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Effects of electromagnetic fields produced by high voltage transmission on physiology of *Juglans regia* L. and *Cerasus avium* L. Moench

Yüksek voltajlı gerilim hattı ile oluşturulan elektromanyetik alanların *Juglans regia* L. ve *Cerasus avium* L. Moench'nın fizyolojisi üzerine etkileri

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Key Words:

Electromagnetic fields, high voltage, abscisic acid, indole-3-acetic acid, gibberellic acid

ABSTRACT

We studied the hormone contents of *Juglans regia* L. (walnut) and *Cerasus avium* L. Moench (cherry) exposed to electromagnetic fields of high voltage transmission line and the effects of the exposure on the physiology of plants. While an increase was observed in abscisic acid (ABA) contents, decreases were observed in gibberellic acid (GA_3) contents and in the chlorophyll a, b quantities of these plants, compared to the control groups. The indole-3-acetic acid (IAA) content exhibited a species specific property with an increase in *Juglans regia* and a decrease in *Cerasus avium* plants.
According to physiological effects, high voltage had negative effects to the growth and development of the plants and their leaf thickness and leaf mesophyll show modifications as densely packed mesophyll in leaf anatomies of plants. Oil cell increases were observed only in the anatomical cross sections of leaves of *Cerasus avium* L. Moench.

Anahtar Sözcükler:

Elektromanyetik alanlar, yüksek voltaj, absisik asit, indol-3-asetik asit, gibberellik asit

ÖZET

Yüksek gerilim hattının, elektromanyetik alanlarına maruz kalmış olan*Juglans regia* L. (ceviz) ve *Cerasus avium* L. Moench (kiraz) bitkilerinin hormon içerikleri ve bitkilerin fizyolojisi üzerine etkileri incelenmiştir. Sonuçlarımızda, Absisik asit (ABA) içeriği artarken, gibberellik asit (GA3) miktarı azalmış, klorofil a ve b içeriklerinde de bir azalış olduğu kontrol grubu ile karşılaştırıldığında gözlenmiştir. İndole-3-asetik asit (IAA) miktarı *Juglans regia 'da* artış ve *Cerasus avium'da* bir azalış ile türe özgün bir özellik sergilemektedir. Fizyolojik etkilerine göre yüksek voltajın büyüme ve gelişme ve yaprak kalınlığı üzerine negatif etkileri vardır ve bitkilerin yaprak anatomilerinde yaprak mezofili daha yoğun paketlenmiş mezofil olarak modifikasyonlar göstermektedir. Sadece *Cerasus avium* L. Moench yaprak anatomik enine kesitlerinde yağ hücrelerinde artış gözlenmektedir.

INTRODUCTION

Field studies of plants and crops exposed to 50-60 Hz (high voltage power lines deliver) revealed no destructive effects in the field. It is well known that trees suffer damage at electric field strengths far above ICNIRP (International Commission on Non Ionizing Radiation Protection)'s levels due to corona discharge at the tips of the leaves. Such field levels are found only at places close to very high voltage power lines (Matthes et.al., 2000).

Epidemiological studies were performed on the effects of extremely low frequency-electromagnetic fields (ELF-EMF) on plant life. These include the experiments carried out on spruce seedlings, chestnut buds, wheat seeds and broad beans (Ruzic et.al., 1993; 1998; Aksenov et.al.,1996; Rapley et.al., 1998). During various phases of intensive growth and (or) in sub optimal environmental conditions (physiological stress), plant systems are prone to exhibit greater sensitivity to extremely low frequency electromagnetic fields. When the spruce seeds (Ruzic et.al., 1998) were subjected to 26 and 105 μT (50 Hz) on the first day an increase but then a decrease was observed in the release of esterase enzymes,, after the swelling course of wheat seeds with the breakage of seed dormancy (Aksenov et.al., 1996). Also, in Vicia faba seedlings exposed to varying magnetic field intensities at different frequencies (0 Hz) 5mT, (50 Hz) 1.5 mT, (60 Hz) 1.5 mT, (75 Hz) 1.5 mT, only prophase was observed through all of the mitotic phases (Rapley et.al., 1998). Rajendra et.al. (2005) suggested that exposure to power frequency electromagnetic fields up to 100 μT did not cause any permanent damage to germinating seedlings since the initial decrease in some important housekeeping enzymes involved in the onset of seed germination under the magnetic fields returned to control values on the 8th day of growth.

Besides the laboratory experiments, there are some studies investigating the effects of high tension line between Austria and the Czech Republic on wheat and corn cultivation (Saya et.al., 2003). Corridor effects of transmission lines on survival rates of endangered Kern mallow plants in California were reported (California State Univ., 2005). This experimental investigation was carried out to evaluate the growth and physiological parameters and activity of basic internal hormones of *Juglans regia* L. (walnut), *Cerasus avium* L. Moench (cherry) trees grown under electrical power transmission lines in Turkey.

MATERIALS AND METHODS

Juglans regia L. (walnut), *Cerasus avium* L. Moench (cherry) trees which are grown under high voltage lines in the gardens of Ege University Hospital and the cherry gardens in Kemalpaşa town were used as material.

Hormone analysis

Hormone analysis was performed with 15 g leaf samples taken from the walnut and cherry trees as three samples for treated and control group far from the power lines.

Scott and Jacops (1964) method used for the extraction of internal hormones was modified by Yürekli (1980) and he extracted internal hormones [indole-3-acetic acid (IAA), abscisic acid (ABA) and gibberellin (GA_3)] of *Juglans regia* L. and *Cerasus avium* L. Moench trees grown under the power lines and far from the power lines. Nitsch and Nitsch's (1955) method was applied for the isolation of these hormones. Quantitative measurements were performed for IAA by Fletcher and Zalik (1963) modified by Yürekli (1980) and ABA by Milborrow (1970) modified by Yürekli (1980) spectrophotometrically. The growth test of lettuce hypocothyl was used in quantitative measurements of gibberellins by Frakland and Waring (1960) from the leaf samples of walnut and cherries. The biological activity of GA_3 was determined by analysis of variance (Steel and Torrie, 1980).

Pigment analysis

Leaf samples taken from walnut and cherry plants were extracted with acetone (80%) on a water bath of 80°C for 30′ and chlorophyll a and b determination was performed according to Witham (1971).

Physiological parameters

Physiological variables were expressed as fresh weight and dry weight of cherry leaves at the same size selected under the power transmission line relative to controls. One hundred leaves were selected for each experiment.

Anatomical cross sections were prepared from the leaves of the walnut and cherry plants in 70% alcohol with hand and razor blade. Sections were stained with Sartur reactive (Çelebioğlu and Baytop, 1949) and photographs were taken with Jena microscope. Leaf thicknesses were measured in Visopan as microns from the anatomical cross sections.

RESULTS

Evaluation of physiological parameters and pigment constituents

There were significant decreases between the fresh and dry weight of cherry plant leaves under power lines and those of the control group (Figure 1).

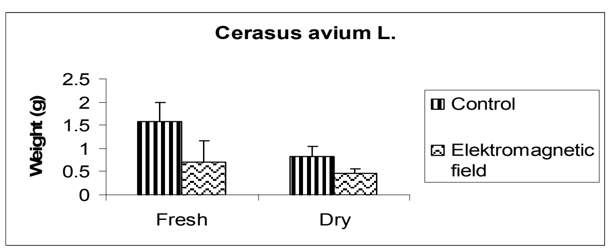


Figure 1. Fresh and dry weights of cherry plant leaves under power lines and control.

Chlorophyll a, chlorophyll b and chlorophyll a+b (total chlorophyll) contents of cherry leaves growing under high voltage lines were 588.477%, 851.528% and 715.344% respectively, and these values were lower than those of the control leaves (Figure 2).

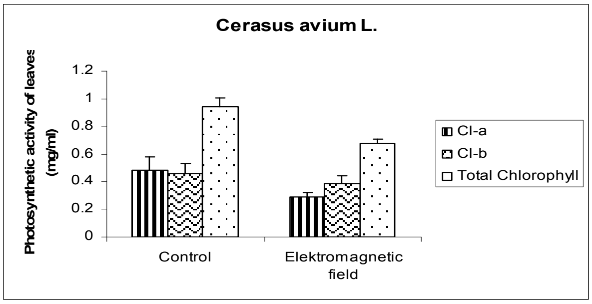


Figure 2. Chlorophyll contents of cherry plant leaves under power lines and control

The ratio of chlorophyll a/b was 0.73 in the leaves of cherry plants growing under power lines while this ratio was 1.06 in the control group.

Hormone analysis

The contents of ABA hormone in walnut and cherry plants exposed to high voltage increased in significantly higher ratios (155% in walnut and 112% in cherry plants) than those in the control groups. In contrary, the IAA contents of each plant revealed different results. While IAA contents of walnut increased significantly (141%) under the high voltage lines, in cherry plants this correlation between IAA and ABA contents was not significant to take into consideration. Cherry plants had similar results approximately, but there was a little decrease in IAA content of leaves under power lines as compared to controls (Figure 3, 4).

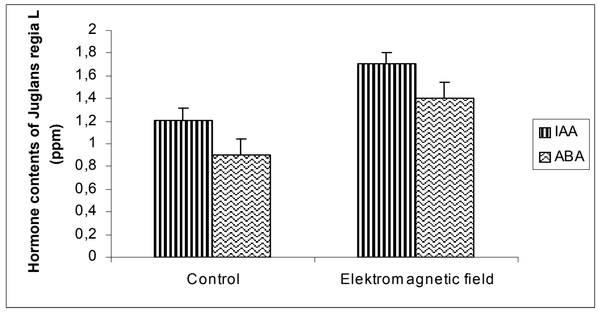


Figure 3.AA and ABA contents of cherry plant leaves under power lines and control plants.

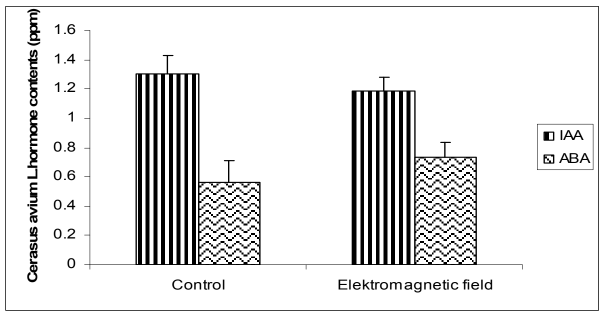
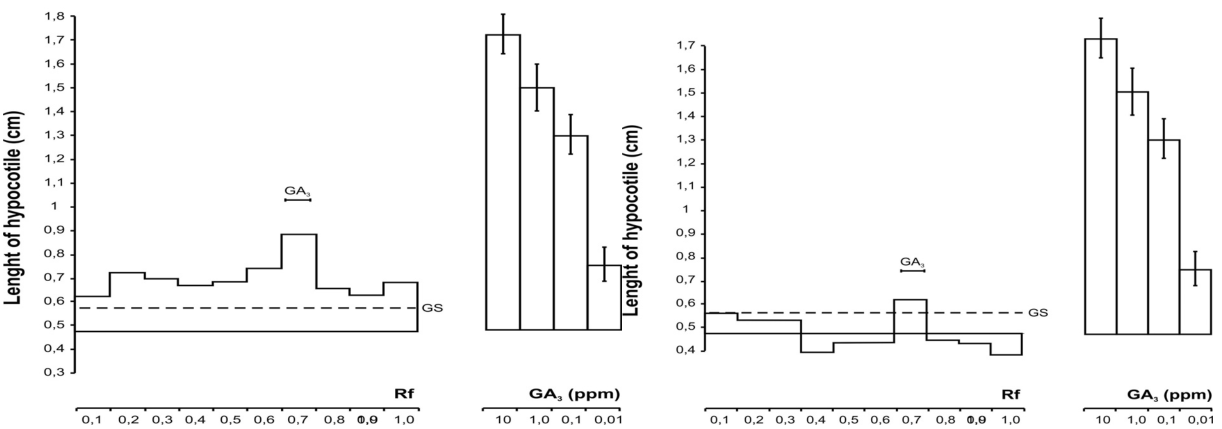


Figure 4. IAA and ABA contents of walnut tree leaves under power lines and control plants.

GA_3 contents decreased in each of the plants under high voltage lines as compared to control groups (Figure 5, 6).



a b

Figure 5. Biological activity chromatograms of endogen GA_3 isolated from *Juglans regia* leaves, a. control plant; b. under power lines by lettuce hypocotyll test. GS: emergency border.

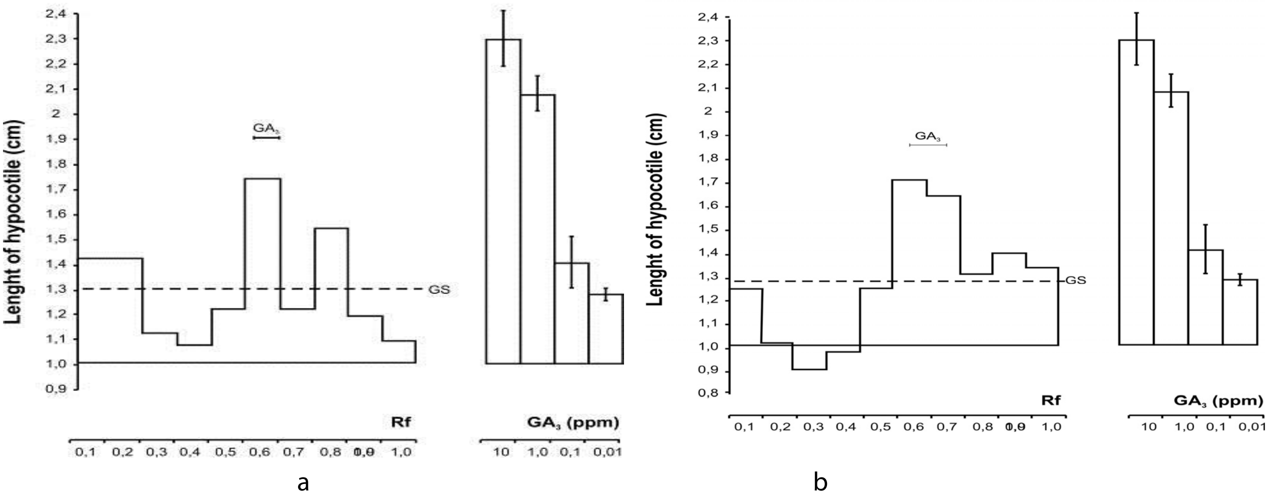


Figure 6. Biological activity chromatograms of endogen GA_3 isolated from *Cerasus avium* leaves, a. control plants; b. under power lines by lettuce hypocotyll test. GS: emergency border

Anatomical results

The thickness of the walnut and cherry leaves decreased and leaf mesophyll was densely packed grown under the high voltage line as compared to control groups (Figure 7, 8). But in the cross-section of the cherry leaves, the oil cells in the cortex tissue of primary vascular bundle significantly increased (Figure 9).

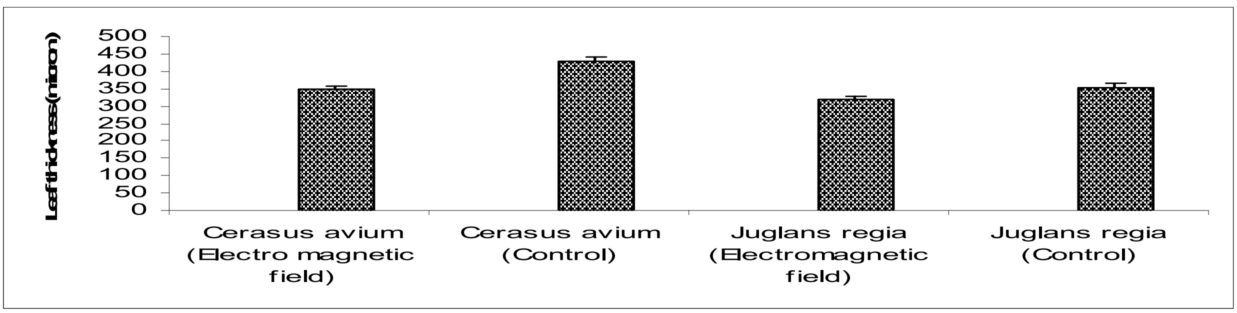
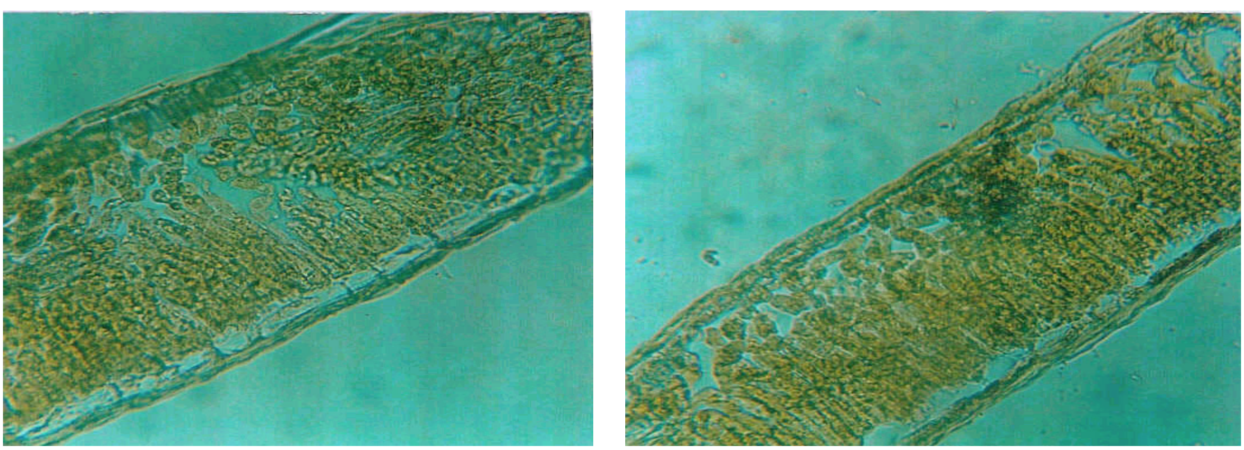
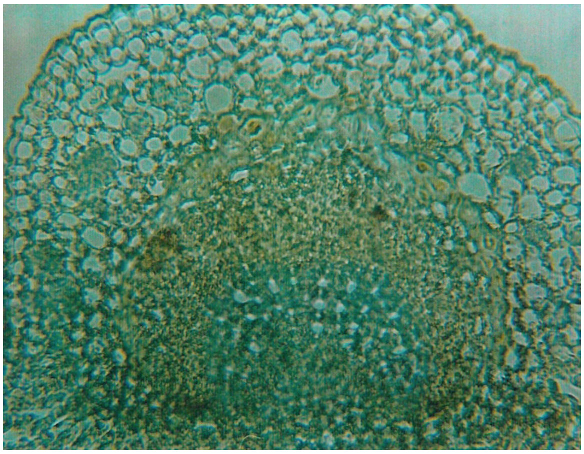


Figure 7. Leaf thickness of walnut and cherry plants under power lines and control plants



a b

Figure 8. Cross-sections of leaves of *Cerasus avium* a. Control, b. under power lines.1cm= 80 µ.


a

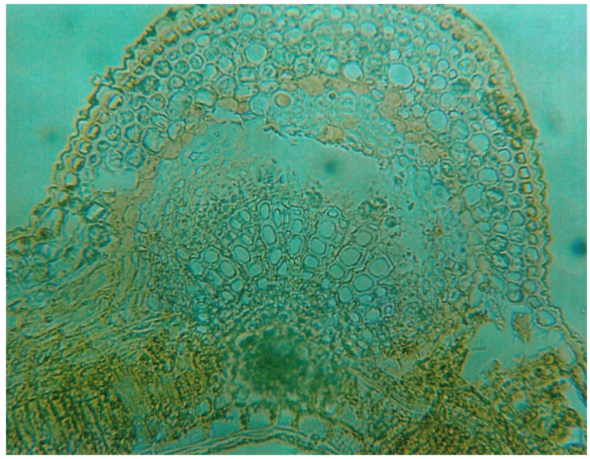

b

Figure 9. Cross-sections of leaf middle veins of *Cerasus avium* a. Control, b. under power lines. 1cm= 80 µ

DISCUSSION

The growth and development of *Cerasus avium* L. was inhibited under the power lines because of the decreasement of dry and fresh weights and photosynthetic pigments as chlorophyll a, b and total chlorophyll amounts of their leaves as compared to control groups of plants. Although there are many reports in the literature that plant growth is stimulated under high voltage lines, work on this as a possible means of increasing agricultural yield began in the early 1900s and continued for several decades under the name electro-culture. It was later abandoned because the results were not always consistent and the growth was often worse if the fields were cultivated under dry conditions (Young, 1997). According to investigations conducted with some (50 Hz) magnetic field forces applied to different germinating plants (Aksenov et. al., 1996; Ruzic et. al., 1993), inhibitory effects of magnetic fields were improved after the initial measurements of the first days' germination. The diversity of responses among the studied species and seasons is in agreement with the existence of several reports on the difficult repeatability of experiments with magnetic fields (Ruzic et.al., 1992). It seems that biological systems are prone to exhibit greater sensitivity to low fields during phases of intensive growth (Penuelas et.al., 2004) and in suboptimal environmental conditions such as under drought stress (Ruzic et. al., 1998 a) or under acid environments (Ruzic et. al., 1998 b).

Perception mechanisms of magnetic and electro-magnetic fields which were present together in high voltage were attributed to radical pair mechanism and the ion cyclotron resonance (ICR). The growth of plants exposed to Ca^{+2}-ICR was shorter and plant weight was lower as compared to the controls. Also, total chlorophyll (a+b) contents decreased. When a continued cultivation of adult plants under natural conditions without any artificial electromagnetic fields showed a retardation of the originally Ca^{+2}-ICR exposed plants compared to control cultures lasting several weeks, with an increased tendency for hydration (Pazur et. al., 2006).

ABA hormone is known to be responsible for drought stress. This seems with the high ABA and IAA values which come from the tolerance of *Juglans regia* to magnetic fields of power lines without reducing their growth and development under drought conditions of power lines but contrary adjusting its osmotic pressure by accumulating sorbitol during drought stress (La Bianco et. al., 2000). Endogenous levels of ABA increase in response to a variety of stresses, including drought, salinity and low temperature, and ABA is thought to modulate the response of plants to these stresses (Zeevaart, 1988). The reduction of IAA is not mediated by a concomitant increase in endogenous ABA, like in *Cerasus avium* L. under magnetic fields and IAA performs a complementary but independent function by increasing the hydraulic conductivity of the plant (e.g. like *Juglans regia*), if we assume that the restriction of water loss through the ABA-regulated stomatal function is critical to maintaining plant turgor (Dunlop et.al., 1996). All these above mentioned responses occur in NaCl stress. So, we can mention here that power transmission lines revealed the similar stress effects of NaCl on endogenous hormones of IAA and ABA (Zhang et.al., 2006).

Also, Wang et al. (2001) defined that ABA and JA (jasmonic acid) generally increased and IAA and SA (salicylic acid) declined in response to salinity. The abundant increase of oil cells in cross-sections of *Cerasus avium* leaves explain the correlation between these endogenous hormones. Oil cells may increase because of JA increasement which is known to be a lipid signaling molecule (Weber, 2002; Kang et.al., 2005).

Leaf thickness (33%) observed in shade leaves of walnut trees relative to sun leaves suggest the occurrence of large modifications of mesophyll structure and organization and a less densely packed mesophyll (Piel et. al., 2002). According to the high decreasement with 18.96% in *Cerasus avium* leaf thickness relative to *Juglans regia* confirmed that cherry leaves are highly responsive to magnetic fields from power lines like the sun leaves. Because lower leaf area, leaf thickness and leaf mass per area together with lower amounts of nitrogen and Rubisco per leaf area, photosynthetic capacity on a leaf area basis, and lower stomatal conductance have commonly been reported in shade leaves as compared with leaves grown in high light environments (Le Roux et. al., 1999 a, b, 2001 a). It is mentioned that an increase in leaf thickness may allow consequent increase of photosynthetic capacity per unit area, offering adaptive advantages in xerothermic environments (Nikolopoulos et. al., 2002).

We conclude by noticing that the present experiment have been performed under high voltage (power) transmission lines (0.1-10 mG and 50-60 Hz) had similar responses shown to NaCl stress with different plants by regulating contents of endogenous IAA and ABA hormones. However, the cherry and walnut plants under power lines showed similarities to the shade plants leaves in the anatomical cross-sections with a lower thickness of their leaves. Meanwhile, it is noteworthy to mention that exposing all the wild-type tomato plants to 900 MHz electromagnetic radiation for 10 minutes evoked rapid and substantial accumulation of basic leucine-zipper transcription factor m RNA [which is known to regulate the response to salt stress (Lorenzo et al., 2009)] in terminal leaf with kinetics very similar to that seen in response to wounding, while in abscisic acid (ABA) mutant, the response was more rapid, but transient (Beaubois et al., 2007).

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