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Effect of Fungicide Treatment on Dielectric Properties of Few Coarse-Cereals Over the Frequency Range 0.01 to 10 MHz

Vishal Singh CHANDEL[1], Atiq Ur RAHMAN[2], Jagdish Prashad SHUKLA[2] and Rajiv MANOHAR[2]

[1]Department of Physics, Integral University, Lucknow, Uttar Pradesh 226026, India
[2]Department of Physics, Lucknow University, Lucknow, Uttar Pradesh 226007, India

(Corresponding author; e-mail: chandel.integral@gmail.com)

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Abstract

The effect of fungicides' (thiram, carbendazim, captan, bagalol) treatment on the dielectric constant and dielectric loss of a few coarse-cereals seeds, namely the sorghum, maize, barley and pearl millet at given moisture content and bulk densities were examined using Hewlett-Packard (HP-4194A) impedance/gain phase analyzer over the frequency range of 0.01 to 10 MHz and temperature range of 30 - 45 °C. Julabo (temperature controller, F-25, Germany) was used for keeping the temperature of seeds constant. The study showed that fungicide treatment caused considerable change in the dielectric parameters namely the dielectric constant and dielectric loss. These changes cannot be ignored when precise and accurate determination of dielectric parameters is required for agricultural technology.

Keywords: Dielectric constant, dielectric loss, moisture content, coarse-cereals, fungicides

Introduction

Seed treatment refers to the application of fungicide, insecticide, or a combination of both, to seeds so as to disinfect them from seed-borne or soil-borne pathogenic organisms and storage insects [1]. Seed disinfection refers to the eradication of fungal spores that have become established within the seed coat, or more deep-seated tissues. For effective control, the fungicidal treatment must actually penetrate the seed in order to kill the fungus that is present. Seed disinfestation refers to the destruction of surface-borne organisms that have contaminated the seed surface but not infected the seed surface. Most seed treatment products are fungicides or insecticides applied to seeds before planting. Fungicides are used to control diseases of seeds and seedlings, while the insecticides are used to control insect and pests. Fungicide treatments are done for three reasons: (i) To control soil-borne fungal disease organisms (pathogens) that cause seed rot, damping-off, seedling blights and root rot. (ii) To control fungal pathogens that are surface-borne on the seed, such as those that cause covered smuts and rust, black point of cereal grains. (iii) To control internally seed-borne fungal pathogens such as the loose smut fungi of cereals.

Most fungicidal seed treatments do not control the bacterial pathogens and most will not control all types of fungal diseases, so it is important to carefully choose the treatment that provides the best control of the disease organisms present on the seed or potentially present in the soil. The degree of control will vary with product, rate, environmental conditions and disease organisms present. Some systemic fungicidal seed treatments may also provide protection against early-season infection by leaf diseases. Fungicide seed treatment products come in a variety of formulations and in a variety of packaging sizes and types. Some are readily available for on-farm use as dusts, slurries, water soluble bags, or liquid ready-to-use-formulations.

The dielectric properties of most hygroscopic biological material, such as seeds and grains are much dependent on moisture, temperature, bulk density and composition [2]. There is no universal physical model that adequately correlates the effective complex permittivity and physical properties of such a medium. A better understanding of such media can be attained through an approach.

Grain quality is an important parameter in commercial marketing as well as in the seed industry. The moisture content is the single most important quality that determines the safe storage of grains and seeds. Grains and seeds with high moisture content are subjected to attack by grain storage fungi and stored grain insets. These infections and infestations produce spoilage and loss of value in significant proportions. Moisture content and temperature determines the longevity and viability of seeds and grains during storage. Therefore, on-line, real time moisture content and other physical properties of wet seed and grain is crucial in agricultural industries where these properties are used as quality control indicators for optimization of given process particularly when large quantities are involved.

Direct methods for moisture content determination of agricultural material are the oven drying method [3] and chemical titration [Karl-Fisher]. The major disadvantages of these methods are their destructive nature and the time they require. Indirect methods are based on the measurement of properties of the material which directly correlate with moisture content. Nuclear radiation, infrared and dielectric based sensors are common examples of the indirect method. Nuclear radiation-based sensors are expensive and present potential hazards. Infrared sensors provide mainly surface moisture content. In contrast, with radio or microwave sensors, the spatial resolution of electromagnetic wave, provide information related to volume rather than just the surface of the material. Radio and microwave moisture sensors are based on measurement of intrinsic properties of materials such as dielectric properties [4-6]. They can continuously provide parameters such as bulk density, moisture content and dry mass from non-destructive measurements of dielectric properties using an appropriate correlation model and functions. Any error in determination of dielectric parameters would cause an error in sensing of the physical properties of the material.

The protection of grain and seeds from fugal and insect damage during harvesting, handling, transportation and storage are of increasing importance with trends towards processing and unit packaging at the time of harvest. For control of the quality of seeds it is necessary to treat the seeds with appropriate fungicide to ward off diseases that infect, infest and damage the seeds and grains. For quality preservation during production, processing, storage and marketing of seeds the agro industries treat seed and grain lots with appropriate antifungal and insect repellent chemicals. These chemicals, though used in meager quantity, would change the dielectric parameters values of the seeds thereby causing error in accurate determination physical properties of seeds and grains if the corresponding correction factor is not addressed. On account of this, the objective of the present investigation is to explore the effect of fungicide treatment on the dielectric parameters of seeds and grains of a few coarse-cereals in the frequency range of 0.01 to 10 MHz.

Dielectric properties of many seeds have been explored a lot, but the effect of fungicides on dielectric properties has not yet been explored, though different kinds of studies relating to fungicides and seeds have been done in past. Tu reported the effects of some pesticides on rhizobium japonicum and on the seed germination and pathogens of Soybean, and the effect of fungicidal seed treatments on alfalfa growth and nodulation by rhizobium meliloti [7,8]. Rathod *et al.* [9] reported the effects of fungicides on seed borne pathogen of groundnut. Manjunatha *et al.* [10] reported the effect of seed coating with polymers, fungicides and containers on seed quality of chilli during storage. Meanwhile Basavaraj *et al.* [11] reported the effect of fungicide and polymer film coating on the storability of onion seeds, Saeidi and Mirik [12] reported fungicide seed treatment and seed colour effects on the seed vigour and emergence in flax. A study of the dielectric properties of some oil seeds at different concentration of moisture content and micro-fertilizer has been done by Singh *et al.* [13] and Khan and Chandel [14] reported conductivity and penetration depth of argemone seeds.

Materials and methods

The certified grains of coarse-cereals, the sorghum (*Sorghum bicolour*), variety NSSG-1899 (Haritha); maize (Zea *Mays L.*), variety hybrid maize-4212; barley (*Hordeum vulgare*), variety BR-31; pearl millet (*Pennisetum typhoides*), variety Multicut were obtained as cleaned and untreated from a local market. Moisture content of each sample was determined by the ASAE standard [3] by drying triplicate10 g samples of the seed in a forced air-oven at 130 °C [15]. The four fungicides that were selected for the present investigation are (1) thiram (75 %WS), chemical name: tetramethylthiramdisulfide, chemical formula: $C_6H_{12}N_2S_4$, molecular weight: 240.44, specific gravity: 1.3, used to protect harvested crops from deterioration in storage and transport. It is also used as a seed protestant and animal repellant. (2) carbendazim or bavistine (50 %WP), chemical name: methyl-benzimidazolecarbamate, chemical formula: $C_9H_9N_3O_2$, molecular weight: 191.2, specific gravity: 1.45- a systemic fungicide with protective and curative action used to control a wide range of fungal disease on cereals seeds. (3) Captan (50 % WP), chemical name: N-(trichloromethylthio)cyclohex-4-ene-1,2-dicarbox-imide, chemical formula: $C_9H_8Cl_3NO_2S$, molecular weight: 300.6, the product belongs to a wide spectrum of fungicides used on cereals seeds to control all kind of diseases. (4) Bagalol [MEMC 6 % (Hg) SD], chemical name: 2-methoxy ethyl mercury chloride, chemical formula:$C_3H_7Cl_3HgO$, molecular weight: 295.11. This fungicide is used against surface born diseases, seed dressing against seed born diseases of cereal.

The standard recommended dose of fungicides is 200 - 250 g per quintal for Indian environmental conditions [16]. Here, in the present investigations treatment was done at the rate of 250 g per quintal of seed by the slurry treatment method. The slurry treatment method is a common method and is used extensively in treatments of various coarse-cereal seeds. In this method the fungicide was applied to the seed in soup-like fungicide-water solution. Commercially no drying is done and it can be bagged for storage. In this study after the slurry treatment the sample was put in a sealed jar for at least two days at 2 - 4 °C for moisture equilibration [15] within the seed kernel and any increment in moisture level caused due to water used in slurry treatment was measured and added to the initial moisture to get the final moisture content. One more sample, called the reference sample of the same moisture level as the same seed lot was also prepared and conditioned in a similar fashion.

From an electrical viewpoint all biological materials can be treated as electrolytes contained in biological cells. These biological cells form the conducting medium, which exhibit electrical impedance when an electrode pair is placed in contact with the conducting medium [17]. The equivalent circuit concepts, where a dielectric material is represented for a given frequency by a parallel equivalent capacitance and resistance have been applied in many measurement techniques [18-20] including the present investigations, where dielectric properties are calculated from impedance or admittance measurements on dielectric material samples.

The capacitances (C_M) and dissipation factor (D_M) measurements were taken with the help of impedance/gain phase analyzer (Model No. HP-4194A) frequency range (100 Hz to 40 MHz) using a coaxial cylindrical capacitor [21,22]. The sample holder was silver plated to reduce the dissipation loss. It was calibrated using standard liquids (Benzene and Methanol), and the error in measurement for dielectric constant (ε′) was found to be less than 1 % and for dielectric loss (ε′′) it was found to be 1.5 %. The dielectric parameters and conductivity were calculated with the help of the following relations:

$$\varepsilon' = \frac{C_M - C_0}{C_G} + 1 \quad (1)$$

$$\tan\delta = \frac{C_M D_M - C_0 D_0}{C_M - C_0} \quad (2)$$

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \quad (3)$$

Here C_M is the capacitance of the sample holder with sample, C_O is the capacitance of empty sample holder, C_G is the geometrical capacitance [$C_G = q/v = 2\pi\varepsilon_0 h/\log_e(b/a)$] where a and b are the internal and external radii, h is the height of capacitor, ε_0 is the permittivity of free space. The coaxial cylindrical sample holder was made of brass with an effective geometrical capacitance 2.085 pF.

Results and discussion

The effect of the fungicide treatment on coarse-cereals, namely the sorghum, maize, barley and pearl millet were examined at initial moisture content 9.8, 8.9, 12.9, 12.5 %; and normal bulk density: 0.795, 0.673, 0.632 and 0.824, respectively. Here the moisture content is reported in percent and wet basis (w.b.) and bulk density is in gm·cm^{-3}. Densities of the samples in the sample holder of one type of seed were kept constant to avoid density variation effect on dielectric parameters by consistent and systematic filling of seeds in the sample holder to get natural course of setting. Analysis of the experimental result showed a considerable effect on dielectric properties of coarse-cereal seeds. The nature of variations in dielectric parameters of coarse-cereal due to fungicide treatments are discussed below.

Effect of fungicide treatment

Sorghum

Analysis of the corresponding bar plots for dielectric constant of sorghum seed at given moisture content and bulk density (**Figure 1**) showed that the dielectric constant of sorghum seed increases with treatment of all fungicides, selected for the present investigation. The changes are quite high at low frequencies but become less pronounced at higher frequencies. The bagalol fungicide caused the highest change in dielectric constant amongst all fungicides followed by thiram and captan, and the lowest effect is noted with carbendazim fungicide. The changes in dielectric constant at 30 °C over the frequency range 5 kHz - 10 MHz are found to lie between the range of 1.27 to 0.291 with thiram, 0.434 to 0.025 with carbendazim, 0.582 to 0.038 with captan, and 2.804 to 0.233 with bagalol. The maximum or minimum change is not necessarily occurring at the frequency 5 kHz or 10 MHz but sometimes occurs at other frequencies of the given frequency range.

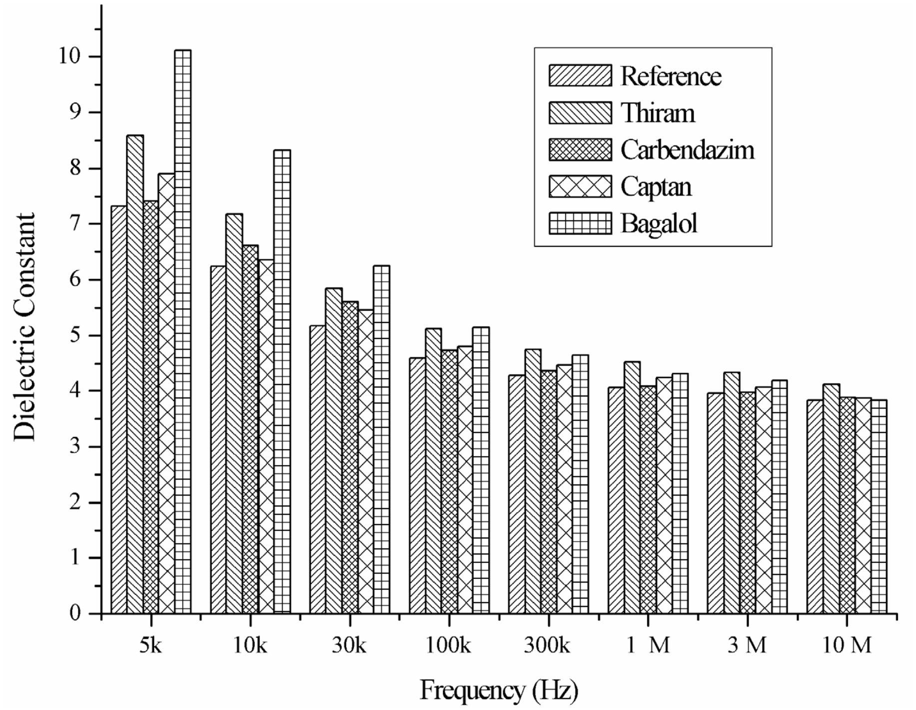

Figure 1 Dielectric constant vs frequency for Sorghum at 30 °C.

The changes in dielectric loss (**Figure 2**) of treated sorghum seed, over the frequency range of 5 kHz to 10 MHz are positive with thiram, captan and bagalol, whereas carbendazim resulted in a negative change at lower frequencies but, at higher frequencies changes are positive and small. Maximum change is noticed with bagalol followed by thiram and captan. The changes in dielectric loss due to fungicide treatment at given moisture content, bulk density and 30 °C, over the given frequency range of 5 kHz to 10 MHz are found to lie between the range of 1.519 to 0.059 with thiram, –0.292 to 0.034 with carbendazim, 0.596 to –0.009 with captan, and 1.987 to 0.167 with bagalol.

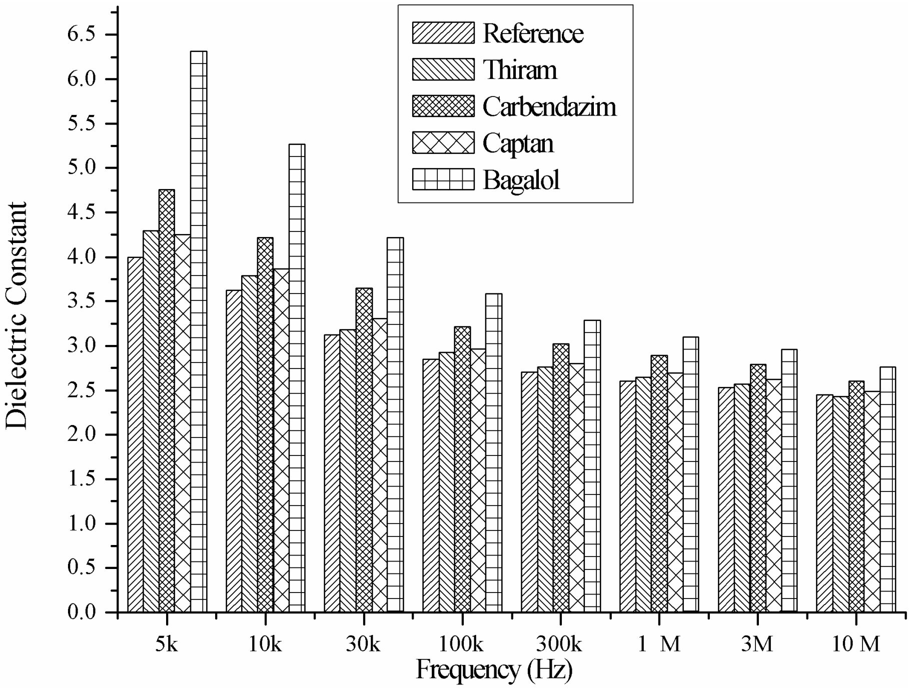

Figure 2 Dielectric loss vs frequency for Sorghum at 30 °C.

Maize

Analysis of data showed that all fungicides in general caused a positive and non-negligible change of varying degree on the dielectric constant (**Figure 3**). Maximum changes are observed with bagalol followed by carbendazim and thiram. Least impact on dielectric constant is noticed with captan. The changes in dielectric constant over the given frequency range, moisture content, bulk density and 30 °C are found to lie between the range of 1.533 to 0.004 with thiram, 1.702 to 0.088 with carbendazim, 1.017 to 0.064 with captan, and 2.324 to 0.056 with bagalol.

The dielectric loss (**Figure 4**) is affected by the treatments of fungicide, and almost always follows the same pattern of change as observed in the dielectric constant. The dielectric loss showed positive change at all frequencies. The changes in dielectric loss over the frequency range of 5 kHz - 10 MHz are found to lie in the range of 0.332 to 0.068 with thiram, 0.220 to 0.071 with carbendazim, 0.988 to –0.055 with captan, and 1.456 to 0.141 with bagalol.

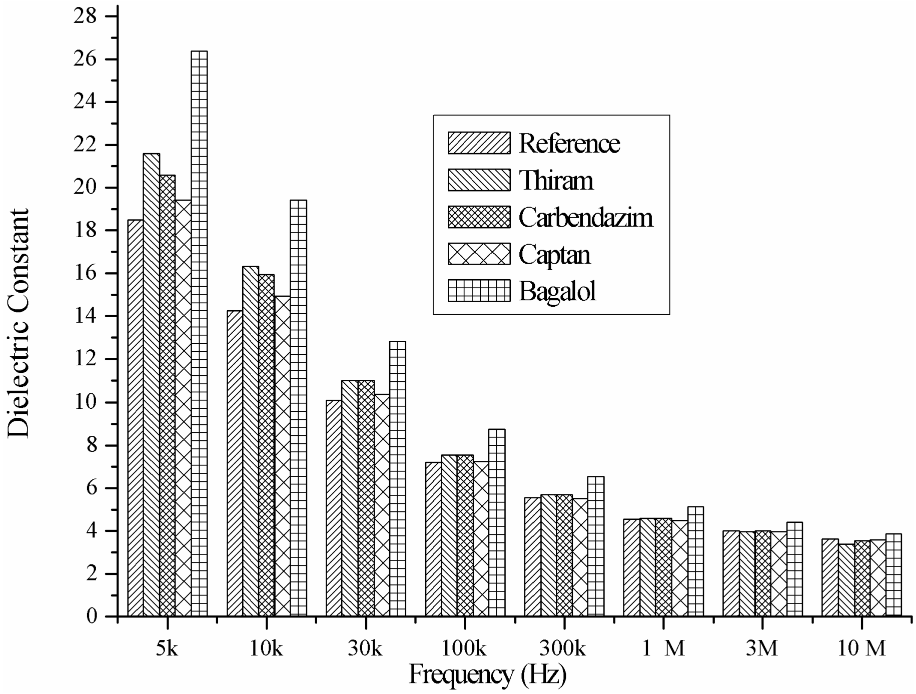

Figure 3 Dielectric constant vs frequency for Maize at 30 °C.

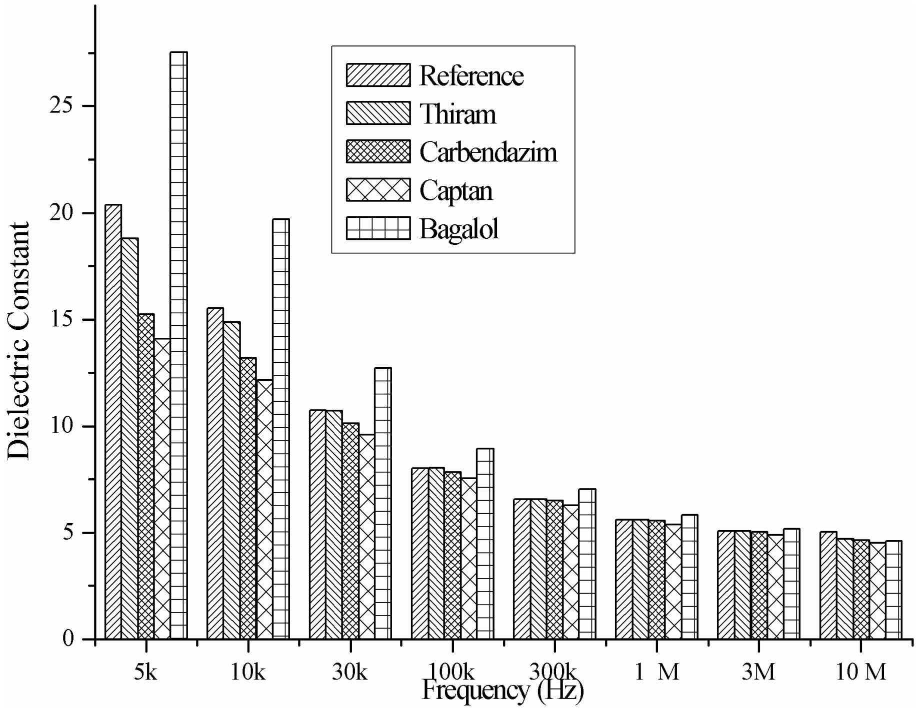

Figure 4 Dielectric loss vs frequency for Maize at 30 °C.

Barley

Examination of data revealed that fungicide treated seed of barley showed considerable change in dielectric constant at lower frequencies (**Figure 5**). Changes decrease with increase in frequency and become negative at higher frequencies with thiram, carbendazim and captan, whereas changes in dielectric constant remain positive with bagalol for all the frequencies. Amongst all fungicides, bagalol caused the maximum change followed by carbendazim and thiram, and least variation is noted with captan. The changes in dielectric constant are found to lie between the range of 3.094 to −0.0223 with thiram, 2.115 to −0.067 with carbendazim, 0.929 to −0.043 with captan, and 7.875 to 0.261 with bagalol.

The dielectric loss (**Figure 6**) of barley is also affected by the fungicide treatment. Changes are negative at lower frequencies with carbendazim and captan, but again become positive at higher frequencies. Positive and large changes are noticed with thiram and bagalol fungicides. In general, changes in dielectric loss diminished with increase in frequency. The changes in dielectric loss are found to lie in the range of 3.821 to 0.111 with thiram, −0.969 to 0.602 with carbendazim, −0.042 to 0.389 with captan, and 24.23 to 0.334 with bagalol.

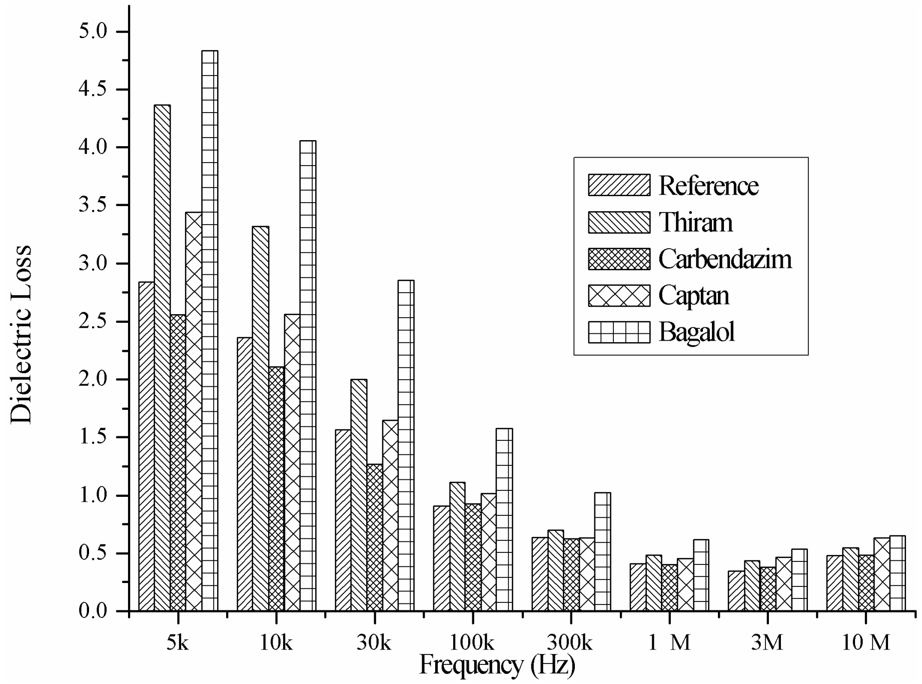

Figure 5 Dielectric constant vs frequency for Barley at 30 °C.

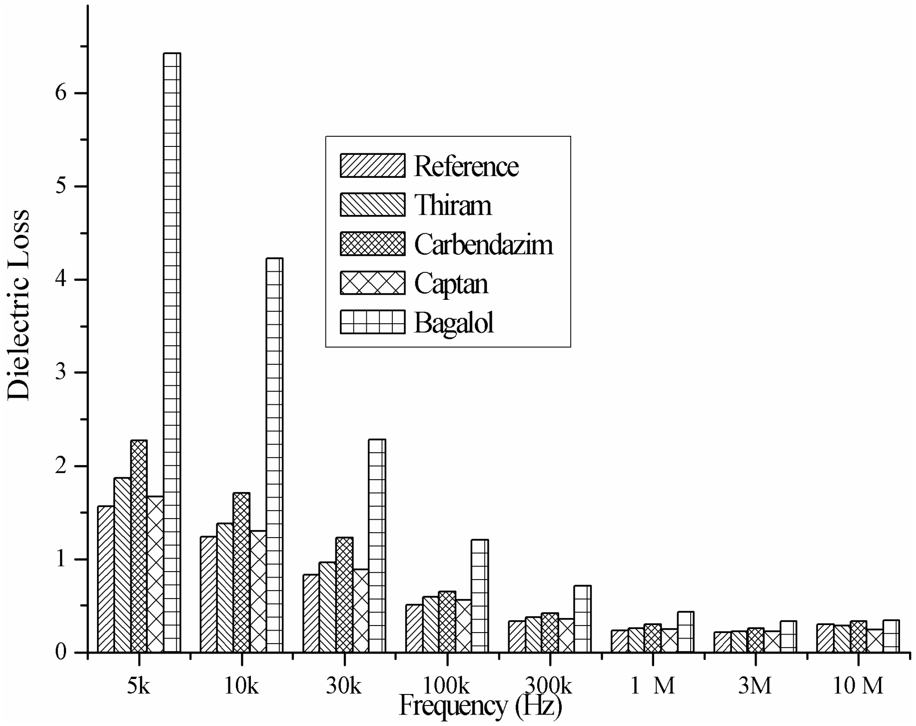

Figure 6 Dielectric loss vs frequency for Barley at 30 °C.

Pearl millet

Pearl millet seeds showed interesting variations in dielectric properties after fungicide treatments. The dielectric constant and dielectric loss (**Figures** 7 and **8**) both showed considerable negative change with thiram, captan and carbendazim for all the frequencies. However, positive changes are noticed with bagalol fungicide only. The changes are diminished at higher frequencies. The changes in dielectric constant over the given frequency range are found to lie in the range of 0.024 to −1.606 with thiram, −0.026 to −5.147 with carbendazim, −0.150 to −6.293 with captan, and −0.398 to 7.137 with bagalol.

Interestingly, the pattern of variation is also observed in dielectric loss (**Figure 8**) of pearl millet seed. Very large changes in the dielectric loss are seen with bagalol fungicide. The changes in dielectric loss, over the given frequency range of 5 kHz to 10 MHz are found to lie between the range of 0.071 to −0.525 with thiram, −7.368 to 0.232 with carbendazim, −9.003 to −0.142 with captan, and 40.91 to 0.138 with bagalol.

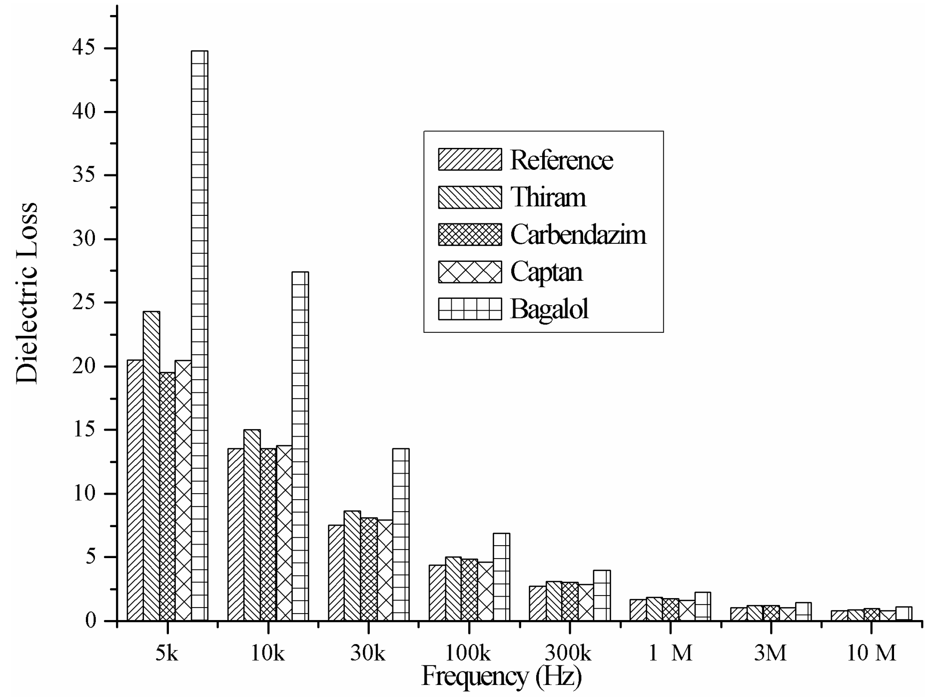

Figure 7 Dielectric constant vs frequency for Pearl millet at 30 °C.

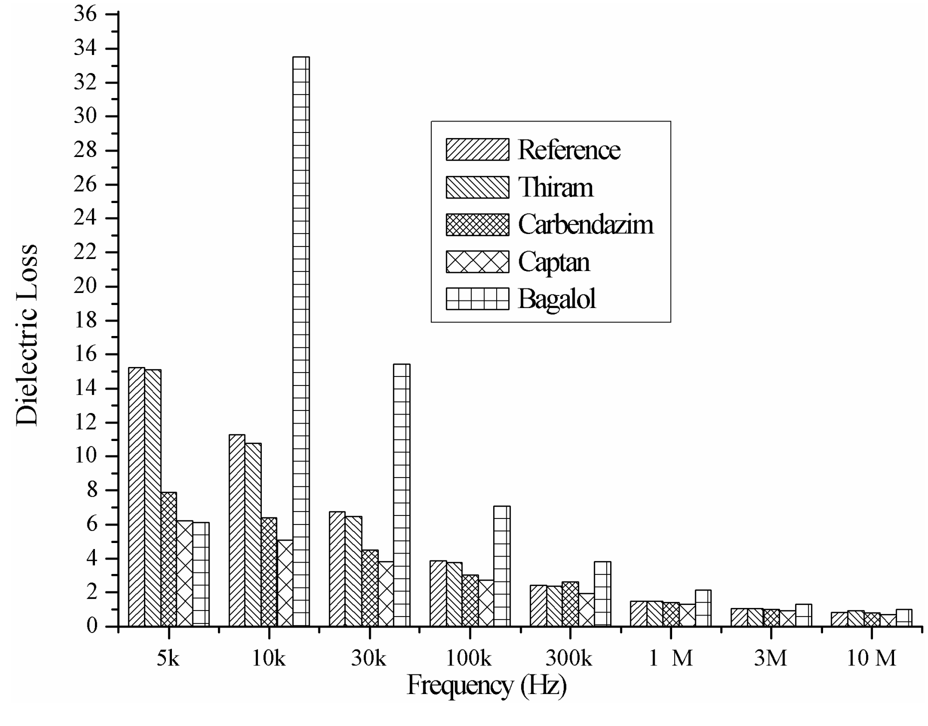

Figure 8 Dielectric loss vs frequency for Pearl millet at 30 °C.

Conclusions

The analysis of impact of fungicides treatment on dielectric parameters of coarse-cereal seeds showed that different fungicides caused different magnitudes of change in dielectric parameters of different coarse-cereal seeds. The changes are quite high and cannot be neglected when accurate and precise measurements are necessitated for determination of any extensive physical properties of grains and seeds, and for other purposes, useful in agricultural technologies.

The study also showed that one can not anticipate any common and generalized changes in dielectric parameters due to fungicide treatment on any particular seed species of coarse-cereals. All fungicides affect different dielectric parameters of different seeds in different proportions and modes. These could be due to the difference in composition, nature of the surface, shape and size of the kernel, moisture adsorption characteristics, energy status and packing density. One cannot rely fully on the dielectric and other chemical properties of fungicide alone to see the effect of fungicide treatments on the dielectric parameters of the seeds. The physical and chemical properties of the seeds have their own contributions in the treatment impacts on dielectric properties.

Further, it is inferred that a meager amount of fungicide causes considerable change in the values of the dielectric parameters in the frequency range 5 kHz to 10 MHz. The study of changes in dielectric parameters of seeds could be useful in assessing the degree of impact of fungicides on cereal seeds, which is always a matter of concern for plant pathologists. Amongst all coarse-cereals the dielectric properties of pearl millet and barley are more prone to fungicide treatments.

The change in the magnitude of dielectric parameters of the seeds due to fungicide treatment could be attributed to the structural difference of constituent molecules of the seed species and the applied fungicide, thus giving frequency dispersion of a different nature. Due to the structural difference, the energetic status of the molecules would be different, and hence a change in the dielectric parameters is observed.

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