A Study of the Prospective Effect of Circularly Polarized Light on the Electrical Conductivity of Aqueous Solutions of Soil Nutrients

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ABSTRACT

This study was conducted to investigate the effect of a circularly polarized light from an 85W incoherent source on the electrical conductivity of aqueous solutions of NPK grade inorganic fertilizer. It was aimed at exploring the prospects of using the circularly polarized light to manipulate the ion availability in aqueous solutions. The results showed that the circularly polarized light significantly lowered the electrical conductivity values of all the aqueous solutions. The process was found to be exothermic as the temperatures of the exposed samples were found to be significantly higher than the unexposed.

Keywords: Circularly polarized light, Electrical conductivity, Inorganic fertilizer, Ionic polarization.

INTRODUCTION

Fertilizers, organic or inorganic/mineral, are materials added to the soil and commonly selected on the basis of local availability and size of farmland to supply plant nutrients to supplement the soil's natural fertility (Coche et al., 1996; Troeh & Thompson, 2005). An agricultural inorganic fertilizer may contain several types of nutrients among which are the primary nutrients nitrogen, phosphorus and potassium supplied as mixed fertilizers and referred to by their NPK grade (Coche et al., 1996). Factors affecting fertilizer use are region specific but generally include crop, soil, climate, economic and management (Troeh & Thompson, 2005). Too much application of some fertilizers such as the NPK fertilizer, which the agriculture industry relies heavily on, can result in nutrient loss and reduced yields. Schrock & Books (2004) reported that excessive application of nitrogen causes the plant to become spindly and unable to set flowers and eventually become prone to infestation. Excess phosphorus in plants causes yelloowing of the leaves and poor growth as a result of zinc and iron deficiency (Hall, 2008; Nardozzi, 2012). According to Nardozzi (2012), excess potassium causes induced magnesium, sodium and calcium deficiencies. Methods such as watering the soil frequently without adding any fertilizer, addition of phosphorus - rich materials and the avoidance of potassium - rich fertilizers for two years (Gehring, 2011) have been suggested for dealing with NPK grade over fertilization. In this study, the prospective use of a circularly polarized light to significantly reduce the level of water - soluble nutrients in an NPK 15-15-15 grade of inorganic fertilizer has been presented. The state of polarization of a light wave refers to the specification of the direction of displacement of its electric field vector and it can be modified by introducing any number of polarizations - changing elements in the path of the light wave (Sharma, 2006). A circularly polarized light wave possesses constant amplitude and in any plane normal to its travelling direction, the tip of the rotating electric field vector describes a circle (Young, 2000). The NPK fertilizer components dissociate in aqueous solutions and release ions and when exposed to the circularly polarized light, it is expected that the rotating electric field vector will cause the ions to be polarized resulting in the formation of induced dipoles. This ability is being explored for similar effects which exist when certain materials are exposed to electric fields. Pollock (1993) and Mitchell (2004) indicated that ionic polarization occurs in ionic materials because the presence of an electric field acts to displace the ions in opposite directions from their equilibrium positions resulting in the formation of induced dipoles. The formation of the induced dipoles increases the covalent character of the positive ions as well as the ease with which the electron cloud density of the negative ions can be distorted towards positive ions.

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(Clugston & Flemming, 2000). Therefore, the possible formation of bonds between the ions of the components of the aqueous solution of the NPK inorganic fertilizer as a result of the exposure to circularly polarized light could cause a reduction in their availability in solution leading to the overall effect of a significantly sustained reduction in the electrical conductivities of the dissolved plant nutrients. Electrical conductivity levels serve as an indirect indication of the amount of water-soluble nutrients available for plant usage such as nitrates, potassium, sodium, chloride, sulphate and ammonia.

MATERIALS AND METHODS

Location of the Experiment

The experiment was carried out in a dark room at the laboratory of the Department of Science Education, College of Agriculture Education, University of Education, Winneba, Mampong - Ashanti, Ghana (Longitude 0.05° and 1.30° W and Latitude 6.55° and 7.30° N) between 20:00 hr and 06:00hr each day for 8 days during February, 2015.

Description of set up

The set up comprised essentially of a 85W fluorescent light source fitted with a beam expander; a 67mm Pro-line commercial circular polarizer fitted with a rotatable ring; a Hanna Instruments Bench Conductivity Meter which measures electrical conductivity and temperature simultaneously; samples of NPK 15:15:15 inorganic fertilizer (composed of urea, calcium phosphate and potassium chloride).

Sample Preparation

Six 0.3g of samples the inorganic fertilizer were weighed using an electronic balance and each crushed into fine powder and transferred into 75cm³ beakers. 50cm³ of distilled water was then added to each sample and stirred continuously for 10 minutes using a magnetic stirrer and then left to stand for a further 30 minutes without agitation to allow the salts to dissolve to constitute 3g/50cm³ solutions. Three of the solutions were randomly picked and used for the treatment and the remaining three for the control. The procedure was repeated using 0.5g, 1.0g, 1.5g, 2.0g, 3.0g and 4.0g of the inorganic fertilizer.

Procedure and Measurements

An expanded beam of light from the source was made to pass through the circular polarizer, which was rotated for maximum effect, and exposed to three of the 0.3g/50cm³ inorganic fertilizer solutions at normal incidence. The remaining three samples were not exposed to any light source and served as the control. The initial Electrical Conductivity (EC) and temperature of the solutions were measured and this was repeated every hour for six hours. The procedure and measurements were repeated for the 0.5g/50cm³, 1.0g/50cm³, 1.5g/50cm³, 2.0/50cm³ g, 3.0g/50cm³ and 4.0g/50cm³ inorganic fertilizer solutions. The schematic diagram of the experimental set up with the circular polarizer is as shown in Fig.1 below.

![Fig1. Schematic diagram of experimental set up](image-url)
Data Analysis
All data collected were analysed using GenStat version 11.1(2008) to compare mean values between treatment conditions at 5% significance level.

RESULTS
Response of Electrical conductivity and temperature of the samples to circularly polarized light
Fig.2 shows how the Electrical Conductivity (EC) and temperature of the samples exposed to circularly polarized light responded in comparison with the unexposed samples. For each concentration of the samples, there were differences between the electrical conductivity values of the exposed samples and the unexposed. The same was observed for the temperature measurements. The mean temperatures of the exposed samples were higher than the unexposed while the mean electrical conductivities were lower in the exposed samples than the unexposed. Generally, the electrical conductivity levels were expected to be higher for higher concentrations of the samples.

![Response of Electrical Conductivity(EC) and temperature of samples exposed to circularly polarized light in comparison with the control](image)

Effect of circularly polarized light on Electrical Conductivity
The results indicate that there are differences between the mean values of both the electrical conductivity and temperature of the samples exposed to circularly polarized light and the unexposed at each sample concentration. Table.1 further elaborates on the statistical significance of these differences. For each concentration, the electrical conductivity of the exposed sample was found to be significantly lower than the unexposed. The differences were highest in the 1.0g/cm³ samples while the 0.30g/cm³ samples recorded the smallest difference.

Table1. Effect of circularly polarized light on Electrical Conductivity of the samples

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Concentration of fertilizer solution in g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>Mean Electrical Conductivity/mS of sample exposed to circularly polarized light</td>
<td>6.08</td>
</tr>
<tr>
<td>Mean Electrical Conductivity/mS of the unexposed sample</td>
<td>6.43</td>
</tr>
<tr>
<td>LSD</td>
<td>0.064</td>
</tr>
</tbody>
</table>
Effect of circularly polarized light on temperature

There were equally significant differences between the temperatures of the samples exposed to circularly polarized light and the unexposed ones. Table 2 shows that the exposed samples became significantly warmer than the unexposed during the experiment. The highest difference was recorded by the 0.30 g/cm³ samples while the 1.50 g/cm³ samples showed the lowest difference.

Table 2. Effect of circularly polarized light on temperature of the samples

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Concentration of fertilizer solution in g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>Mean temperature / °C of sample exposed to circularly polarized light</td>
<td>27.78</td>
</tr>
<tr>
<td>Mean temperature / °C of unexposed sample</td>
<td>26.26</td>
</tr>
<tr>
<td>LSD</td>
<td>0.635</td>
</tr>
</tbody>
</table>

DISCUSSION

The results generally indicate that the circularly polarized light from the incoherent light source had an effect on the electrical conductivity of the exposed samples. For each concentration, the electrical conductivity of the exposed sample was found to be significantly lower than the unexposed. The incoherent light source used was of fluorescent type and its ability to be polarized is consistent with Malacara (1988). Since the circularly polarized light arrived at normal incidence to the surface of the samples, the portions that were transmitted through remained unchanged in accordance with Chapman (2002) who stated that the refracted portions of a polarized light incident normal to the plane of incidence retain their original state of polarization. It therefore implies that the samples actually received circularly polarized light and the marked differences recorded occurred as a result thereof.

The NPK fertilizer components (urea, calcium phosphate and potassium chloride) dissociate in aqueous solutions and release ammonium ions, potassium ions and phosphate ions according to the following equations (Corradini et al., 2010):

\[
\begin{align*}
CO(NH_2)_2(s) + 2H^+(aq) + 2H_2O(l) & \iff 2NH_4^+(aq) + H_2CO_3(aq) \\
KCl(s) & \iff K^+(aq) + Cl^-(aq) \\
Ca(H_2PO_4)_2 \cdot H_2O(s) & \iff Ca^{2+}(aq) + H_2PO_4^-(aq) + H_2O(l)
\end{align*}
\]

Therefore the exposure of the aqueous solutions to polarized light can cause the cores of these ions to oscillate (Giordano, 2013) in response to the light’s rotating electric field vectors and the vibrating ions act to set up dipole - dipole short order interactions which affects their polarizability (Pollock, 1993; Mitchell, 2004; Danek, 2006; ). The polarizability of a negative ion measures the ease with which its electron cloud density can be distorted towards the positive ion whose polarizability indicates the covalent character of the bond it forms with a given negative ion (Clugston & Flemming, 2000). Consequently, the circularly polarized light creates the conditions for the ions composed in the aqueous solutions of the NPK fertilizer to form compounds such as \( NH_4Cl \) and \( H_2PO_4 \) thereby reducing their availability. This is indicated by the significantly lower levels of the electrical conductivity values recorded during the period of exposure as shown in Table 1.

The evidence for the formation of covalent bonds which reduced the availability of the ions can be found from the temperature of the exposed samples. Bond making is an exothermic change and when covalent bonds are formed, heat is given out (Briggs, 2007) which resulted in the temperature of the exposed samples becoming significantly warmer than the unexposed for each concentration used during the experiment, as shown in Table 2.
CONCLUSION

In this study, the prospective use of a circularly polarized light from an incoherent source to significantly lower the electrical conductivity of aqueous solutions of NPK grade inorganic fertilizer has been demonstrated. The process was found to be exothermic as the temperatures of the exposed samples were found to be higher than the unexposed.

REFERENCES