Influence of coal humic acids and their complexes with iron on plant photosynthesis under Fe-deficiency conditions

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Humic acids (HA) are generally considered to improve plant growth by enhancing nutrient supply. For example, iron chlorosis, a symptom of iron deficiency in plants, can be corrected by applying HA which play a beneficial role in Fe acquisition by plants. This beneficial effect of HA is generally attributed to the chelating activity of HA that provides plants with Fe in easily assimilated form. However, HA are known to be universal adaptogens providing plant adaptation to various stress conditions and therefore HA themselves could be expected to mitigate negative effects of iron chlorosis. This study was aimed to compare influence of coal humic acids, their complexes with iron and commercially available agricultural iron additive Fe-EDDHA (ferrous chelate with ethylenediaminedi(o-hydroxyphenylacetic) acid) on plant photosynthesis under Fe-deficiency conditions.

Bioassay experiment were conducted using cucumber *Cucumis sativus* L. as target plants. Plants were grown at the iron concentration of 25 μmol/l and HA concentration of 15 mg/l. Plant photosynthesis efficiency in terms of electron transport rate (ETR) and quantum yield of regulated energy dissipation (Y(NPQ)) were estimated using pulse amplitude modulation (PAM) fluorometer (PAM-2000, Walz, Germany). Complexes of HA with iron (Fe-HA) were obtained using potassium humate (K-HA) as parent material. The content of iron was measured using o-phenantroline method after oxidative digestion and was (in % mass) 1, 9, and 6, in K-HA, Fe-HA and Fe-EDDHA, respectively.

Our experiments revealed the beneficial effects of all preparations studied on the growth of Fe-deficient cucumber plants. Treatment with the preparations under study resulted in an increase in biomass, plant length, as well as in chlorophyll content as compared to blank (no iron added). The highest Fe content in plant tissues was observed with Fe-EDDHA treated plants. Fe-HA treated plants possessed intermediate content of Fe, whereas this value in K-HA treated plants was just slightly higher than in the blank experiment. Of particular interest were data on photosynthesis efficiency of cucumbers in the presence of K-HA, Fe-HA and Fe-EDDHA. Both K-HA and Fe-HA treated plants showed higher values of Y(NPQ) which is a measure of non-photochemical fluorescence quenching, reflecting regulation of photosystem II as a protective mechanism against excess of light intensity. The high Y(NPQ) value indicates that the sample has retained the physiological capacity to protect itself by the dissipation of excessive excitation energy into harmless heat. On the other hand, Y(NPQ) values in plants treated with Fe-EDDHA did not differ significantly from that of blank. Therefore, mitigating activity of K-HA under Fe-deficiency conditions was caused not only by availability of Fe present in the HA sample, but also by its protective impact on photosystem II.