insig. = insignificant, St.D.= Standard deviations**= highly significant
***= very highly significant

**Table (4):** Correlations between the most significant morphological characters and the number of exposure cycles.

| | Correlation coefficient | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Var. | Cy. | R.L. | Sh.L. | Sh./R. | No.B. | T.L.No. | Leaf L. | Leah W. | No.Infl. | Infl. L. |
| Cy. | 1.00 | 0.35 | -0.13 | 0.61 | 0.46 | 0.56 | 0.24 | 0.36 | 0.64 | 0.32 |
| R.L. | 0.35 | 1.00 | 0.69 | -0.26 | 0.63 | 0.52 | 0.79 | 0.42 | 0.76 | 0.66 |
| Sh.L. | -0.13** | 0.69 | 1.00 | 0.51 | 0.87 | 0.89 | 0.94 | 0.71 | 0.64 | 0.82 |
| Sh./R. | 0.61 | 0.26-** | 0.51 | 1.00 | 0.63 | 0.58 | 0.32 | 0.40 | 0.36 | 0.28 |
| No.B. | 0.63*** | 0.63* | 0.87* | 0.63* | 1.00 | 0.98 | 0.93 | 0.73 | 0.68 | 0.58 |
| T.L.No. | 0.56 | 0.52 | 0.89* | 0.58 | 0.98* | 1.00 | 0.89 | 0.71 | 0.53 | 0.64 |
| Leaf L. | 0.24 | 0.79* | 0.94* | 0.32 | 0.93* | 0.89* | 1.00 | 0.79 | 0.69 | 0.70 |
| Leaf W | 0.36 | 0.42 | 0.71* | 0.40 | 0.73* | 0.71* | 0.79* | 1.00 | 0.68 | 0.51 |
| No.Infl. | 0.64*** | 0.76* | 0.64* | 0.36 | 0.68* | 0.53 | 0.69* | 0.68* | 1.00 | 0.89 |
| Infl.L. | 0.32 | 0.66* | 0.82* | 0.28 | 0.58 | 0.64* | 0.70* | 0.51 | 0.89* | 1.00 |

*Characters very highly correlated with each others.
** Negative correlations means that correlation is reversible i.e. when one variable increases the second decreases.
***Characters highly correlated with the number of exposure cycles.
Correlations are significant when the value is more than 0.05. Variables : Cy=number of exposure cycles; R.L.=root system length; Sh.L.=shoot system length; Sh./R.=ratio between shoot length and root length; No.B.=number of lateral branches; T.L.No.=total number of leaves; Leaf L.=leaf length; Leaf W.= leaf width; No.Infl.=number of inflorescences; Infl.L.=inflorescence length.

grain shapes can be slightly affected, but shape and numbers of apertures are constant characters. Accordingly we have to reconsider the environmental disorders in studying the morphological characters of the plants in taxonomy. We can conclude that applying few magnetic cycles to the seeds can stimulate the embryo and activate the physiological processes of the plants without disturbing the morphological characters of sweet basil plants. Whereas, many cycles seeds resulted in some morphological disturbance in sweet basil plants since all the physiological processes and water relations are affected and accordingly can alter its morphological characters. Magnetism has significant effect on the studied morphological characters of plants but the more fixed characters are those of pollen grains and seed coat ornamentations on which we can relay on identifications and constructing taxonomical keys.

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# تأثير القوى المغناطيسية الساكنة على بعض الصفات الشكليه في نبات الريحان (الفصيلة الشفوية)

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## الملخص العربــــي

ستة وثلاثون صفه من صفات الشكل الخارجي قد تم دراستها في نبات الريحان النامي تحت تأثير قوى مغناطيسية مختلفة الشدة والمنبعثة من قطع مغناطيسية موضوعة في أماكن مختلفة. المجموعة الأولي تم وضع القطع المغناطيسية معلقة في الهواء علي ارتفاع 25 سم من سطح التربة والمجموعة الثانية تم وضع القطع المغناطيسية علي سطح التربة وفي منتصف الأصص، أما المجموعة الثالثة فقد دفنت القطع المغناطيسية في منتصف الأصص وعلي عمق 10سم. تم دراسة تأثير ثلاث قوى مختلفة داخل كل مجموعة بجانب المجموعة الضابطة كما تم عمل ثلاث مكررات من كل قوة في كل النظم المدروسة بكل أصيص 100 بذرة موضوعة علي محيط دائرة ثابت وتم قياس القوة المغناطيسية عند موضع البذور . كما تم دراسة تأثير تعرض البذور لعدد دورات مختلفة لقوه مغناطيسية معلومة الشدة قبل الزراعة علي الصفات الشكلية للنباتات الناتجة.

تم ملاحظة نسب الإنبات والصفات الشكلية للنباتات الناتجة في كل الأصص وتدوينها يوميا . وبعد مضي ثلاث أشهر تم حصاد كل النباتات ودراستهم دراسة تفصيلية لتدوين الاختلافات في الصفات الشكلية وصفات النورات والأزهار وحبوب اللقاح والبذور ومقارنتها بالنباتات الضابطة. كما تم عمل تحليل إحصائي لتقييم الاختلافات الناتجة ومدى تأثرها بالقوى المختلفة داخل كل نظام مغناطيسي .

من النتائج التي وصلنا إليها وجدنا أن القوى المغناطيسية المختلفة داخل النظم المغناطيسية الثلاث قد أثرت علي الصفات الشكلية لنبات الريحان بجانب تأثيرها علي نضج الأزهار وتكوين وشكل حبوب اللقاح والبذور بالإضافة إلي شكل النقير. ومن الصفات التي تأثرت تأثرا شديدا طول كل من المجموع الخضري والجذري والعدد الكلي للأفرع الهوائية والأوراق الكلية علي النبات بالإضافة إلي شكل ولون الأوراق الخضرية وأيضا طول وعدد الأفرع الحاملة للنورات.

وكان أكثر النباتات تأثرا هم الناميين تحت تأثير المغناطيس المعلق في الهواء يليه تلك الناميين تحت تأثير المغناطيس المدفون تحت سطح التربة, بينما النباتات النامية تحت تأثير المغناطيس السطحي فكانت أقلهم تأثيرا. أختلافات القوى المغناطيسية داخل كل نظام مغناطيسي لم يعطي تأثيرا معنويا علي حده ولكن التأثيرات كانت ناتجة من النظام المغناطيسي بشكل عام. كما كانت النباتات الناتجة من بذور معرضة لعدد دورات قليلة قبل الزراعة قد تحسنت صفاتهم التصنيفية المظهرية. بينما النباتات النامية من تعرض البذور إلى ثلاث دورات مغناطيسية قد أظهر عليها الإعياء الشديد حيث تقزمت وكانت الجذور الثانوية بها عديدة كما أن نضج حبوب اللقاح والبذور قد تأثرت تأثرا بليغا. بينما النباتات الناتجة من أربع وخمس وست دورات بدأت أحوال النبات في التحسن والتأقلم وبدأت الأفرع الجانبية والأوراق في الزيادة. ولكن يبدو أن العمليات الفسيولوجية بالنبات قد تأثرت أيضا حيث أزداد عدد الأفرع الهوائية الحاملة للنورات ولون القنابات بشكل معنوي كلما زادت عدد الدورات المغناطيسية كما تأثر شكل الخارجي للأوراق.

من هذه الدراسة يمكننا استنتاج أن النظم المغناطيسية لها تأثير واضح علي نبات الريحان, مما قد يغير من صفاته الشكلية الخارجية وعلى نضج البذور وحبوب اللقاح. كما يمكننا أن نستنتج أن تعرض البذور إلى جرعات مغناطيسية ضئيلة قد يحسن الصفات الشكلية لنبات الريحان دون التأثير على عملياته الفسيولوجية, بينما زيادة الجرعات المغناطيسية قد تحسن من الصفات الشكلية للنبات ولكن سوف يكون لها تأثير على العمليات الفسيولوجية للنبات مشابه إلي حد كبير لتأثير الجفاف عليه, وبالتالي على نضج كل من حبوب اللقاح والبذور وحيويتهم.

ولذا فعلينا أن نأخذ صفات أكثر ثباتا في عمل المفاتيح التصنيفية ودراسة الفلورات المختلفة خاصة في ظل الضغوط البيئية الواقعة على النباتات في يومنا هذا.