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Energy seed treatments: A review

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Abstract
Energy seed treatment is an innovative area of research and acts as a magical tool which could enhance the yield levels. The application of electricity, magnetism, irradiation and sound intensities can stimuli the growth response in plants to a greater extent. This little-known technology plays a major role in accelerating growth rates, increasing yields, improving seed quality parameters, protecting plants from diseases, insects and frost. These methods also can reduce the requirement of fertilizer or pesticides and farmers can grow better crops in less time, with less effort and at a lower cost.

Keywords: Electric, magnetic, irradiation, sound, seed treatment

Introduction
Seed treatment: Seed treatment refers to application of inorganic, organic chemicals, fungicide, insecticide, or a combination of all, to seeds so as to invigorate, disinfect and disinfest them from seed borne or soil borne pathogenic organisms and storage insects.
Seed treatment is a term that describes both products and processes. The usage of specific products and specific techniques can improve the growth environment for the seed, seedlings and young plants.

Why Do We Treat Seed?
- To promote good seedling establishment and uniform plant stand
- To minimize yield loss
- To maintain and improve quality
- To avoid the spread of harmful organisms

Seed quality enhancement and its techniques
Seed quality enhancement means the application of physical, biological and chemical agents to the seed in order to enhance the physical, physiological, genetical, biochemical and health qualities of seed.
Seed enhancement technologies are gaining increasing attention for their potential to confer greater disease resistance in seeds, improve seed vigor and modify seed emergence capabilities**.**

Energy seed treatments
- Physical methods of stimulation and are innovative area of research which have emerged as a magical tool to improve the yield of crops.
- Seed is an extremely complex biological system and its state of expression cannot always be controlled.
- Changing of seed vitality indices (germinating energy, germination and uniformity of germination)
- Physical methods of seed treatment may initiate physiological and biochemical changes which reflects upon the plant growth and developmental processes and ultimately improves the yield and quality of the produce
- Helps to elucidate the mechanisms of energy exchange in molecules and thus stimulation of metabolic processes for better plant development.
- It is a kind of energy treatment that stimulates the enzymes and other biochemical reactions that helps in pre-germinative processes.

- The stimulation is possible at lower levels of treatment intensity (that means lower energy).
- All living processes are highly dependent on energy exchange between the cell and the environment.
- Physical factors import different kind of energy into the cells.
- Imported energy is absorbed by the electrons in different molecules.
- The absorbed energy may be transformed in another kind of energy (most probably chemical one) and then used for accelerating the metabolism in the seed.
- *In-vitro* studies of physical seed treatment showed that changes in the activity of the enzyme and stimulation of biosynthetic process that

1. Involve RNA polymerase
2. Quenching of free radicals

- In case of chemical amelioration the necessary substances are directly inserted into the cell.
- In the case of physical treatment the energy introduced in the cell creates conditions for molecular transformations.

Table 1: Gist of seed quality enhancement treatments

Dormancy breaking techniques	Germination augmenting treatments	Seed coating treatments	Protective seed treatments
Soaking in water	Seed fortification	Seed pelleting	Seed dressing with insecticides
Hot water treatment	Seed infusion	Seed coating	Seed dressing with fungicides
Leaching of inhibitors using tap water	Pre-germinative sprouting	Seed colouring	Botanicals seed treatment
Wetting and thawing	Osmopriming	Polykote film coating	Bio control agents
Alternate wetting and drying	Osmocondtioning		
Mechanical scarification	Seed invigouration		
Acid scarification	Solid matrix priming		
Bio scarification	Seed conditioning		
Scorching/ burning	Fluid drilling		
Warm stratification	Seed priming		
Cold stratification	Electric seed treatment		
Electric seed treatment	Magnetic seed treatment		
Seed treatments with stimulants	Irradiation seed treatment		
Seed treatment with retardants	Sound Seed treatment		

Types of energy seed treatments/ Physical methods:
I. Electric seed treatment
II. Magnetic seed treatment
III. Irradiation seed treatment
IV. Sound seed treatment

I. Electrostatic Systems/ Electric seed treatments
Study of the effects of electricity on plant growth began in 1746, when Dr. Maimbray of Edinburg treated myrtle plants with the output of an electrostatic generator, thereby enhancing their growth and flowering. Electrical stimulus (electrotherapy) as pre-sowing seed treatment is an innovative area of research and which could improve the yield of crops.
Electric current treatment may initiate physiological and biochemical changes which reflect the plant growth and development processes and ultimately improve the yield and quality of produce.
It is a kind of energy treatment that stimulates the enzymes and other biochemical reactions that helps in early germination.

Types of Electrical Current treatments
1. Direct Current (DC Voltage)
2. Alternate current (AC Voltage)
3. Electromagnetic field

Direct Current
Direct current (DC) is the unidirectional flow of electric charge (Fig. 1a). It is produced by such sources as batteries, thermocouples, solar cells, and commutator - type electric machines of the dynamo type. Direct current may flow in a conductor such as a wire, but can also be through semiconductors, insulators, or even through a vacuum as in electron or ion beams that be used in seed treatment.

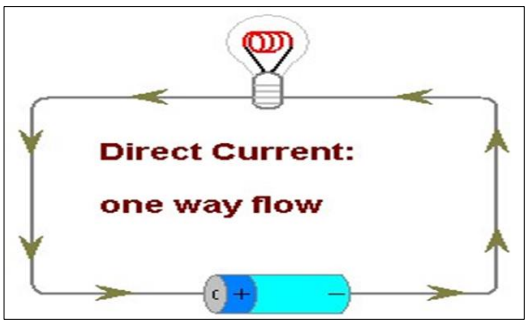

Fig 1a: Direct current

Alternating Current
An electric current that varies periodically in value and direction, first flowing in one direction in the circuit and then flowing in the opposite direction Alternating Current (Fig. 1b). Each complete repetition is called a cycle, and the number of repetitions per second is called the frequency; usually expressed in Hertz (Hz). This is best source for treating seeds. Naturally produce voltages alternating in polarity, reversing positive and negative over time. Either as a voltage switching polarity or as a current switching direction back and forth, this "kind" of electricity is known as 'Alternating Current'

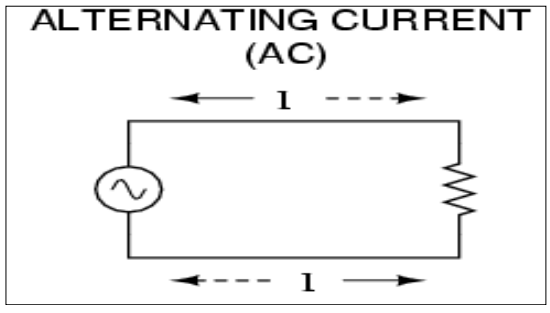

Fig 1b: Alternate current

How dose current generated and sample treatment

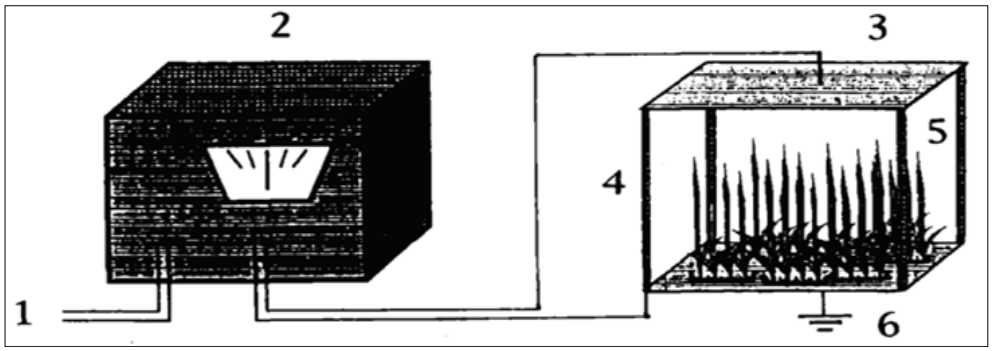

Fig 2: Schematic diagram of circuit for electric field generation. 1. Electric source of alternating current (100 V); 2. Regulator; 3. Electrode plate (300 mmx200 mm); 4. Plastic support; 5. Sample; 6. Ground.

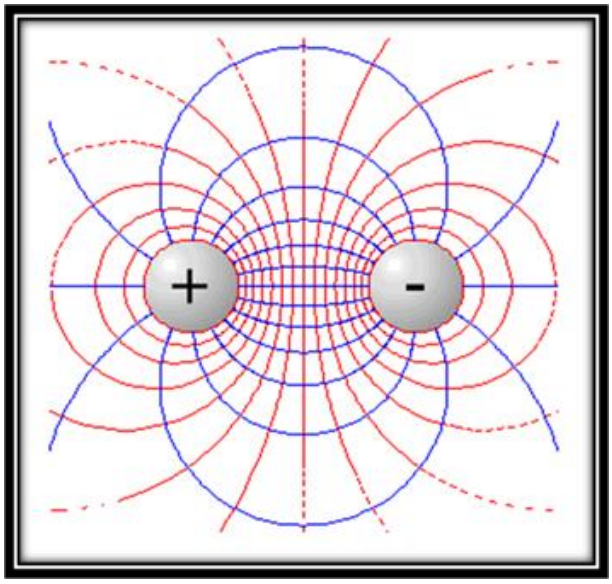

Fig 3: Electric field

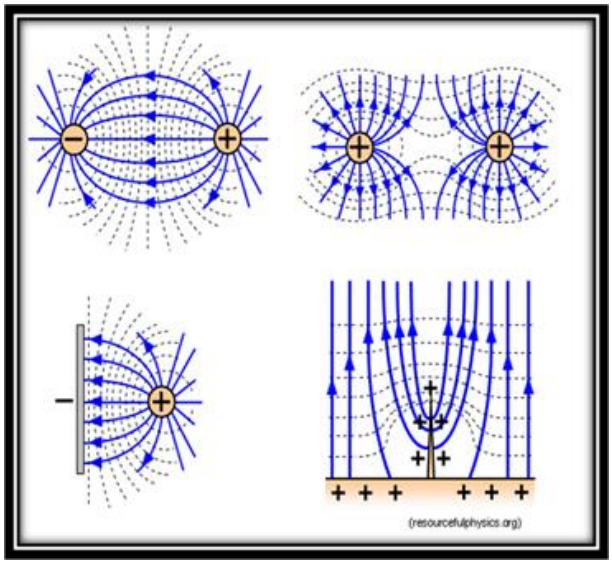

Fig 4: Electric field

How does current affect seed quality?

1. Current stimulation affects the metabolic processes arising from DNA duplication or the process normally associated with cell division.
2. Translocation or change in the concentration or the activity of auxins.
3. Leaching of inorganic enzyme activators such as chloride ions. In imbibed seeds, it triggers the enzyme activators due to action of magnetic field and promotes germination.
4. Stimulates the synthesis of protein and nucleic acids.
5. Decomposition and translocation of phosphorus containing storage material such as 'phytine' in cotyledonsof Mungbean
6. Seed purification before storage by electric current treatment helps to overcome infestation of pests and diseases of crop plants.
7. Enhances, biochemical and physiological changes in cell structure

Use of electric current seed treatment

- Brief exposure of seeds to electric current ends their dormancy, accelerates development throughout the period of vegetation, and ultimately increases yields.
- Electro-culture can protect plants from diseases, insects and frost.
- These methods can also reduce the requirements for fertilizer or pesticides.
- Farmers can grow better crops in less time, with less effort and at a lower cost.
- Enhances germination
- Breaks dormancy and enhancesvigour
- It is cheap, less hazardous and easy to apply, within affordable
- It reduces application of toxic chemicals which are dangerous to consumers health
- The risk of food safety hazards can be avoided

Enhancement of seed quality parameters by energy treatments

An experiment on effect of Electric Field Intensity on Bean Sprout Growing was conducted by Kiatgamjorn *et al*. (2007) [8] opined that, Beans seeds treated with electric field intensity at 25 kV/m recorded highest root and stems length as compared to seed without any electrical field treatment and suggested that it might be due increased activity of electron that may circulate the flow of sap through all rootlets and helpful in carrying various essential elements from roots to other plant parts and depositing them in the proper places leading increased length. While, Waman and Patwardhan., (2014) [16] revealed that tomato seeds treated with electrical field intensity of 2 kV for20 Sec exhibited 100 per cent germination, suggesting that it might be due to germination process was related to basic mechanism which explains stimulating effect of electric field exposure. As well as ozone

generation by partial discharge between seeds and activation of OH radicles under the action of high intensity electric field was assumed to be responsible for the intensification of the biological processes.

Mahajan and Pandey (2014) [9] conducted an experiment to find the resonating electric field effect on germination and growth of chickpea seeds. In resonating state, there is always maximum transference of energy and may change in behaviour of seed germination. Chickpea seeds were exposed to the electric field (by varying voltage from zero to 1300 V) for 15 min at three different temperatures (13, 16 and 19°C).The exposure of chickpea seed under varying electric field from 0 to 1300 V indicate that there is a critical (resonating) effect which is around 700 V (or at 466.6 V/cm) for 15 min exposure causing more stimulation in chickpea seeds may be due to the Seeds exhibited ferroelectric properties and Dipole-dipole interactions are responsible for delay or acceleration in water absorption. Ferroelectric effect of the seeds decreased linearly with an increase in temperature. It implies that effect of voltage on seed germination reduced with increasing temperature.

Similarly the laboratory experiment was conducted to study the influence of electrical energy on seed quality attributes of cereal crops. The study revealed both positive and negative impact on its beneficial and harmful effects. Hence, there is a need to standardize the effective optimum dose of electric current in relation to seed quality. Results of the experiment revealed that among three electrical current intensities viz., 910 mA, 1023mA and 2750 mA, the electric current intensity of 1023 mA found to be optimum for enhancing various seed quality attributes such as per cent germination, first count of germination, root and shoot lengths, seedling dry weight, seedling vigour index, speed of germination, Bartlett's germination rate index and field emergence with decreased electrical conductivity of seed leachate for four vigour level seeds of five cereal crops viz., maize, sorghum, paddy, wheat and bajra. The exposure of all the vigour level seeds of maize, sorghum, paddy, wheat and bajra seeds to one minute duration in all the current intensity levels was found to be beneficial for various seed quality parameters over control and found to be optimum period of exposure. Interaction between the treatment electric current intensity of 1023 mA for one minute duration of exposure was found to be best to obtain better seed quality of all the vigour level seeds of maize, sorghum, paddy, wheat and bajra seeds (Muttanna, 2011) [11].

II. Magnetic Seed Treatment

- Magnetic seed treatment is a simple treatment which involves exposure of seed to a magnetic field.
- Astonishing, this is still a new area though research on it was started as early as 1883 by Toolmei
- Magnetic field have been reported to exert a positive effect on the germination of seeds (Carbonell *et al*., 2002) [4]

Uses of magnetic field

- Can also be used as inhibitor of micro-organisms.
- It is cheap, less hazardous and easy to apply
- The substitution of chemical amelioration by physical one can reduce the toxins in raw materials and thus – raise the food safety
- It reduces application of toxic chemicals which are dangerous to consumers health
- Enhances germination (Carbonell *et al*., 2002)
- Rise in respiration was correlated with increased final germination % and faster germination rate

Method of application (De Souza et al., 2005) [5]

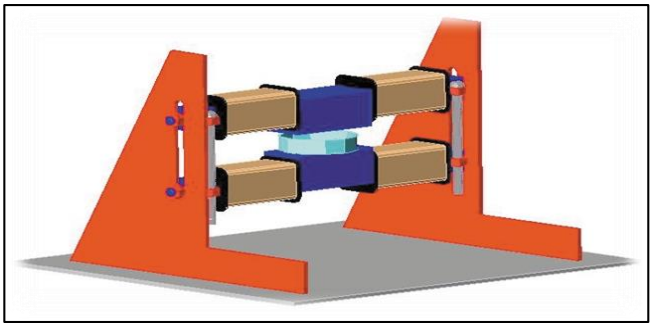

Fig 5: Magnetic seed treatment experimental setup

- This consists of two pairs of energizable, cylindrical coils, each formed by 4,026 turns of 0.41 mm enamelled copper wire. Each pair of coils was wound 11 cm apart on an iron bar (dimensions 40 × 3.5 cm) (Fig. 5).
- The two bars were placed one above the other, their ends held by metallic supports. The coils were connected in series and fed a rectified sinusoidal voltage to reach a full wave with an effective value of 200 volts.
- When electric current passed through the coils, a non-uniform and dynamic magnetic field was generated in the air space between the two bars.
- This was adjusted by moving one of the bars up or down (using a mechanical system) until the required working strength was achieved.
- The experimental electromagnet apparatus. A Petri dish is placed in the air gap between the two iron bars to expose the seeds to the magnetic fields
- Different treatment, with exposure to a dynamic magnetic field of different range mT for different minutes with comparison with Control (exposure to the local geomagnetic field only)

De Souza *et al*., (2005) [5] opined that tomato seed exposed to dynamic magnetic field of 120 mT for 10 min were very positive since they appear to induce an improved capacity for nutrient and water uptake, providing greater physical support to the developing shoot and its corresponding parts. Better root growth and development in young seedlings might lead to better root systems during early growth. The enhancement in growth of leaf parameters at vegetative and generative stage may be because of increased photosynthetic rates due to the greater interception of light and the greater amount of assimilates available for vegetative growth. This resulted in an increased SLA, which had a strong influence on crop growth and positive effect of magnetic treatment on leaf parameters. The fact that the number of open flowers and fruits set per plant were positively influenced by magnetic treatment suggests that it might, in some way, reduce flower and/or fruit abortion. The remarkable improvement in fruit yield per plant and per area resulted from an increase in the number of harvested fruits per plant and mean fruit weight induced by the magnetic treatments. They may be the result of bioenergetic structural excitement causing cell pumping and enzymatic stimulation. However, the basic mechanisms responsible for the magnetic stimulation of plant growth remain a mystery.

Naz *et al*. (2012) [12] studied the effect of pre-sowing magnetic treatments on germination, growth and yield of okra. The seed exposed to 99 mT magnetic field for 11 minutes recorded higher germination percentage, number of flowers per plant, leaf area (cm^2), plant height (cm) at maturity, number of fruits per plant, pod mass per plant and number of seeds per plant compare to control and other treatments.

Nimmi and Madhu., (2009) [13] reported a significantly higher percentage of seed germination was observed in Petri dishes having treated chilli seeds in comparison with the non-treated seeds (control). The highest percentage of germinating seeds, 100%, was recorded when the seeds were exposed to T4 (24 h) both at north and south pole of magement, followed by 82% in T3 (12 h). It was suggested that it might be due to the resonating effect in seeds when exposed to longer duration might helped accelerated electron ion movement might helped in triggring the enzyme responsible for germination like alpha amylase. It was also noted that among the magnetic treatment groups, seeds treated with south pole were showing maximum influence of permanent magnetic field (PMF) on growth and development of chilli. The results indicate that germination was intensely affected by the magnetic treatment.

The effects of pulsed magnetic field (PMF) treatment of soybean (*Glycine max* L. cv CO3) seeds were investigated on rate of seed germination, seedling growth, physico-chemical properties of seed leachates and soil microbial population under laboratory conditions. Seeds were exposed to PMF of 1500 nT at 0.1, 1.0 10.0 and 100.0 Hz for 5 h per day for 20 days, induced by enclosure coil systems. Non-treated seeds were considered as controls. All PMF treatments significantly increased the rate of seed germination, while 10 and 100 Hz PMFs showed the most effective response. The 1.0 and 10 Hz PMFs remarkably improved the fresh weight of shoots and roots, leaf area and plant height from seedlings from magnetically-exposed seeds compared to the control, while 10 Hz PMF increased the total soluble sugar, total protein and phenol contents. The leaf chlorophyll a, b and total chlorophyll were higher in PMF (10 and 100 Hz) pretreated plants, as compared to other treatments. In addition, activities of alpha-amylase, acid phosphatase, alkaline phosphatase, nitrate reductase, peroxidase and polyphenol oxidase were increased, while beta-amylase and protease activities were declined in PMF (10 Hz)-exposed soybean plants. Similarly, the capacity of absorbance of water by seeds and electrical conductivity of seed leachates were significantly enhanced by 10 Hz PMF exposure, whereas PMF (10 Hz) pretreated plants did not affect the microbial population in rhizosphere soil. The results suggested the potential of 10 Hz PMF treatment to enhance the germination and seedling growth of soybean (Ramalingam and Bollipo, 2013) [14].

While Ahamed (2013) reveled that Percent germination rate and seedlings growth of pepper plants were increased in response to magnetic field. It was previously proposed that magnetic field accelerates seed germination, seedling growth and activates proteins formation and root development (Aladjadjiyan, 2002; Atak *et al*., 2003) [2, 3]. These effects may be due to that magnetic field interacts with ionic current in the plant embryo cell membrane that induces changes both osmotic pressure and ionic concentrations on both sides of the membrane (Yaycili and Alikamanoglu, 2005) [17]. Reina and Pascual (2001) [15] reported that changes in the ionic fluxes across cell membrane cause alterations in the mechanism of water uptake, due to the fact that osmo-regulation in embryo cells is controlled by the ionic transport across the membrane. The positive effects of magnetic fields may be a result of bioenergetic structural excitement causing cell pumping and enzymatic stimulation as they might affect the regulation of crucial ion mechanisms such as the ATP hydrogen pump, and possibly the configuration of pivotal proteins (De Souza *et al*., 2005) [5]. However, the effects of magnetic field on plant growth still require proper explanation especially for the late growth period such as flowering and fruiting stages.

III. Irradiation Seed Treatment

- Pre-sowing irradiation of the seeds is a novel measure which enable to harness atomic energy in the form of ionizing radiations to increase the yield potential
- The stimulatory effect of radiations especially with radiation, UV radiation, ultrasonic vibration and other sources of energy have been reported in seeds

Gamma irradiation

- Gamma rays, which were discovered by Paul Villard in 1900
- Most energetic photons, having no defined lower limit to their wavelength
- Gamma rays typically have frequencies above 10^{19} Hz, and therefore have energies above 100 keV and wavelength less than 10 picometers, often smaller than an atom
- Gamma rays are having high energies and very short λ which cause ionization/physical damage to matter that it strikes
    1. Material will absorb and break molecular and chemical bonds.
    2. It can break molecular bonds and damage cell
- The measure of gamma rays' ionizing ability is called the exposure
- SI unit of ionizing radiation exposure coulomb per kilogram (C/kg) = J/kg) =100 rad = sievert (Sv) = 1 gray

Uses of seed irradiation

- Laser is used for the irradiation of food and seed for sterilization.
- Increases the resistance to the mutagenic effects of further irradiation in plants, bacteria, insects and mammals.
- Augment the immune response.
- Contamination, eradication or control of insect pests, reduction of food- borne diseases and extension of shelf life.
- It is usedin solving various agricultural problems such as reduction of post-harvest losses through suppressing sprouting.

Khalifa and Ghandoor (2011) [7] investigated the Effect of Nd-Yag Laser Beam (523nm) on Soybean (*Glycine max*) leaves at the Protein Level and observed that, presowing laser treatments of seeds led to increased concentration of the RubisCO large subunit and concomitantly enhanced growth and productivity of soybean plants. Such an increase in the large subunit concentration of the enzyme in the chloroplast might act as a positive feedback signal that increases the expression level of other genes in the nucleus. One other possible mechanism is that laser treatments were found to increase immobilization of thyllakoid membrane proteins. This immobilization might facilitate the entrance of more cytoplasmic RubisCO small subunits and activase into the chloroplast. This would then enhance the formation of more active RubisCO, more CO2 fixation and accelerated plant

growth. However, such proposed model needs further investigation.

The amylases activity of brinjal seeds increased gradually and the maximum activities of a-amylase were noted in shoots and roots of seedlings derived from 25 J cm^2 laser irradiated seeds, whereas the activity of b-amylase showed maximum activity at 20 J cm^2 which was found to be significant ($P < 0.001$) compared with respective un-irradiated control group. The enhanced percentage of germination due to laser irradiation has positive correlation with induced internal energy level of seeds, Increased activities of amylases and proteases from He–Ne laser treated seeds. This improved biological activity may be due to increased entropy and intrinsic energy of seeds during the germination process (Muthusamy *et al.* 2014)

IV. Sound Seed Treatment

Sound is the sensation of hearing/ a stimulus that is capable of producing the sensation of hearing/ what is actually heard by the human ear.

- Variations in air pressure against the ear drum, and the subsequent physical and neurological processing and interpretation, give rise to the subjective experience called "sound/music".

Types of sound

Sonic, ultrasonic and infrasonic

- Sounds capable of being heard by the human ear are called SONICS. 15 Hz to 10,000 Hz (Fig. 6a & 6b.)
- Sounds below 15Hz are known as infrasonic

Sounds above 10,000Hz are known as ultrasonic.

Ultrasound treatment: Ultrasound is cyclic sound pressure with a frequency greater than the upper limit of human hearing 20 kilohertz (20,000 hertz).

Sound is in the form of physical waves have the potential to crash into objects, such as plants or plant cells, and damage them.

Jagadish Chandra Bose in his research in plant stimuli, experiments showed that plants grow faster in pleasant music and their growth is retarded in noise or harsh sound.

- The production of ultrasound is used in many different fields, typically to penetrate a medium and measure the reflection signature or supply focused energy.
- Some animals — such as dogs, cats, dolphins, bats, and micehave an upper frequency limit that is greater than that of the human ear and thus can hear ultrasound.
- The plants are likely to die within a month or two, depending on the quality of the sound and its intensity. Very loud, high frequency sound causes cellular disruption and death

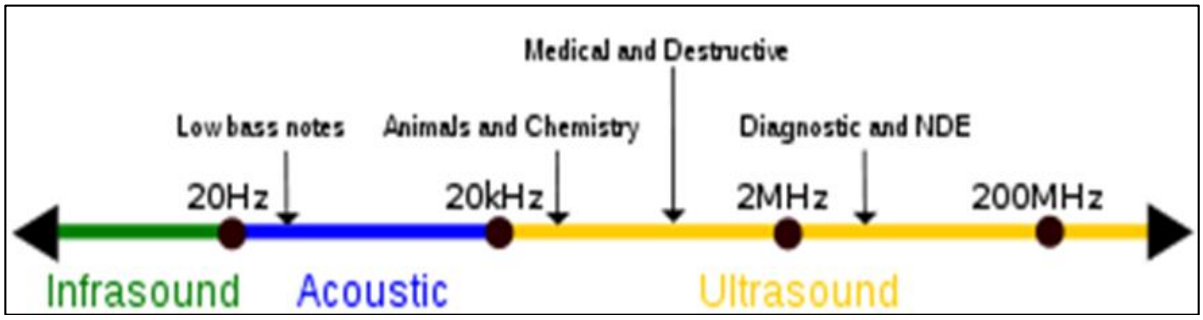

Fig 6a: Approximate frequency ranges corresponding to ultrasound, with rough guide of some applications

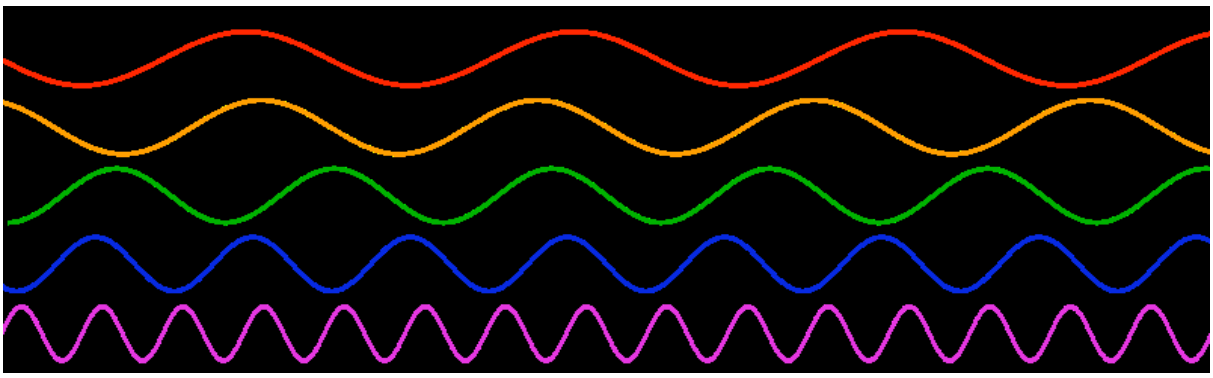

Fig 6b: The bottom waves have higher frequencies than those above

How does sound affect plant growth……?

- Possibly activate certain genes in cells.
- Resonate with objects.
- Cavitation phenomenon
- Wave propagating pressure variations.

Uses of Energy Seed Treatments

- Electro-culture can protect plants from diseases, insects and frost.
- These methods can also reduce the requirements for fertilizer or pesticides.
- Farmers can grow bigger and better crops in less time, with less effort and at a lower cost.
- Enhances germination (Carbonell *et al*., 2002)
- Breaks dormancy and enhancesvigour
- It is cheap, less hazardous and easy to apply, within affordable

Few of the preliminary studies clearly indicates that the plant is able to differentiate between “some sound” and “no sound”; “music “and “noise “and al-so between low (50-100) frequency and high (1500-2000) frequency; near (25cm) and far (550cm) in particular. For plants, both silent classical music and rhythmic rock music are proving to be beneficial. Silent classical musical sound is showing better results at some places but the results are very close and in case of traffic noise plants feel stressed condition. It suggested that the mechanical perturbation produced by sound in the physical environment of the plant, is what matters more than the type of sound and varying frequencies which the plant encounters be it silent classical music; rhythmic rock music and non rhythmic traffic noise by applying varying frequencies (Devendra and Vaidya, 2014) [6]

Conclusion

Energy treatments are innovative area of research which can improve yield of crops in an unprecedented manner. Plant responses to energy treatment, yet, so far it has not been fully exploited for commercial purposes. During last two decades, commendable attempts have been made to increase yield by pre-sowing electrical stimulus of seed and results so far available are encouraging. Although, improvement in yield by application of this technology has been reported in several crops, yet the physiological and biochemical mechanism by which energy stimulus influences yield is yet to be explored.

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