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BRIEF COMMUNICATION

Effects of microwave treatment on growth, photosynthetic pigments and some metabolites of wheat

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Abstract

Wheat (*Triticum aestivum* L. Sakha 61) grains were exposed to microwave radiation of a wavelength 2.85 cm and frequency 10.525 GHz for 15, 45, or 75 min. The exposed grains were germinated and then harvested after 7 and 14 d. While 15- and 45-min exposure of the grains stimulated seedling shoot length and fresh and dry masses, the exposure for 75 min had no pronounced effects. 15 and 75-min irradiation increased succulence and pigment contents in 7- and 14-d-old seedlings. While the ratios chlorophyll (Chl) *a*/*b*, carotenoids (Car)/Chl were higher in 7-d-old seedlings than in the control ones for all doses, they decreased in 14-d-old seedlings. The microwave radiation increased protein and amino acid contents, but decreased the contents of saccharides, nucleic acids, and phenolic compounds. Low dose (15 min) stimulated proline synthesis, whereas the other doses showed negative effect on its production.

Additional key words: amino acids, carotenoids, chlorophylls, nucleic acids, phenols, proline, proteins, saccharides.

Microwave is the name given to electromagnetic waves arising as radiation from electrical disturbances of the high frequencies (Fuller 1979). It embraces the frequency range of 1 to 10 GHz and a characteristic wavelength range of 30 cm to 0.3 mm. Due to the wide and growing use of mobiles and other microwave applications there has been an increasing concern about their toxic and side effects (Hermann *et al*. 1997, Adey *et al*. 1999). High frequency of microwave (up to 2.45 GHz) releases a large amount of energy to the tissues during exposure, which is directly proportional to the wavelength frequency. The microwave thermal effect can produce harmful or lethal effects on the cell, without breaking the chemical bonds and can affect the charged particles leading to orienting the dipolar molecules or including voltage changes across the cell membrane (Chiang *et al*. 1989).

In winter and spring wheat, spring barley, oat, rice, mustard and rye (Rao *et al*. 1989, Hu *et al*. 1994, Kozai *et al*. 1995, Creanga *et al*. 1996, Ponomarev *et al*. 1996) microwave improved germination percentage, plant height and fresh mass, and growth of buds. However, these effects varied among species and depended on the duration of irradiation (Ponomarev *et al*. 1996). The effect of microwave also depended on its source, *e.g*. the cucumber grew better under microwave-powered sulfur lamps than under metal halide lamps (Krizek *et al*. 1998).

Microwave affected photosynthetic pigment contents in treated rye seedlings, especially when the samples were also treated with aqueous solution of KNO_3 (Creanga *et al*. 1996). Sicher (1997) observed leaf yellowing in 17-d-old barley under high-irradiance discharge lamps (irradiance of 800 μmol(photon) m^{-2} s^{-1}). He found also leaf yellowing on primary leaves of plants grown under microwave-powered sulfur lamps at 800 but not 550 μmol m^{-2} s^{-1}.

The present study aimed to find out the effect of different microwave doses applied to dry seeds on growth and some metabolites of wheat seedlings.

The dry grains (*Triticum aestivum* L. cv. Sakha 61) obtained from the Ministry of Agriculture, Egypt were irradiated by *Microwave Optics* model *WA-9314 B* in Physics Department, Tanta University, Egypt. This system used 2.85 cm wavelength transmitter and a receiver with variable amplification. The unit consists of

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Abbreviations: Car - carotenoids; Chl - chlorophyll.
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a Gunn diode in a 10.525 GHz resonant cavity, a microwave horn to direct the output, and an 18 cm stand to help reduce table top reflections. The Gunn diode acts as a non-linear resistor that oscillates in the microwave band. Wheat grains were set in a thin colourless transparent plastic bag attached to the horn (as used by Mashaly 2001). The quantum energy of the used wavelength was 4.36×10^{-5} eV. Irradiation of dry grains was carried out for 0, 15, 45, and 75 min. Irradiated grains were distributed in Petri dishes on a moist filter paper with about 5 cm^3 distilled water. Grain germination was carried out in the dark using thick black bag for 4 d, then under natural light. The temperature ranged between 12 ± 3 °C at night and 22 ± 3 °C at daytime. After 3 d of exposure to natural light, samples were collected and washed thoroughly with distilled water. Records were made for the seedling root and shoot length [cm], fresh and dry masses [mg per seedling], and succulence (Weatherley and Barrs 1962). Succulence = fresh mass/dry mass. The photosynthetic pigments were extracted by 85 % cold atone and estimated according to Metzner *et al*. (1965). Contents of total saccharides, total proteins, nucleic acids, proline, phenolic compounds and amino acids were estimated according to Smith *et al*. (1964), Chaykin (1970), Bates *et al*. (1973), Jindal and Singh (1975), and Lee and Takahashi (1966), respectively. Three replicates were estimated for each determination. The differences in the studied parameters were statistically evaluated by using one-way analysis of variance and the relation between each pair of variables was carried out using simple linear correlation according to Snedecor and Cochran (1980).

The root length of 7-d-old wheat seedlings (Fig. 1) tended to increase after microwave irradiance for 15, 45, and 75 min, compared with the control but the differences were not significant. Different doses of microwave slightly increased (15 and 45 min) or decreased (75 min) shoot length and fresh mass of 7-d-old plants. The dry mass did not significantly change. The seedling succulence increased in the all three doses, compared with the control ($P < 0.001$). In 14-d-old seedlings root and shoot lengths, fresh mass and succulence were significantly increased in all doses. The correlation between shoot length and succulence was positive. The improvement of growth may be attributed to the breakdown of saccharides in grains by irradiation (Braginets 1989, Dario and Salgado 1994) and thus the mobilization of nutrients to the embryo. This was consistent with the work of Ponomarev *et al*. (1996) on oats and barley, Hu *et al*. (1994) and Kozai *et al*. (1995) on rice, and Rao *et al*. (1989) on mustard. However, the improvement also depended on duration of irradiation and age of the plant.

Contents of chlorophyll (Chl) *a*, and carotenoids (Car), of 7-d-old seedlings increased in 15- and 45-min doses and decreased in the 75-min one, compared with the control ($P < 0.001$) (Fig. 1). However, Chl *b* content increased only in the 15-min dose and decreased in the other two doses ($P < 0.01$). The ratios Chl *a*/*b*, Car/Chl *a* and Car/Chl (*a*+*b*) were higher in treated plants than

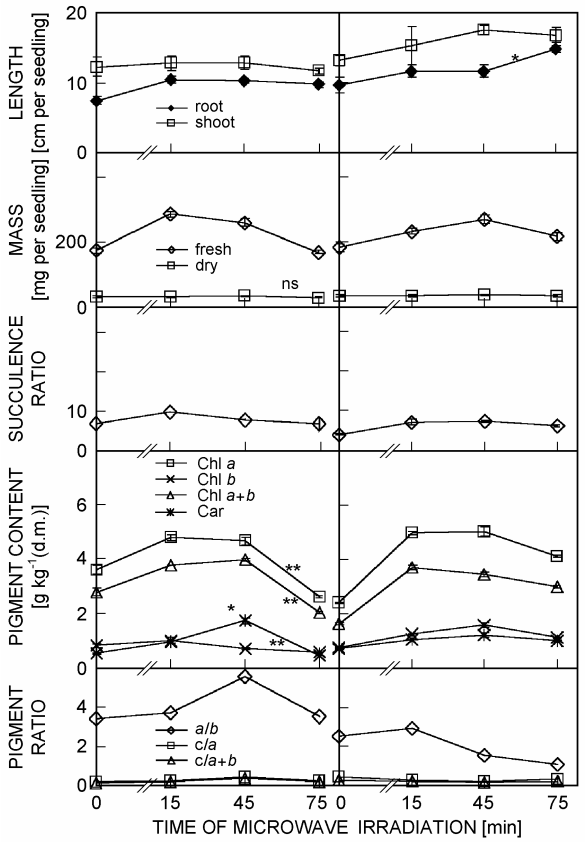

Fig. 1. Root and shoot lengths, fresh and dry masses, succulence, and chlorophyll (Chl) and carotenoid (Car) contents and their ratios of 7- and 14-d-old wheat seedlings in response to microwave irradiation.

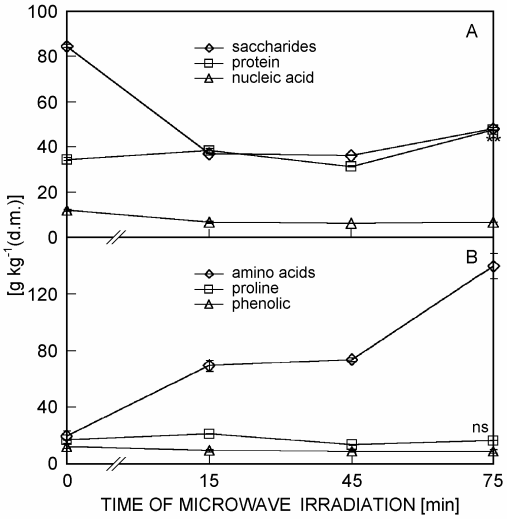

Fig. 2. Contents of saccharides, proteins, nucleic acids, amino acids, proline, and phenolic compounds of 7- and 14-d-old wheat seedlings in response to microwave irradiation.

those in the control. This showed that low doses stimulated pigment contents in 7-d-old seedlings. These results were in agreement with those of Creanga *et al*. (1996) and Cao *et al*. (1998).

Contents of Chl *a*, Chl *b*, and Car increased after 14 d of germination of irradiated grains. However, the ratios Chl *a*/*b* (except for 15 min dose), Car/Chl *a*, and Car/Chl (*a*+*b*) decreased, compared with the control. The seedling leaves were yellowish green. The decrease in Chl *a*/*b* was mainly due to the relative increase of Chl *b* content. This was in agreement with the work of Sicher (1997). In addition, correlations between dry mass, succulence, Chl *a*, Chl *b*, or Car were significant at $P < 0.001$.

Content of total available saccharides (Fig. 2*A*) of 7-d-old seedlings decreased from 84.8 g kg^{-1}(d.m.) in the control to 31.4 g kg^{-1}(d.m.) in 45 min-dose. However, it decreased less in the 75-min dose (to 47 g kg^{-1}). On the contrary, protein content of 7-d-old seedlings increased from 34.5 g kg^{-1}(d.m.) in the control to 47.6 g kg^{-1}(d.m.) in the 75 min dose. There was a remarkable increase in the free amino acid content from 1.97 g kg^{-1}(d.m.) in the control to 14.05 g kg^{-1}(d.m.) in the 75-min dose. Hence the microwave stimulated accumulation of free amino acids as well as of protein.

The effects of microwave radiation on the content of phenolic compounds and nucleic acids were not significant. Proline content was increased slightly in the 15-min dose then decreased in the other two doses. This slight increase could protect plants from changes happening due to microwave irradiance.

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